DE FOREST-IVES ELECTRIC WAVE-LENGTH STANDARD.

By A. FREDERICK COLLINS.

It is an easy matter to measure the capacity of a condenser or the inductance of a loop of wire or of a small coil by the bridge methods as indicated by Maxwell; but to determine the constants of an aerial wire

indicating, upon graduated semi-circular dials, the angle through which it is moved. By rotating the inner ring through various degrees of arc, it is obvious that the inductance may be varied at will between the maximum and minimum values, i. e., from 3,600 abhenries to 5,800 abhenries.

The contact bar *b*, to which the arms of the standard are connected, is formed of a heavy brass rod having

FIG. 1.—THE IVES-DE FOREST INSTRUMENT FOR MEASURING ELECTRICAL WAVE LENGTHS.

used as an antenna for wireless telegraphy is quite another thing.

Fleming has cleverly pointed out a way, however, for the direct measurement of the capacity of an aerial by means of a rotating commutator; but since it is quite impossible to connect both terminals of an aerial wire in the bridge, the only means left to ascertain the value of the inductance is by measuring the capacity and the wave length, and then calculating the inductance from these known quantities.

To determine the wave length, Drs. De Forest and Ives have devised a standard of wave length by which the measurements may be made direct. The instrument is illustrated photographically in Fig. 1 and diagrammatically in Fig. 2; by referring to the latter, it will be seen that it consists of a closed-circuit oscillator formed through the medium of a spark gap *s*, the terminal electrodes of which are connected to opposite adjustable condensers, *c*₁, *c*₂; these in turn are connected to two variable inductance coils, *r*₁, *r*₁' and *r*₂, *r*₂', these finally leading to the contact bar, *b*.

The condensers are made up of glass plates of varying thicknesses, and of which there are forty-three to each side; these are covered with tinfoil seven inches square and are connected into suitable divisions, ten groups being formed by the outside plates and nine groups by the inside plates. By means of a sliding metal contact a large number of capacity values may be easily obtained, ranging from 200 abstatfarads to 22,500 abstatfarads.

Each of the inductances is formed of two concentric hard-rubber rings, the outer and larger one measuring 11¼ inches in diameter; these are fastened permanently in a vertical plane while the inner and

FIG. 2.

smaller ones, which are 9½ inches in diameter, are arranged to rotate about a horizontal axis; around each of the rings is wound a single turn of No. 10 hard copper wire.

Connection between the fixed and movable inductances is formed by small brass brushes fastened to the former, making contact with small concentric flat brass rings secured to the latter. The inner rings are attached to a common shaft carrying a pointer for in-

dicating, upon graduated semi-circular dials, the angle through which it is moved. By rotating the inner ring through various degrees of arc, it is obvious that the inductance may be varied at will between the maximum and minimum values, i. e., from 3,600 abhenries to 5,800 abhenries.

To calibrate the standard, that is to determine its wave length when a certain number of sections of the condensers are used, and the coils are turned through a given angle, a system of Lecher wires was used. This system, first used and described by a German scientist, Lecher, consists of two parallel copper wires, shown in Fig. 3, as *ba* and *b'a'*. In this figure *s* is a spark gap; *AB* and *A'B'* are air condensers formed by big square

FIG. 3.

metallic plates; *bb'* is a piece of copper wire forming a conducting bridge between the two wires *ab* and *a'b'*; and *c* is a Geissler tube placed across the ends of the wires *ab* and *a'b'*. The spark gap *s* is excited by a small induction coil not shown in the figure, so that a spark is caused to pass across it. When this is the case, electrical oscillations of current and potential are set up in the circuit formed by the spark gap *s*, the condensers *AB* and *A'B'*, and the bridge *bb'*. The circuit being in electrical oscillation sets the two wires *ab* and *a'b'* wagging electrically. If the parallel wires *ab* and *a'b'* are long enough, by moving the bridge *bb'* to and fro along them, a position can be found for the bridge which will make the Geissler tube glow brightly. When this is the case, we know that the wires *ab* and *a'b'* are vibrating electrically in resonance with the closed oscillating circuit *SABb'b'A'*. The wires *ba* and *b'a'* will then have the same period of electrical vibration as the closed oscillating circuit, and the distance from *b* to *a* will be equal to one-quarter of the wave length of this vibration. As it is an easy matter to measure the distance *ba*, it is possible in this way to measure the wave length of the oscillating circuit.

The Lecher arrangement employed by the designers was an extensive modification of the above simple form. Hertz in his researches on the mechanical action of electric waves in wires used a system having wires only 20 feet long; whereas it is obvious in the very nature of the uses to which the wave standard was to be put, that is, the direct measurement of lofty aërials, a large space would be required for the purposes of calibration, and this was provided for by utilizing a loft having a width of 50 feet and a length of 122 feet.

The wires, which were separated a distance of 6 inches, were stretched in a rectangular form, as shown in the diagram, Fig. 4, making a total length of 500 feet; these wires were cut at intervals of about 12 feet, and these were provided with short pieces of heavy wire, so that the cuts could be bridged and the wires could, therefore, be arbitrarily made of any length desired.

To test the accuracy of the predetermined wave length, the terminals of the parallel wires nearest *p*₁ and *p*₂ were attached to the contact bar, as indicated in the diagram. The next operation was to cause a spark to pass through the gap *s* by means of a small induction coil, not shown but connected to opposite sides of the oscillator balls. This sets up electric oscil-

lation in the opposite arms of the tuned system, forming a standard, as well as in the Lecher waves, closed-circuit oscillators or aerial wires attached to it, as the case may be.

As in the Lecher experiment, a Geissler tube was placed across the free ends of the parallel wires at a point where it was previously determined by calculation that the wave should be a maximum; to further assist the effect, and so cause the vacuum tube to glow more brightly, the condensers were varied—equally in each arm, of course—until this result was attained; finally, the movable coils of the inductances were swung through an arc sufficient to accentuate the luminosity of the tube to a maximum.

When the phenomenon occurred, it was evident that the Lecher wires and the standard were then in reso-

FIG. 4.

nance, and that the quarter wave length indicated by the standard was equal to the length of the parallel wires to the point where the terminals of the tube rested on them. This operation was repeated at least half a hundred times, for the purpose of plotting a calibration curve for all wave lengths from 40 feet up to 500 feet.

This obtained, the instrument affords a ready method for the measurement of wave lengths of closed-circuit oscillators and open-circuit aërials. To ascertain the wave length of a closed circuit, such as a tuning coil, the circuit, which includes a hot-wire ammeter *A*, a conductor *C*, and inductance *S*, is connected to the contact bar of the standard as shown in Fig. 5. When the coupled systems are charged by the induction coil, and the spark passes at the gap *s*, oscillations will be

FIG. 5.

set up in the standard and in the closed circuit, the current strength of which will be indicated by the hot-wire ammeter, and when this is greatest, the standard and the closed circuit are known to be in resonance.

In order to obtain these resonant values, it will be necessary to adjust the condensers and vary the inductance coils of the standard. It will be observed that the contact bar is made of a continuous strip of metal, and that the terminals *p*₁, *p*₂ are connected in shunt with the circuit of the instrument. The object of this arrangement is so that the amount of electrical disturbance to which the closed circuit is subjected may be readily varied, which is done by simply changing the distance between *p*₁ and *p*₂. These contact points

FIG. 6.

should be made of large copper wires, and placed as closely together on the contact bar as possible, to avoid inductive effects of this part of the circuit.

Open-circuit oscillators, such as radiators used in wireless telegraphy, are connected to the contact bar of the standard, and at approximately the same point where the aerial and earth wires are usually fixed to the spark gap of a coil. For instance, in Fig. 6, *a* represents the aerial wire, *p*₁, *p*₂ the points of contact with the standard, *A* the hot-wire ammeter, and *E* the earth. The adjustments and readings are made exactly as in the preceding case, with closed-circuit oscillations.

This form of wave-length standard marks an advance in the accurate determination of coefficients of

radiators and resonators; and since it is extremely portable and capable of measuring electric waves of any length employed in the present practice of wireless telegraphy, it will undoubtedly be hailed with delight by every worker engaged in the experimental or practical development of the art.

THE INSTALLATION OF A TRANSMISSION PLANT.*

By A ROAD ENGINEER.

It was late in the fall about eight years ago when I arrived at one of the principal cities of the West. An electric transmission system was in course of construction with a power house newly built at the foothills of the mountains some thirteen miles away and a rotary converter sub-station located in the city itself. I had been detailed to superintend the installation of the apparatus for the transmission system, which was a comparatively new piece of work in those days.

I had been through the old student course at Pittsburgh and had gotten some little outside experience, just about enough to make me a little nervous over the outcome of my trip. For no matter how long you have been on the road, each new job is found to be different from the others that you have done. It is often some engineering feature not foreseen in the laying out of the plant, or some operating condition not duly appreciated, or again it happens that the proper facilities for doing the work are not at hand. Indeed enough uncertainties are always present to arouse in one the liveliest interest and no man can foresee just when he will encounter some problem which will test his mettle to the uttermost. And I had a premonition that perhaps this job was mine. I already knew that there were some engineering features about this plant, common enough now-a-days, but unusual enough at that time to arouse my liveliest anticipation.

This particular plant was laid out for three 750-kilowatt generators, but only two were to be installed. They were 60-cycle three-bearing machines arranged to have an impact water wheel mounted on the shaft just where a pulley would be placed if the machine were to be used with a belt drive. Two exciters were furnished, each mounted with a water wheel similarly to the generators. A switchboard, two banks of two phase-three phase transformers for stepping up to 15,000 volts, some high-tension bayonet switches and type R lightning arresters completed the power-house equipment. The transmission was thirteen miles and at the receiving end were two 400-kilowatt, 550-volt, 18-pole rotary converters. These converters were the largest that had yet been built for 60 cycles. Indeed few of any size were then in service. The local company had but recently organized and was not yet operating. It had no electrical engineers in its employ and only one employe, a lineman, had ever done any electrical work. The company was to furnish all necessary labor and the manufacturers of the electrical apparatus were to lay out the system and superintend the installation.

The first generator had been shipped some time previous to my arrival and had already been hauled across country from the railroad and was lying at the power house in the mountains, much the worse for its trip. The men who had contracted to do the hauling had not a sufficiently stout wagon to carry the heavy generator weights and the wagon with the armature had broken down, ruining a considerable portion of the bar winding and end connectors. The first thing to be done, therefore, was to determine what material was needed for repairs and write out an order for the local company to send to the manufacturer. In situations such as this, where the work is done many miles from any kind of a shop, it is quite essential that the road man be prepared to work with his own hands as well as to superintend, and if he have a well-equipped tool chest it facilitates the work very much. I had use for mine when that winding came.

The location for the switchboard and the station wiring had been laid out by the manufacturing company, but on arriving at the plant I learned for the first time that a separate building had been provided by the local company for the raising transformers. It was in such a location that the plans for the switchboard and the station wiring would have to be changed. As usual, no provision had been made in the construction of the power house for putting any wiring into it at all. There was, therefore, no difficulty in changing the proposed location, and I gave instructions to the local company for the building of a suitable wiring conduit. This was put in at once.

The transformer house had been built without any provision for high-tension switches or lightning arresters. It was only after considerable planning and a sacrifice of desirable head room that I arranged to have a second floor built in it, which permitted the installation of the apparatus. It was a very cramped position, but it was absolutely needed.

As the engineer was to stay at the plant until it was put in operation it was advisable, in order to save time, to assemble the water wheels and their governing mechanism. While this did not prove to be a difficult task, it was an eye-opener. I got some experience in handling machinery which was new to me and a little out of my line.

The rotary converters, on account of the type, naturally required considerable attention and some experimentation to get into satisfactory service. One of the characteristics of these machines, which occasioned special treatment, was the high commutator speed,

which greatly increased the influence of surface roughness upon the commutator. The combination of high speed and roughness caused the brushes to vibrate, which resulted in rather poor contact between them and the commutator. Of course sparking took place. If the commutator was neglected, the sparking would accentuate the roughness of the commutator and this increased roughness would further aggravate the sparking, so that the sparking would increase at an accelerating rate until the machine would finally buck. This with a uniform load, while all other conditions were good. The cause was not fully understood at the time and it was thought to be chiefly in the setting of the brushes. After a short experience with this machine it was discovered that a smoothness sufficient for slow-speed commutation might not be sufficient at a high surface velocity. Although the commutator might feel smooth to the finger, if the end of a lead pencil was pressed against the back of a brush, a good deal of vibration might be felt. In overcoming this, it was found quite advantageous to support a piece of a grindstone on a properly constructed rest and crowd it against the commutator, while running with the starting motor. This was persisted in until a fresh surface was obtained. After following this up with very fine sandpaper, a surface was gotten which caused no perceptible vibration of the brushes.

A further aid to smooth running was obtained by saturating the brushes with cylinder oil. Two sets of brushes were fitted to each machine and while one set was in operation the other was immersed in oil. After receiving the above treatment, a machine would commute perfectly for a very considerable period of time. After this a few hours' work would be required to put it in shape again.

When first put into commission these rotary converters pumped quite badly and no adjustments of their fields would materially improve them in this respect. After some correspondence with the manufacturing company instructions were sent out to me to bore out the fields for a larger air gap and bevel the pole corners. The boring out of the fields was somewhat of a puzzler at first, as the machines were too large to be handled by any machine shop in that territory. After a time a boring bar was located that had been used to bore out the cylinder of a medium-sized Corliss engine. This bar was mounted in the bearings of a rotary converter after having been reconstructed to bore a sufficiently large diameter. It was belted to the end of the shaft of the other rotary converter which was carrying the railway load. This belt was necessarily small and ran at such a slow speed that it would not transmit power enough to pull the cutting tool through more than a very fine cut, but by taking a large number of cuts the bore was increased to the required amount. While this was being done the manufacturing company sent out two sets of copper dampers to be tried on the pole pieces. One of these sets consisted of sheets of copper bent to the curvature of the pole face and each made to completely cover one pole face. The edges of each sheet were bent up an inch or so all the way around to secure it to the side of the pole piece.

As soon as the above changes had been made on one machine it was brought up to speed by the starting motor and the field was built up. Before, however, the field attained full strength, the machine commenced to make an ominous noise and slowed down. On investigation it was found that the copper facings on the poles had bulged out against the armature and were actually acting as brakes on the armature core. The armature being of the open-slot type, its teeth caused the magnetic flux in the air gap to gather in tufts, and as these tufts followed the teeth across the pole faces, they generated such excessive currents in the copper plates that the latter were discolored by heat and pulled out of position by the magnetic action of the induced currents. This difficulty was so great that these dampers could not be used at all. Their action is now well understood and with partially closed slots they make an effective damper. The other set of dampers was made of rectangular bars of copper surrounding the pole pieces near the tips. Their use and the change in air gap and beveling of the pole corners resulted in decreasing the pumping to an unobjectionable amount.

Before the above difficulties had been overcome, and, in fact, immediately after the railway load had been transferred from the old steam plant to the rotary converters, the local telephone company and a considerable number of its patrons, whose lines were placed directly above the railway feeders, were much disturbed by a hum in the telephone receivers whenever they were raised from the hooks. In some cases this hum could be heard across a large room, and when the receiver was placed to the ear the noise was very disagreeable. A periodic variation of the sound in synchronism with the pumping of the rotary converters was its most noticeable feature. It did not take the telephone company long to locate the cause of the disturbance, and they then proceeded to make things interesting for me, among other things hinting that steps would be taken to prevent the operation of the substation. This looked pretty serious, as the rotary converters were of a new type and anything tending to bring discredit on them would surely affect future business.

In situations like this it is of advantage to the roadman if in addition to being an engineer he be something of a diplomat. In this instance the roadman was not skilled in this direction, but he did his best to assure the telephone company that his company, to

whom the matter had been reported, would do everything in its power to overcome the difficulty, and that a remedy would speedily be found, and then he lay awake at nights trying to think of a remedy, but without much success. Various theories had been advanced by different people to explain the difficulty. One was that the armature teeth, which were large and not very numerous per pole, presented varying amounts of iron to the pole faces, thereby causing slight fluctuations in the total magnetic flux, with corresponding pulsations in the E. M. F. and current. The vibration of the brushes was also thought to be a cause of the trouble, the vibration making the contact resistance a variable one with corresponding variations in the current. The smoothing of the commutator and the lubrication of the brushes described above would have reduced the effect of this cause and the increase in the air gap would have reduced any effect caused by the armature teeth. It was never determined how much, if any, of the trouble came from either of these causes, because the complaints from the telephone company suddenly stopped and no further investigation was made. The telephone company had found that the trouble existed mostly on circuits using a ground or common return and was negligible on an all-metallic circuit properly transposed. They evidently decided that the most satisfactory solution of the problem was the reconstruction of their circuits.

The transmission company had a few telephone troubles of its own. Its circuit from the power house to the sub-station was placed on the same poles as the transmission circuits and it consisted of two insulated wires under one covering. In addition to the braid common to the two, one wire had a braid covering and the other a rubber covering. I never learned just what reasons prevailed in the adoption of this style of construction. It was installed when I arrived and I was called on to operate it for a time. The main difficulty came in getting a sufficient amount of current through the circuit. The talk was very weak at all times. Another and very unique kind of trouble was caused as follows: In the country districts hunters were often out after small birds about the size of meadow larks. These birds frequently lit on the telephone circuit, and when the charge of bird-shot came, one or more of the shot would frequently wedge between the twisted telephone wires and short circuit them. As the wires were seldom cut in two and the insulation was but little frayed these faults were quite difficult for the patrolman to locate. These short circuits prevented the telephone bells from ringing, but did not prevent the transmission of speech over the circuit, so the operatives at every recurrence of this trouble, would simply go to the phones at prearranged times, lift off the receivers, and commence talking. This circuit was soon reconstructed with separated wires and this trouble ended too.

Some months later I was made superintendent of the power company and had ample opportunity to determine the expediency of various things I had done in getting the plant in operation.

MEASURING TIME: ANCIENT AND MODERN METHODS.

THE "Christmas lectures" at the Royal Institution have been given by Mr. Henry Cunynghame, who devoted his first lecture to the methods of measuring time known to the ancients. The first people who got any idea of time, and had notions of measuring it, were the Chaldeans, who 1,000 or 1,200 years before the birth of Christ had taken observations of days and months and even of eclipses; and they doubtless derived their first ideas from watching the heavens and noting the steady progress of the sun, moon, and planets among the fixed stars, in relation to which they were ever changing their positions. In time, too, they came to recognize that when the sun was darkened by an eclipse it was at a period when the moon was between the earth and the sun; and when the Egyptians discovered the periodicity of eclipses it became possible to predict them. The next thing to be discovered was the impossibility of supposing the earth to be flat. If this were the case, it was seen that the light of the polar star must always appear the same from every point in the earth's surface; but as its apparent height in the heavens varied with the situation of the observer, the conclusion was necessary that the earth was round. Coming to the motion of the earth, the lecturer said that Pythagoras founded a school which affirmed that the earth went round the sun, not *vice versa*; but this opinion, after careful examination, was rejected by ancient philosophers, Ptolemy's reason being that, if the earth were moving, a ball thrown straight up into the air would not return to the exact spot when it was thrown, but to one a little way behind. The lecturer next explained the changing of the seasons, and, by the aid of a globe with its axis fixed at the proper inclination rotating round a lamp representing the sun, showed how in summer the sun at the North Pole was visible throughout the twenty-four hours, and in England the days were long; whereas in winter the sun at the North Pole was not seen at all, and in England the days were short. To explain why the earth kept its axis steady in this way would, he said, require more advanced mechanics than he could introduce into his course; but he gave his audience some idea of how it was dependent on the rotation of the earth on its own axis, by showing that when a spinning gyroscope was moved in a circular path, its axis remained steady in space, whereas, if it were not spinning, the position of its axis was continu-

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