Southampton, and the Ryde and Sconce Point plates by a wire through Newport; the circuit was completed by the sea, and signals were passed easily so as to read by the Morse system, but speech was not practical with the telephone."

The following is the report of the paper on "Telegraphing without Wires," read by Mr. J. B. Lindsay to the Mathematical Section of the British Association, at its meeting in Aberdeen, in September, 1859, which appeared in the *Dundee Advertiser*. After relating various minor experiments, he proceeded to describe his process, saying:

"Recently he had made additional experiments, and succeeded in crossing the Tay where it was three-quarters of a mile broad. His method had always been to immerse two plates or sheets of metal on the one side, and connect them by a wire passing through a coil to move a needle, and to have on the other side two sheets similarly connected, and nearly opposite the two former. Experiments had shown that only a fractional part of the electricity generated goes across, and that the quantity that thus goes across can be increased in four ways: First, by an increased battery power; second, by increasing the surface of the immersed sheet; third, by increasing the coil that moves the receiving needle; and fourth, by increasing the lateral distance. In cases where lateral distance could be got he recommended increasing it, as by that means a smaller battery was requisite. In telegraphing by this method to Ireland or France, abundance of lateral distance could be got, but for America the lateral distance in Britain was much less than the distance across. In the greater part of his experiments the distance at the side had been double the distance across; but in the experiments in the Tay the lateral distance was the smaller, being only about half a mile, while the distance across was three-quarters of a mile. Of the four elements above mentioned, he thought that if any one were doubled the quantity of electricity that crossed would also be doubled; and if all the elements were doubled the quantity transmitted would be eight times as great. In the experiment across the Tay the battery was of four square feet of zinc, the immersed sheets contained about ninety square feet, the weight of the copper coil was about six pounds; the lateral distance was less than the transverse distance, but if it had been a mile, and the distance across also a mile, the signal would no doubt have been equally distinct. Should the above law (when the lateral distance is equal to the transverse) be found correct, the undermentioned table might then be formed.

"But supposing the lateral distance to be only half the transverse, then the distance crossed might be 16,000 miles, and if it was only a fourth, then there would be 8,000 miles, and thus a greater distance than the breadth of the Atlantic. Further experiments were, however, necessary to determine the law. Since last experiment he had increased the coil, and thought there was power to come two miles. According to this calculation, he thought a battery of 130 square feet, immersed sheets of 3,000 square feet, a coil of 200 pounds weight were sufficient to cross the Atlantic with the lateral distance that could be obtained in Great Britain."

The following is the table above referred to:

Zinc for Battery.	Immersed Sheets.	Coil.	Distance Crossed.
4 sq. ft.	90 sq. ft.	6 lb.	1 mile.
8 "	180 "	12 "	8 "
16 "	360 "	24 "	64 "
32 "	720 "	48 "	512 "
64 "	1,440 "	96 "	4,096 "
128 "	2,880 "	192 "	32,768 "

If Mr. Lindsay's hopes are to be realized, some great discovery yet remains to be made, for, by the laying of the Atlantic telegraph cables, we know that the electric current, transmitted across the wide expanse of the Atlantic, must be of extraordinary power to be apparent on the other side, even with a cable to lead it. Without a cable it would be hopeless to expect to find it, although the best apparatus were employed. Telegraphic instruments are greatly improved since Mr. Lindsay worked with them, and as regards batteries and coils he would find available for his purpose all that he could wish. No currents, however, are in use which would induce another current 2,000 or 3,000 miles away. Still it is within possibility that such may be found, and to a Dundonian must be ascribed the honor of having first conceived the scheme of transoceanic telegraph communication without the aid of cables.

ON ELECTRIC METERS.*

By C. VERNON BOYS.

MR. BOYS exhibited an extensive series of models bearing on the subject of power-measuring in general, which might be applied to electrical measurement in particular. The general principle was applicable to differential metronomy, and all the apparatus were based on the same idea, though the application made to the special case of measuring differences of potential was in one or two of the instruments exceedingly complicated. The fundamental idea utilized in the mechanism consisted in a wheel rotating in contact with a cylinder, but at an angle of about 30 degrees with the perpendicular cross-section of the latter. The result was a transference of the rotating motion of the wheel into a longitudinal motion of the cylinder, if the cylinder was left free to move endwise. By a clockwork arrangement the wheel motion, when the cylinder had reached the end of its path, was transformed into a motion in the contrary direction, and thus the cylinder was forced to turn continuously within its field with an alternating to-and-fro movement. The applications of this mechanical principle, which Mr. Boys described as comparatively novel, were described as numerous and of wide range. One instrument adapted as a differential electric meter was spoken of by Sir William Thomson as novel and highly ingenious. The apparatus consisted of two small magnetized steel cones, revolving on separate spindles, point downward, so that each spindle might be connected with a separate source of power. A small cross-piece of soft iron was hung between the cones, touching each of them with one end, and retained in position merely by the fact of the cones acting as magnets. When revolution was set up in the cones, the inventor showed that the cross iron remained always parallel to its original position if the two velocities were equal; but immediately that either of the cones moved more rapidly than the other, it was demonstrated that the angular displacement of the iron indicated with absolute accuracy the differential velocity of the spindles. Sir William Thomson, in remarking on the ingenuity displayed, stated that the latter instrument might be a valuable application in the measurement of potential differences between two electrical currents.

* From a paper read before the British Association.

THE THICKNESS OF WIRE NECESSARY TO CARRY DIFFERENT ELECTRIC CURRENTS WITHOUT OVERHEATING.

By PROF. G. FORBES.

ONE would expect that if one wire would carry a current of one volt, then two similar wires would carry two volts. This is so if the currents are very far apart, but when the currents are near together we have to take into consideration the surface from which radiation is continually taking place. Consequently, however likely it would seem at first sight that the current carried would be proportional to the section, as a matter of fact it is not so. I find by experiment that if there is a departure from the law of the square of the diameter, then the law is that the current is almost proportional to the diameter of the wire. If you can carry a definite amount of current through a wire of a millimeter of thickness without heating it over a temperature of 150°, then if you want to carry a current twice as great through a wire you must have one of two millimeters diameter—i. e., four times the section. This is a very serious matter in regard to the extension of electric lighting. The method of arriving at the law was by taking pieces of wire of different diameters, putting a trace of beeswax upon them, and then by diminishing the resistance slowly so as to heat very gradually indeed, find the current necessary to melt the wax. Another very important law which is necessary for us to know in order to be able to change the type of dynamo so as to produce another which will give any desired electromotive force, is that when the wire is wound in coils so that the coils are the same size, then the strength of the current which is allowable is proportional to the square of the diameter of the wire—i. e., to the section. In determining this law I used small coils in tubes closed at one end, and filled with water of a definite temperature, then the current was raised by changing the electrical resistance until the temperature was definitely increased and the strength of the current was read off—this law being the result.

RECENT PROGRESS IN TELEPHONY.*

By WILLIAM HENRY PREECE, F.R.S.

THE telephone was first introduced to the British public at the meetings of the British Association. In 1876, at Glasgow, Sir William Thomson startled all his hearers by announcing the fact that he had heard, in Philadelphia, Shakespeare quoted through an electric wire, by the aid of the invention of Mr. Graham Bell, which he then pronounced to be "the greatest by far of all the marvels of the electric telegraph." In 1877, at Plymouth, I had the pleasure of showing in actual operation the finally developed instrument now known as the Bell Telephone, which I had just brought over from America, and conversation was actually maintained between Plymouth and Exeter. Five years have elapsed since then, and it is fitting that the British Association should hear of the progress made in the application of this astonishing apparatus.

In 1877, it was simply a scientific toy; it has now become a practical instrument. £1,550,000 capital is already embarked in its extension in England, and it is earning a revenue of £109,000. Hitherto it has been practically a monopoly in the hands of a private company, who hold the controlling patents, and of the Post-office, who possess the controlling power, but owing to the policy of the present Postmaster-General, this monopoly has been broken up, fresh patents have come into existence, and we are about to witness severe competition. It is often said that competition in any business will have the effect of reducing the rates charged to the public, but the experience of the past in railways and telegraphs scarcely teaches this lesson; competition does not always benefit the public. Undue competition tends to lower the rates for a time, but it eventually leads to amalgamation, to the absorption of the weak by the strong, to swollen and watered capital, and finally, in many instances, to higher rates to a too-confiding public. Competition, however, induces better service, and ultimately, in this respect, the public gain.

The free traffic in patents, however, leads to jobbery and speculation of the worst type. We have recently seen a mania for electric speculations that almost rivals the South Sea Bubble period. The public have wildly rushed into ill-matured schemes that have swollen the purses of gambling promoters, have turned the heads of inventors, have retarded the true progress of the beneficial application of this new science to the wants of man, and have thrown away millions upon imperfect schemes. Much has been said against the monopoly of the Post-office in telegraphic business, but it has, at any rate, the merit that it has checked the rapacity of company promoters and patent-mongers in that branch of the practical application of electricity, while no one can assert that it has checked the progress of telegraphy. During the first week that the telegraphs in this country were transferred to the State, the total number of messages transmitted was 26,000, while in the week ending August 11, it amounted to 724,000. There is no inventor who can assert that his scheme has not received proper consideration, nor show a real improvement that has not been adopted and remunerated; while the improvements of the Post-office itself are freely adopted by other countries, and America itself, the home of the inventor, has found the advanced system of England worthy of acceptance.

Receivers.—The original telephone receiver of Bell has scarcely been improved upon; it remains in form and construction very nearly the same as that which I exhibited in 1877. The perfection of its working depends upon the truth and perfection of its manufacture. It is now more solid and substantial than it was at first, more powerful magnets are used; but still it is the same simple, marvelous, and beautiful instrument that I brought over from America. Mr. Gower has increased its loudness by varying the form of its various parts, and using very powerful horse-shoe magnets of peculiar form; but experience shows that loudness is always obtained at the expense of clearness of articulation; and, although for many purposes the Gower-Bell instrument, which is adopted by the post-offices, and is now in use to connect together all the sections of the British Association scattered through the town of Southampton, is more practical, nothing for delicate articulation surpasses the original Bell.

The Paris Exhibition of last year, so fruitful in electrical novelties, did not bring forth any marked improvement in telephonic apparatus. It was noticeable chiefly for its practical applications of the telephone, and particularly to the transmission of singing and music to a distance. M. Ader's modification of Bell's receiver is that almost universally used in Paris. It is a very handy, pretty, and convenient form. He utilizes a principle which he calls "surexcitation." A thick ring of soft iron is inserted between the ear-piece and the diaphragm, and this is said to increase the attractive power of the little horse-shoe magnet upon the vibrating iron diaphragm. A simple experimental apparatus of M. Ader's shows that there is some foundation for this fact: when a thin steel spring is adjusted close to the poles of a magnet without being attracted by them, the near approach of a mass of iron to the spring will cause it to be attracted by the magnet.

D'Arsonval has also modified the Bell receiver. He has placed the coil in a powerful magnetic field of annular form, and has thereby concentrated the lines of force upon the induced coil. He brings the whole coil within the influence of the field. The effects are considerably magnified, and the increased loudness is not accompanied by the usual loss of articulation. Speech is said to be reproduced without any change of *timbre*.

Telephone receivers of the Bell type are all based upon the magnetic effects of currents of electricity flowing around magnets or bars of soft iron. The rapid and rhythmic magnetization and demagnetization of a bar of iron, or the increment and decrement of the magnetism of a magnet, will produce molecular disturbances, in its own mass and in the matter about it, that lead to the oscillatory motions of the whole, which produce sonorous vibrations that can be made manifest by various devices, and particularly by that patented by Graham Bell.

Other principles of electricity have also been utilized for telephonic receivers. For instance, Mr. Edison used the electro-chemical effect. The decomposition of a chemical solution in paper or on chalk by the passage of currents through it produces a modification of the friction of two moving surfaces, which can reproduce sonorous vibrations, and the result is a very loud-sounding apparatus. I myself had the pleasure, in 1880, of submitting to the Royal Society a receiver based on the electro-thermal effects of the current. The passage of a current through wires always heats them and therefore produces expansion. If the wire be made fine enough, the heat is generated and dissipated so rapidly, the expansion and contraction are so quick, that sonorous vibrations are the result. Although I was able to speak through it very clearly, I have not as yet developed this instrument into a practical form. Professor Dolbear has recently utilized the electro-static effects of currents. His receiver is even more simple than that of Bell. Two flat circular disks of metal are rigidly fixed very close to each other in an insulated case of ebonite. When one disk is electrified positively by a charge of electricity, the other is electrified negatively by induction. These two opposite states produce attractions varying in force with the strength of the signals sent, and the result is that, when telephonic currents are transmitted, we obtain sonorous vibrations, and consequently, the reproduction of speech.

Many other forms of telephone receivers have been devised and exhibited, in fact I have recently seen quite a crop of them; but as they involve no new principle, and introduce no particular improvement, having been brought out chiefly to try to avoid existing patents, I pass them over, and proceed to the next branch of my subject. Our present patent law is, unfortunately, in so disorganized and chaotic a condition that evasion is often possible, and hence the questionable morality of doing a thing in another way in order to avoid the incidence of a royalty is practically encouraged. The possession of a patent is now no guarantee of property; it is granted without any discrimination, and cannot be upheld without tedious litigation and wasteful expenditure before a non-technical and scientifically incompetent tribunal. We therefore cannot hope for any virtue in English inventors or security for real improvements until our law is thoroughly revised. The question is before the House of Commons, and when wordy agitators have fully exhausted the patience of our legislators, we may hope for some attention to so real and pressing a want.

Transmitters.—The great novelty and peculiarity of Bell's telephone was that the receiver and transmitter were similar and reversible. Sonorous vibrations of air impinging on an iron disk caused it to vibrate in front of a magnet, around one pole of which a portion of an electric circuit was wound. These vibrations of a magnetic substance in a magnetic field produced currents of electricity in the coil of wire on the magnet, varying in strength and direction with the sonorous vibrations, which, proceeding along a wire to a distant station, there varied the magnetic strength of a similar magnet so as to vary its attractive force on a similar disk, by which it reproduced the motions of the first disk, and thus, reproducing the sonorous vibrations of the air, repeated speech. The currents, however, were very feeble; much energy was lost *en route*, and the effect scarcely attained a practical standard. Mr. Edison showed how to strengthen these currents. Taking advantage of a peculiar property of carbon, which was supposed to vary in electrical resistance with the amount of pressure brought to bear upon it, he caused the vibrating disk which was spoken against to press upon a button of carbon, and so to vary the strength of a current of electricity passing through it. This varying current, passing through the primary wire of an induction coil, set up in the secondary coil more powerful currents than the Bell instrument produced, and caused louder and more marked effects at the receiving station. Professor Hughes went a step further. He found a combination of materials that were directly affected by sonorous vibrations, which he called a "microphone," and he proved that the effect of a carbon transmitter of Edison was not due to any influence of varying pressure on the mass of the carbon, but was a phenomenon of loose contact. He found a new fact in nature, and he startled the scientific world by introducing an instrument which did for minute sounds what the microscope had already done for minute objects. By the light thrown on the theory of the instrument by Hughes, Edison's carbon transmitter has been so improved by Blake, Hunnings, Moseley, Anders, and others, that little apparently remains to be done. The telephone as a speaking instrument is now well-nigh perfect. It is quite possible to swear to a friend's voice at 100 miles distance. The difficulty of making the telephone a practical instrument under all circumstances is not due to any defects in the instrument itself, but to disturbing influences external to it, and consequent on its surroundings. The very perfection and sensitiveness of the apparatus itself are its chief enemies.

The true action of the microphone, or carbon-transmitter, is very little understood; it introduces into a closed electric circuit, through which a current is flowing, a resistance which, varying exactly with the sonorous vibrations impinging upon it, causes the current to undulate in a way exactly analogous to the varying sound waves. This effect

* Paper recently read before Section G, British Association.