respectively. Dr. Smart, using Pontecoulant's elements, obtained 31·3 and 0·62 miles per second.

Messrs. Cowell and Crommelin have been awarded, jointly, the Janssen medal of the Société astronomique de France, for their precise determination of the orbit of the comet for this present apparition.

A number of interesting representations of comets, some certainly of Halley's, are reproduced in the May number of the *Bulletin de la Société astronomique de France* from the "Theatrum Cometicum" of Lubienietz. Each drawing is accompanied by a note explaining it, and directing attention to contemporary occurrences; in concluding the article, M. Flammarion suggests that great comets were of more frequent occurrence in early times than they are now.

A NEW TELEPHONE RELAY AND ITS APPLICATIONS.[1]

EVER since the introduction of the telephone a real need was felt for a telephone relay, for the distance over which telephones could be used was found to be comparatively limited. Edison, soon after his invention of the carbon button transmitter, caused an electromagnet to act upon the iron diaphragm, and thus turned it into a relay, but it was not a success. Hughes (Proceedings of the Royal Society, vol. xxvii., p. 362, 1878), in his paper before the Royal Society in 1878, describing his extremely delicate microphones, stated that a telephone receiver, if included in the microphone circuit and placed upon the resonant board, caused a continuous sound to be produced. It follows, he said, that the question of providing a relay for the human voice in telephony is thus solved. Unfortunately, it was not solved; he had shown how to make a relay that would magnify a noise or musical note, but not one that would intensify articulate speech.

Sir Oliver Lodge (Journal of the Institution of Electrical Engineers, vol. xxvii., p. 799, 1898), in a paper read in December, 1898, before this society, described a relay consisting of three or four reeds or tuning-forks, each carrying carbon contacts and working in series with one another. Each reed was arranged to resonate to one particular musical note, and when this note was passed through the string of relays it was multiplied in power to a considerable extent. An instrument of this character, however, is not effective in intensifying speech. An articulate relay must have its vibrating parts damped, or, in other words, possess no resonating properties; it is therefore far more insensitive to sound than one that is arranged to resonate to one particular note.

The invention of the powerful granular transmitters of the Hunning type stimulated further efforts to obtain the speaking relay, and some progress was made with this type of microphone, particularly in America. I will not describe these relays further than to say that they consist in combining the telephone receiver and the granular carbon transmitter; both of these are designed as efficiently as possible, and in some cases automatic means are provided to shake up the granules should they become packed. These relays are only partially successful. Their advantages are not decisive. They require relatively powerful currents to work them; that is to say, when the telephone currents become sufficiently feeble to require their services, it is at this point that the carbon instrument fails to work. The telephone relay to be successful has to magnify in a continuous manner varying currents that are too feeble to affect properly a Bell telephone receiver. Such currents would be of excessive weakness, say of the order of the one one-hundred millionth of an ampere (10^{-8} ampere), and the mechanical movements produced by such currents, which have in their turn to bring about the increased electrical changes, are therefore microscopic in dimensions.

The author's telephone relay has had to be developed along quite new lines. It takes as its basis the researches of J. J. Thomson, Earhart, Kinsley, and others, with regard to the flow of electrons across a microscopic air-gap between two conducting surfaces at different potentials (see "Conduction of Electricity through Gases," J. J. Thomson, chap. xv.). Earhart made a series of experiments on the difference of potential required to produce sparks the length of which is comparable with the wave-length of sodium light, and he found that when the distance between the metal electrodes falls to less than about 3×10^{-4} cm., the spark potential falls off rapidly with the distance, and seems to become proportional to the distance; that is to say, when the electrodes are placed very close together, within a distance such that the average intensity of force F between the electrodes reaches a value of about a million volts per centimetre, the discharge or

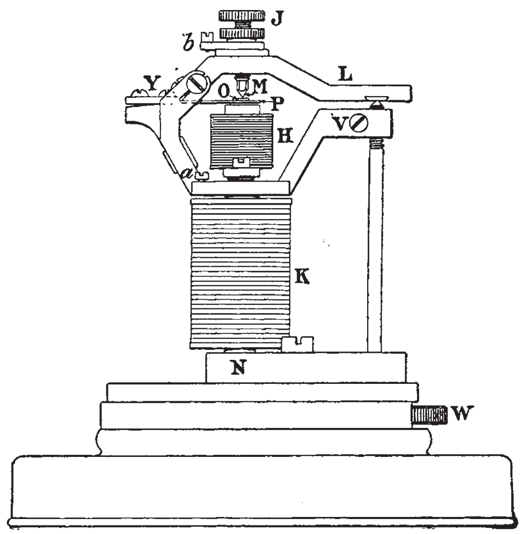

FIG. 1.

current passing is determined by the condition that F, which is V/d, reaches this value (where V is the potential difference and d the distance between the electrodes). If the metallic circuit of a dry cell be interrupted by a minute opening or space of the order of 5×10^{-7} cm., the metal at the point of interruption being platinum, the current will continue to flow round the circuit and across the opening, and any slight alteration in the length of the space, which I shall call the conduction space, will vary its resistance and greatly affect the value of the current that flows round the circuit. This conduction space is therefore exactly what is wanted for the current-varying device of a telephone relay, where microscopic mechanical movements are to be transformed into large current changes. The dimensions of the conduction space are so small that it is difficult to ensure and maintain it by direct mechanical means. The current that flows across the space was therefore made to do its own adjustment, very much in the same way as the current that passes through the arc of an arc lamp is made to strike and maintain the length of the arc.

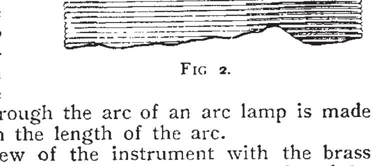

FIG 2.

Fig. 1 is a side view of the instrument with the brass cover removed. N is a permanent magnet, continued by soft iron poles right up to, but not touching, the "invar" steel reed P. Round the soft iron pole extensions are wound the two sets of coil windings H and K. The telephone currents to be magnified circulate round the winding H, and thus, by varying the magnetism, set the reed P in vibration. M, O are the top and bottom metal contact-pieces, which are opened to an infinitesimal degree to form a microphone by the fine adjusting screw W and

[1] From a paper read before the Institution of Electrical Engineers on May 5 by Mr. S. G. Brown.

by the action of the local current passing through the contact and round the winding K. It is by the action of the local current operating through this winding that the conduction space is formed and afterwards maintained. So good is the automatic adjustment that the instrument may be turned upside down, producing hardly any noticeable alteration in the value of the local current and without any effect on the working of the relay. The regulating winding K must not act when traversed by the rapidly varying telephonic currents; this is brought about by surrounding the iron under the coil by a closed circuited

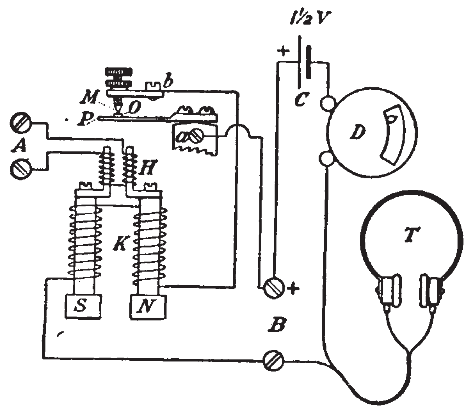

FIG. 3.

copper sheathing. Eddy currents set up in this sheathing by mutual induction destroy the self-induction of the coil.

Fig. 2 is an enlarged view of the reed P and the contact-pieces M, O. In the present instrument the contact is made between metal pieces of hard osmium iridium alloy. The top contact is pointed; the lower one is flat, and is soldered to the reed; both are polished, and work under a small drop of thin oil.

In earlier instruments the lower contact O was carried by a thin iron disc; the relay was then very susceptible to outside noises. For this reason a reed is now used; it exposes such a small surface to the air that it is practically unaffected by extraneous sound.

Fig. 3 shows the connections of the relay. C is a dry cell (this is the normal voltage, which is as high as it is

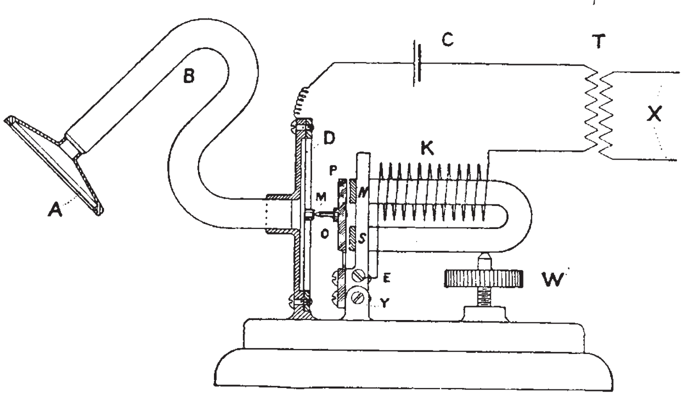

FIG. 4.

desirable to employ), K the low resistance regulating winding, T the receiving telephone or telephone head-piece of approximately 40 ohms resistance, D is an amperemeter or current indicator; when the microphone contact is opened so as to cut down the local current to half its maximum value, the relay is usually at its best adjustment. The telephone currents to be magnified enter by the terminals marked A, and circulate through the winding H.

The relay will magnify the very feeblest telephone currents. Speech or signals that are too faint to be heard in the ordinary Bell receiver may be heard clearly through the relay. If a watch be held against the ear-piece of a Bell telephone the induced currents produced when passed through the instrument will reproduce the ticking in the receiver attached; this is a severe test.

This property of magnifying feeble telephone currents has made it particularly useful in wireless telegraphy. On replacing the telephone by the relay the increased sensitive-

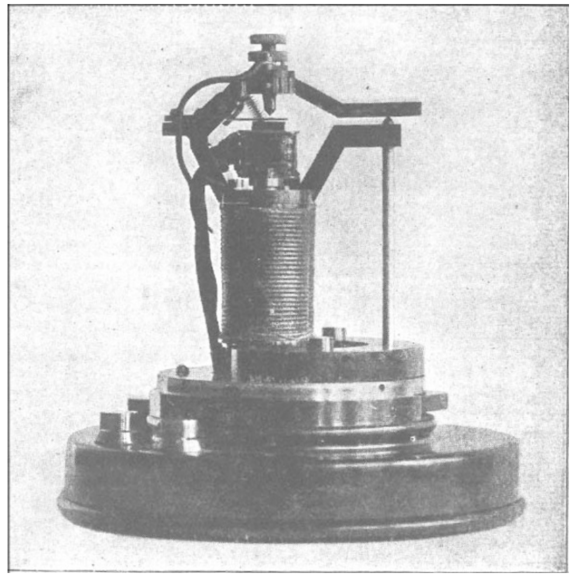

FIG. 5.—The Telephone Relay.

ness thus obtained doubles the distance over which it is possible to receive signals. Its utility in this direction has been tested, among others, by the Admiralty and the Post Office. In a wireless receiving station, messages, the very existence of which was not even suspected, owing to their extreme feebleness, when listened for under former conditions with the relay in circuit, were easily read. At the invitation of Mr. Marconi I took two instruments to the Haven Hotel, Poole. In one of the tests (Clifden, in Ireland, sending with the Marconi musical spark) the signals were heard in the telephone, directly connected, as a faint but clear and pleasing series of musical notes; but with two relays joined to the system and working in series the notes were rendered so loudly as to be heard clearly by everyone in the room, and an operator listening at a distance of several yards from the instrument could have deciphered the message. The relay is not easily affected by extraneous noises and vibration. It can thus be carried on board ship and worked in all weathers.

As regards its utility on ordinary telephone lines, speech may be magnified many times in loudness without perceptible loss in the articulation, and it will work with large currents to a point at which the Bell receiver in its local circuit is responding with uncomfortable loudness. In experimenting over a 20-lb. standard cable and speaking only one way, it has been proved that, when the relay is applied, thirty miles may be added to any length through which it is possible now to speak direct. For instance, supposing the length of the core for direct speaking be twenty miles, this may be increased to fifty miles for the same loudness and approximate clearness when the relay is in circuit, either as a single repeater at the end of the first twenty miles or as a receiver at the end of the fifty miles.

These tests prove that the telephone currents must be increased in strength to the extent of something like twenty times. If still greater magnifications are required than can be obtained with one relay, the simplest method would seem to be to employ two relays working in tandem. Their combined power would then be 400 times. In the majority of cases it is not necessary to add to the natural electrical damping of the reed, but if a piece of soft rubber be made to touch it, the voice can be transmitted with greater clearness even than if the conversation were taking place ordinarily in a room. This may be due to the complete absence of echoes.

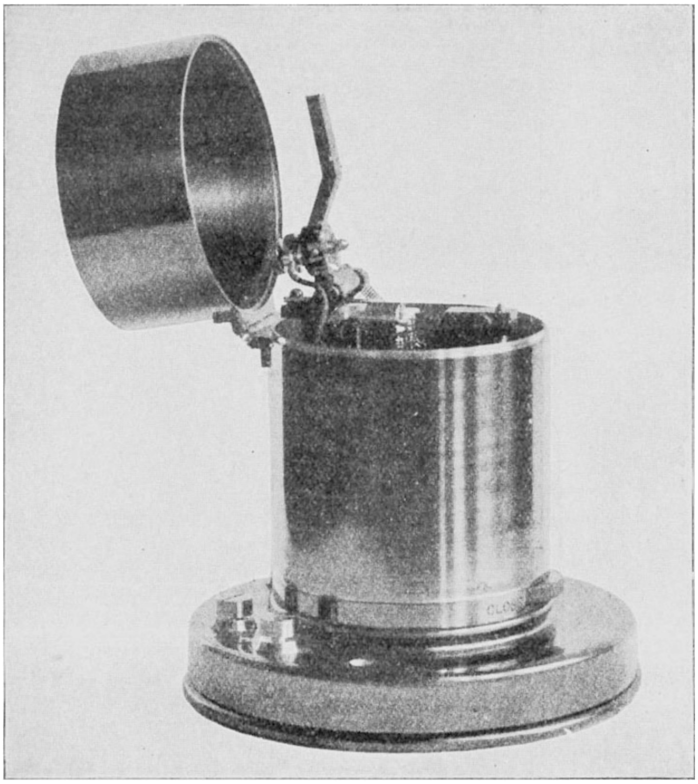

FIG. 6.—Telephone Relay in brass case with upper arm raised for cleaning the contents.

By means of the local regulating winding (see Fig. 2) the metal contact M, O is transformed into the most exquisitely delicate microphone, more sensitive, there is every reason to believe, than could be formed by light pressure between carbons. Such a microphone has rendered possible the construction of an electric stethoscope, an instrument by the use of which the sound of the heart or other internal organs may be greatly magnified. This, I have been informed, may render it possible to detect in the earlier stages heart disease, aneurism, and gall-stones.

Fig. 4 is a diagrammatic illustration of the stethoscope. A is the front part, and consists of a shallow brass cell faced by a thin ebonite diaphragm. A is placed upon the part of the body to be examined, say the heart; the beating of the heart is communicated to the ebonite diaphragm, then to the air inside the tube B, and thus the metal diaphragm D is set in vibration. M, O, as before, are the osmium-iridium contact-pieces. M is mounted on the diaphragm, and O on the steel reed P. The magnet N, S and the reed are carried by a brass frame E, which is pivoted or hinged at the lower support Y. The conduction space is formed between the contacts M, O by turning the fine adjusting screw W, and by the automatic action of the local current from the cell C flowing through the winding K and round the magnet. T is a special telephone transformer of equal windings of, say, 20 ohms resistance in the primary and in the secondary.

The electric stethoscope in its present form causes the sound of the heart to be three times as loud as in the ordinary stethoscope. This is scarcely sufficient for practical purposes; but if a telephone relay, such as I have previously described, be attached to the wires x of the transformer, the two instruments combined raise the intensity of the sound some twenty times and more, and this is ample for all ordinary purposes. The sound to be examined is picked up by the end of the tube A, and is heard in the telephones of a head-piece attached to the relay.

At the invitation of two physicians I took the complete instrument, stethoscope and relay, to the London Hospital, where it was tested upon a number of diseased heart cases. Not being a doctor myself, I cannot discuss the merits of the instrument with regard to its medical value, except to say that it seemed to render diagnosis particularly easy and revealed some phenomena only previously suspected. From a sound-magnifying point of view the general results were as follows. When the instrument was applied directly to the heart the sound of the beats given out in the telephones was uncomfortably loud, and easily heard by the patient and all those that stood round, and this even if the telephones were in position on the head of the operator. The stethoscope as used increased the heart-beats to the almost complete exclusion of the shriller or breathing

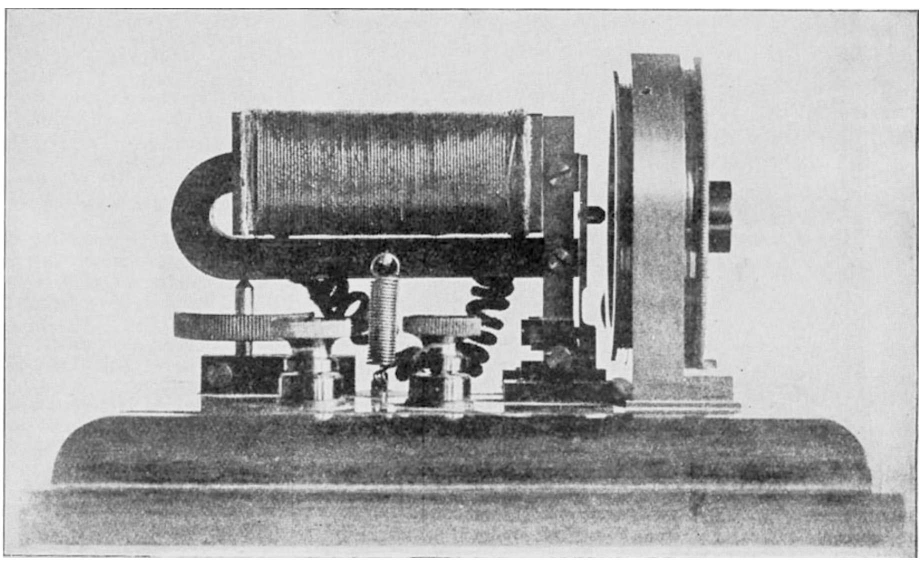

FIG. 7.—Electrical Stethoscope.

sounds. This has been brought about by mechanically tuning the disc D and the reed P of the telephone relay to the corresponding low note, and by a proper proportioning of the volume of air enclosed by the tube B. On other occasions, during private experiments, the instrument has been tuned so that nothing but the breathing sounds were audible; the passage of air through the lungs was heard as the roar of the wind through a forest of trees. This power of discrimination should be of service in allowing the independent examination of various organs of the body.

Replacing the telephone head-piece by a transformer, the stethoscope has been joined to the telephone service in my house, and, for the sake of experiment, the sound of the heart has been transmitted over several miles of telephone line to doctors in various parts of London and to other friends who were interested. All of them reported that the sounds received in the telephone were as loud and clear as when heard locally. The line, therefore, does not appear to produce much loss or distortion. This trial proved that it is now possible for a specialist, say, in London, to examine a patient, say, in the country, stethoscopically, and to arrive at a correct diagnosis.

The instrument must of necessity, to replace the ordinary stethoscope, be more sensitive to sound than the human ear. This is proved by slight noises made in the room being heard in the telephones as loud noises. In consequence of this, the apparatus is padded and guarded, so far as is possible, from all outside disturbances, and the patient should be examined in a quiet room. If the instrument is provided with a small funnel in place of the tube B, it will pick up and magnify the slightest sound, and ordinary speaking may be increased to a deafening shout in the telephone. Such an instrument, when properly constructed for the purpose, may be of use to those who are afflicted with deafness.

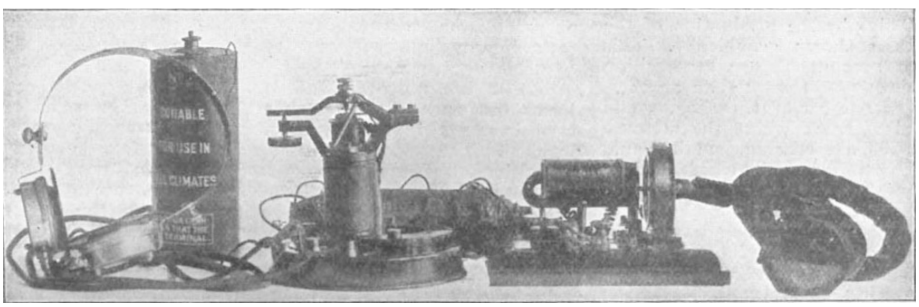

Fig. 8.—Electrical Stethoscope and Telephone Relay ready for use.

The relay has been used on the electrophone system, and by its aid, damping the reed with a piece of rubber, the speaking and music from the theatres are rendered with loudness and greater clearness than it is possible to have on the telephones supplied by the company, and by adding a loud speaker with trumpet the sounds can be heard in the room.

THE IRON AND STEEL INSTITUTE.

THE annual general meeting of the Iron and Steel Institute was held on Wednesday and Thursday, May 4 and 5, at the Institution of Civil Engineers. The retiring president—Sir Hugh Bell—inducted the president-elect, His Grace the Duke of Devonshire. After presentation of the Bessemer medal to Mr. E. H. Saniter, of Rotherham, for scientific services rendered to the iron and steel industry, the Duke of Devonshire gave his presidential address. In the course of a long and detailed account of the rise and progress of the coal, iron, and steel industries in this and foreign countries, the president also reviewed the social and economic conditions over the period from 1869, when the institute was founded under the presidency of the seventh Duke of Devonshire, to the present time. Conditions of work are now safer and more sanitary; wages are better, and working hours lighter. Housing is better, and a host of improvements in traffic, lighting, education, and public assistance have made for the comfort, health, and enlightenment of the people. Taking increase in wages paid to the worker, and also the increased spending power of these wages, into account, His Grace quoted statistics showing a net increase, for the period mentioned, of 90 per cent.

The meeting then proceeded with the reading and discussion of papers, thirteen of which were presented. Owing to lack of time, several of these had to be taken as read. In the case of those actually presented at the meeting, the time allowed to the author for explaining the contents of his paper was in each case ten minutes. The institute is to be congratulated on the high standard and importance of the papers presented, but we think that it will be difficult to maintain this standard unless in future more time is placed at the disposal of the authors at the meetings.

Mr. D. Selby Bigge, in a paper on the development in the production of electric power, pointed out that considerable progress had been made in the cost at which electricity can now be produced in iron and steel works having at their disposal waste gas, waste heat, and waste steam. One of the means by which low cost of production has been attained is the mixed pressure steam turbine. Such turbines differ from exhaust steam turbines in that the latter are intended to derive their supply of steam from engines which run continuously, such as blowing engines and pumping engines. Mixed flow turbines may work with reciprocating engines which are only in action intermittently. A continuous supply of steam is obtained for the turbine by adopting a form of regenerative accumulator, the action of which is as follows. The exhaust steam is taken from the engines and mixed with water, both coming to the same temperature. Supposing, now, a drop in pressure of $1\frac{1}{2}$ to 2 lb. per square inch to take place in the accumulator, owing to the exhaust steam supply being cut off, the water in the accumulator at once gives off vapour, thus keeping up the supply to the turbine. Any sudden rushes of exhaust steam from the engine are utilised in storing heat in the accumulator, and will be drawn on for supplying the turbine during the next pause in the supply of exhaust steam.

The turbine is built in stages, one set being designed for the working pressure of the existing boilers, and so constructed as to give off the full output of the turbine upon live steam when required; the other set is designed for the utilisation of exhaust or low-pressure steam received from the accumulator in the case of engines working intermittently, or direct from the exhaust of engines running continuously. The low-pressure end of the turbine is also designed to give out the full rating or output upon low-pressure steam alone. Should the full supply of exhaust steam fail from any cause, live steam is automatically admitted to make up the temporary deficiency in the exhaust steam available. Further, high-pressure steam is admitted when required to the high-pressure stage without the intervention of a reducing valve. To secure efficiency, a high vacuum must be secured, and the selection of a suitable condenser must be carefully considered. Various types of turbines, gas engines, and electrical installations for steel works are described by the author in the paper. The adoption of any particular system must obviously depend on the circumstances; each case must be considered on its merits. It is of interest to note that the Duke of Devonshire in his address cited the economy effected last year at the Barrow Works, where the installation of eight gas engines to replace the steam-driven engines produced an immediate saving of 1500 tons of coal weekly.

An interesting paper on the cutting properties of tool steel was contributed by Mr. Edward G. Herbert, of Manchester. It is well known that a high-speed steel tool with