

Mr. Preece. wished to apply it, and who possessed the current prices of materials. The subject had been more fully worked out by Mr. T. Gray.¹ He however agreed with Mr. Blakesley, that the number of amperes per sectional area which could be transmitted with safety and economy was greater than that given by Sir W. Thomson and the late Sir W. Siemens.

Sir J. W. Bazalgette. Sir J. W. BAZALGETTE, President, said that the Paper had led to a very practical discussion. There had been a healthy rivalry between the manufacturers of iron and copper wire, and if, as the Author had pointed out, those gentlemen would call in the aid of the chemist, the result would be that conductors would be greatly improved both in regard to conductivity, strength, and cheapness. He might mention that he had just received a message through an electric conductor, stating that communication had been that day established between the two ends of the tunnel under the Mersey.

Correspondence.

Mr. Atkinson. Mr. W. ATKINSON concurred with the Author in thinking it desirable that iron electrical conductors should be covered with zinc, notwithstanding zinc was readily dissolved in soft water. He might mention some observations that had been made, and experiments tried, with the hope of harmonising opposing views. A galvanized iron roof exposed for fifteen years still retained the mottled markings of a new plate, though in a less degree. The inside of a galvanized iron cistern, after containing water supplied by the Lambeth Company for eighteen years, was in good condition, though there was a visible formation of the carbonate of zinc on that part to which the water did not reach, or only very rarely. Zinc exposed to the air for some time, and that had lost its brightness, had one side rubbed with emery cloth, and was then placed in a bottle of boiled rain-water, and the bottle was then corked. After one hundred and twenty hours no action had taken place. A similar strip was placed in unboiled rain-water in the same way in every respect, and the polished side was covered with a very fine and uniform film of white matter, no doubt the carbonate or oxi-carbonate of zinc. On the other side there was also a slight whiteness. Another strip was placed in rain-water in an open vessel, and there was a considerable formation of the carbonate on the polished side, at and just below the

¹ Philosophical Magazine, 1883, vol. xvi., 5th series, p. 187.

water-level, and some, but much less, on the side that had not Mr. Atkinson. been recently polished. Another strip was placed in the Lambeth Company's water in an open vessel, and on the polished side there was a marked formation of the carbonate, but on the unpolished only a faint whitening of the surface. Hence it seemed evident that the clean surface of zinc was acted on both by hard and soft water when carbonic acid was present, but that no action took place when it was absent. Also that when zinc had been exposed to the air for a considerable period, its surface was so altered by oxidation or otherwise, that it was only slightly affected by rain falling on and running over it.

Mr. A. JAMIESON observed that the Author had referred to Mr. Jamieson. Matthiessen's standard resistance, namely, "100 inches, weighing 100 grains, giving 0.1516 ohm at 60° Fahrenheit," as well as the specific resistances—

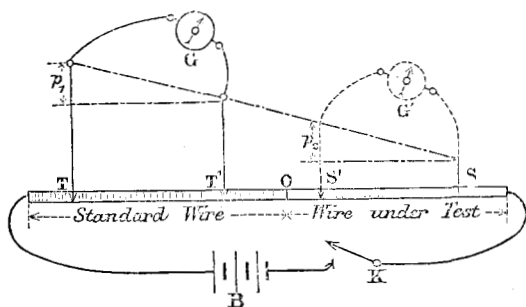
1 metre weighing	1 gram	=	0.144 ohm at 0° C.
1 foot	"	1 grain	= 0.2064 " "
1 knot	"	1 pound	= 1091.22 " "
1 mile	"	"	= 842 " "

These results of Matthiessen's were not, however, in true ohms, as represented by the Author, but in the B. A. units as published by the British Association Committee on Electrical Standards in 1864. To reduce them to Lord Raleigh's determination in October 1882, namely, "one B. A. unit = 0.9865 of the true ohm,"¹ each of the above values had therefore to be lessened by 1.35 per cent. This correction, small as it might appear when applied to the standard length-weights metre-gramme and foot-grain, reduced the knot-pound from 1091.22 B. A. units to 1076.49 ohms, or a difference of 14.73 ohms. Many careful experimenters were having their resistance coils corrected to Lord Rayleigh's value of the ohm. Another point worthy of attention was this, that the values mentioned by the Author were for pure annealed copper wire, which was seldom met with in practice; it was better, therefore, to take the specific resistances in ohms (B. A. unit results corrected) of hard-drawn pure copper wire when dealing

¹ A mean of three series of experiments carried out at the Cavendish Laboratory in 1882, by the method of Lorentz, gave 0.98677 ($\times 10^9$ C. G. S.) = 1 B. A. unit, which would amount to a reduction of 1.32 per cent. in converting from B. A. units to true ohms. The Units Committee will probably issue, after their meeting in April next at the Congress in Paris, a definite "determination."

—A. J.

Mr. Jamieson. with telegraphic or electric light measurements. For example, 1 metre of copper weighing 1 gram = 0.1469 B. A. unit = 0.1449 ohm at 0° Centigrade. The Author said that "the test for purity is extremely simple;" but, although he gave the formula by which the results, when obtained, might be used for finding the percentage purity of any wire, he did not indicate which was the easiest and most accurate test to employ. If a specimen of but 2 or 3 feet of thick wire were handed to an electrician with the request that he would determine its percentage purity, the resistance was so small that the ordinary Wheatstone Bridge methods with resistance coils were useless, and recourse must be had to Sir William Thomson's Wheatstone Bridge arrangement, or Messrs. Matthiessen and Hockin's modification thereof, with Kirchoff's bridge wire, or to the difference of potential method, which was by far the simplest of application and needed but little apparatus. As it was not as yet well known to engineers, and its application to the measurement of short lengths of thick wire or very low resistances had not yet been recorded in text-books, it might be well to mention it. Sir William Thomson had recently designed a mhometer for obtaining the conductivities or "mhos" $\left(\frac{1}{\text{ohm}}\right)$, or the reciprocal of very low resistances.¹



DIFFERENCE OF POTENTIAL TESTS FOR SMALL RESISTANCES.

1. Join a standard wire of known resistance or percentage purity by a good metallic connection at O to the wire to be tested, and put them in circuit with a constant battery B by a key K.

¹ "Electrical Pocket Book." By Munro and Jamieson, p. 95.

2. Mark off on the standard wire a certain length T T' (say Mr. Jamieson. 100 inches or 100 centimetres), and apply the electrodes of a quadrant electrometer to T and T', or mirror galvanometer of high resistance, compared with the wires under test, and note the deflection d_1 due to the difference of potential p_1 between these points.

3. Switch the electrometer or galvanometer quickly into the position G', and note the deflection, d_2 , due to the difference of potential p_2 between points S and S', and if possible so adjust the lengths T T' and S S' that the deflections d_1 and d_2 are equal.

Then, if the sectional areas of the standard wire and the wire under test are the same—

Length. Length.

T T' : S S' :: 100 : y = the percentage purity of the wire under test as compared with the standard wire.

But if the wires are of different sectional area, let A be the cross area of the standard wire, and A' that of the other.

Then T T' : S S' :: 100 : y = percentage conductivity required ;
and A' : A.

Example: 100 inches of pure copper No. 16 in circuit with a copper wire, 55 inches of No. 18 wire when deflection $d_1 = d_2$, what is the percentage conductivity of the No. 18 wire?

Here T T' = 100 inches, S S' = 55 inches, A = 0.0033 square inch, and

A' = 0.0019 square inch ;

∴ 100 : 55 :: 100 : y = 95.5 per cent. purity.
and 0.0019 : 0.0033.

The Author omitted to mention the properties of aluminium and aluminium-bronze wires. From some experiments which Mr. Jamieson had been carrying out lately on these wires, it appeared that the former, from its extreme lightness, might be used for military telegraphic purposes, where weight and bulk of bag and baggage played such an important part, while the latter aluminium-bronze seemed admirably adopted for high resistance coils under certain circumstances, for it had about double the resistance of German silver for the same length and area. He was still engaged on these tests, and herewith sent those of two of the first samples that came to hand, but he was in hopes of getting still better results from others which had just arrived.

Mr. Jamieson.

TESTS of ALUMINIUM and ANNEALED COPPER WIRE.

Taken at the College of Science and Arts, Glasgow, December 1883.

1. CHEMICAL TESTS by Dr. CLARK, F.C.S., &c.

Copper, sp. gr. . . .	= 8·822	French aluminium, sp. gr. = 2·736	
	Per cent.		Per cent.
Copper	99·99	Aluminium	98·39
Arsenic	0·01	Iron	1·24
		Silicon	0·37
	<u>100·00</u>		<u>100·00</u>
Weight per cubic foot = 550 lbs.		Weight per cubic foot = 170·6 lbs.	

$$\text{Ratio of weights, } \frac{\text{copper}}{\text{aluminium}} = \frac{3·225}{1}.$$

2. ELECTRICAL TESTS by A. JAMIESON, F.R.S.E. Temperature 59° Fahrenheit.

	Diameter.		Weight and Length.		Resistance and Length.	
	Millimetre.	Inch.	Grains per Foot.	Lbs. per Mile.	Ohm per Foot.	Ohms per Mile.
Copper wire . .	2·413	0·095	188·1	141·9	0·01125	5·94
Aluminium ¹ „ . .	„	„	58·4	44·0	0·02210	11·67

$$\text{Ratio of resistances, same length and area, } \frac{\text{aluminium}}{\text{copper}} = \frac{1·96}{1}$$

$$\text{„ „ „ weight, } \frac{\text{aluminium}}{\text{copper}} = \frac{0·6}{1}.$$

3. ELECTRICAL TESTS of ALUMINIUM-BRONZE, COMPARED with PURE COPPER WIRE.

	Diameter.		Weight and Length.		Resistance and Length.	
	Millimetre.	Inch.	Lbs. per Mile.	Feet per lb.	Ohms per Mile.	Feet per Ohm.
Aluminium-bronze .	2·108	0·083	104	50·8	200·00	26·0
Pure copper . . .	„	„	110	48·0	7·91	667·3

$$\text{Ratio of resistances, same length and area, } \frac{\text{aluminium-bronze}}{\text{pure copper}} = \frac{25·3}{1}.$$

This specimen of aluminium-bronze broke with a tensile stress of 70,000 lbs. per square inch, but several specimens had stood 100,000 lbs.

¹ The results were obtained for an aluminium wire of cross area 0·008219 square inch, and reduced by calculation to the area of the copper wire, namely, 0·00709 square inch.—A. J.

Mr. W. H. MASSEY, would be glad if the Author could give Mr. Massey. some further explanation of the law which Sir William Thomson was said to have laid down with regard to wasted energy and interest on capital. At one of the British Association meetings, Sir William gave a rule for finding the size of copper conductor required for a certain purpose, and he directed attention to the fact that the most economical size of the copper conductor would be found by comparing the annual interest of the money value of the copper with the money value of the energy lost in it annually; but the Author stated that "the wasted energy must equal the interest on the capital expended in laying down the conductor to give the maximum useful economical result,"—which might or might not be true in every instance, as an example would prove if the cost of laying the conductor was small.

It had also been shown by Sir William Thomson that the size of conductor did not depend on the length of it through which current was to be sent; and, as every electric light engineer knew that twice the area of conductor would not carry twice the current (although twice the weight of copper would do so if put into two separate cables), it would appear that neither the length nor the size of a conductor should be considered apart from its shape, and that no law or rule could be called general which did not take into account the heat-radiating surface of the conductor and the character of the insulating material by which it was surrounded.

Dr. H. MILITZER, of the Austrian Telegraph Administration, Dr. Militzer. contributed some particulars of the conductors used in that department. From 1846 to 1855 a copper wire $2\frac{1}{2}$ millimetres in diameter was employed almost exclusively. Trial of an iron 3-millimetre wire in 1852 gave unsatisfactory results because of its defective joints, and for a time no further effort was made in that direction. But as the number of conductors fixed to the poles increased, and crossings of the wire became more frequent, the exclusive use of copper was impracticable, on account of its insufficient tensile strength, and also because of its cost. Since 1856 iron had been almost exclusively used. The first iron wires had the same diameter—3 millimetres—and that size satisfied the conditions until about 1865, when high-speed and long-distance transmitters began to be adopted. Then by degrees $4\frac{1}{2}$ and 5 millimetres were taken, and the latter dimension was now generally recognised as the standard for the whole network of Austrian telegraphs. At first efforts were made to reserve the use of the thicker wires for the long through lines, wires of 3 millimetres being retained for the local traffic. But experience showed that

Dr. Militzer. the simultaneous employment of wires of different dimensions, hung to the same poles, was inconvenient; further, the smaller wires were not sufficiently resistant to the great cold of winter, and were found to break easily under the weight of the snow, which sometimes obstructed them to an almost incredible extent. Wire 3 millimetres in diameter had therefore only been retained in towns and in the immediate neighbourhood of large stations, where there was not room for big wires. It was, nevertheless, not improbable that its use would be discontinued even under these exceptional circumstances, recourse being had to silicium-bronze.

The iron wire used in Austria was not galvanized, but was steeped when hot in linseed-oil, which was expected to protect it from rust when in store. Some trials had been made of galvanized wire, but with only moderate success. The cost was enhanced nearly 30 per cent., while the valuable qualities inherent in the Styrian iron were injuriously affected by the process, since galvanized wire was much less easy to handle, and also became brittle. According to his experience, 3-millimetre iron wire ungalvanized would last for fifteen years, and similar wire 5 millimetres in diameter from twenty to twenty-five years, and that endurance was satisfactory. All the iron wire was made from Styrian and Carinthian ore, although some of the works were situated in Bohemia. The wire had to satisfy certain official conditions, which had remained almost unchanged for the last fifteen years, although the wire now furnished greatly surpassed the specifications alluded to. The administration insisted that 5-millimetre wire should bear, in a length of 16 centimetres, fifteen complete twists without cracking or breaking, and from fifteen to twenty bendings at right angles in opposite directions. It must also support a weight of 695 kilograms without breaking, even if it contained a joint. The wire was furnished in coils of 400 metres, with not more than three joints per coil. No special test for conductivity was exacted, because the Styrian iron, from its purity, was very constant in this respect. Joints were made by twisting each wire several times round the other and soldering the connection with tin, after having placed between the spirals a small length of copper wire as an additional security.

For spans, beyond from 250 to 300 metres, wire of cast steel or Bessemer metal was employed, ordinarily 3 millimetres in diameter. Trial had been made, for the neighbourhood of chemical works, of an American compound wire, but it had not answered, the iron core separating from the copper casing after a very short time.

Mr. J. R. Mosse observed that in thinly settled countries the strength of a telegraph wire was as important a consideration as its conductivity; for otherwise in forests the wire would be frequently broken by the falling of branches of trees, or by other casualties. Across the deep ravines in the "up country" of Ceylon, the spans of wire were sometimes as much as 600 yards, and for this distance strength was requisite. One point connected with the choice of a telegraph wire was not likely to occur to an electrician accustomed only to English practice, namely, what description of wire would be less generally useful for other than telegraphic purposes? About thirty years ago, a teamster in Nova Scotia who had broken his traces would occasionally climb the nearest telegraph post and cut off a few yards of wire to mend them, and then sometimes join the wire with a piece of string. Similarly telegraph wire was occasionally used for mending gaps in fences; but owing to stringent laws this practice has long since been discontinued. In North America the posts were generally of oak or juniper, spaced about 60 yards apart; including wire and a Morse instrument, say every 20 miles, the cost of a telegraph line several years ago was about £20 sterling per mile. The cost of transport in a new country necessitates the use of the lightest materials commensurate with strength. In Ceylon, about twenty years ago, many iron lattice bridges, 80 to 160 feet in length, 15 to 18 feet wide, manufactured in England, were carried several miles by coolies to the spot at which they had to be erected; and at the present day barrels of cement, bags of lime, and tools, were thus transported from the nearest point on the cart-road to the railway works, the load being generally slung on a pole and carried by two or four men. One coolie could carry about 50 lbs. a distance of some 10 miles per day, returning without a load to the starting point; and he would of course carry proportionately further when not so returning. Coolies with loads would not average more than 15 miles per day when on a long journey, and with wages at 10*d.* per day, the cost of transport by coolies was generally about 3*s.* 6*d.* per ton per mile, or say double the usual cost of transport by bullock carts.

Dr. WERNER SIEMENS thought the Author had with good reason drawn attention to the great importance of increasing the specific conductivity of the metals used for Electrical Conductors, as the working capacity of submarine or underground cables, under otherwise similar conditions, increased in direct proportion with the specific conductivity of the copper. In the Tables communicated by the Author, giving the specific conductivity of the copper

Dr. Werner
Siemens.

Dr. Werner Siemens. used since the time of the first cables, it was of great interest to observe to what a high degree industry was in a position to follow scientific demands, and how important it was to continue in the endeavour after still further improvements in this direction in the manufacture of copper. Considering that the value of the copper used in a submarine cable was only about one-twentieth part of the whole cost of the cable when laid, and that an improvement in the conductivity increased the working value of the cable in much greater ratio, it was worth while to use much dearer copper, if greater conductivity could be thereby obtained. The standard of conductivity still in use in England (pure copper) was no longer sufficient, since the limit of maximum conductivity was now approached. The conductivity of copper depended not alone on its chemical purity, but it was also influenced by the degree of softness. Moreover, the absorption of oxygen, hydrogen, and carbon, in so small quantities that they could not be detected by chemical tests, had a great influence on the conductivity of copper. These substances were taken up in the process of smelting, and in the necessarily repeated annealing during the drawing of the wire. Hence purity, as determined by chemical tests, was not a safe measure of conductivity. On these grounds he had proposed, as early as the year 1860, to take as the standard of conductivity that of pure mercury at a temperature of 0° Centigrade.¹ Taking the English standard, the maximum conductivity of copper was expressed by 58.9 in terms of the conductivity of mercury at the freezing-point; but this was certainly not the extreme limit of conductivity attainable. A copper wire, drawn without re-smelting from a piece of Caucasian reguline copper was found to have a conductivity of 61 according to the mercury standard. It was therefore probable that, by continuing the present efforts to obtain high conductivity, there would soon be in the market copper of greater conductivity than "pure copper." It would therefore be advisable that England should adopt the mercury standard accepted on the continent. He entirely agreed with the remarks on the great durability of iron wire for overhead conductors. Even ungalvanized iron wires had lasted unexpectedly long in neighbourhoods where the air was not much vitiated by manufactures. In Russia many conductors of ungalvanized iron wire, 5 millimetres thick, were still in existence which had been erected by Messrs. Siemens and Halske between 1854 and 1856. A firmly-adherent layer of oxide was soon formed on the surface of such wires, which

¹ Poggendorff's *Annalen*, Bd. 110, § 1. Reprint of Papers, p. 229.

completely protected the iron from further attacks of the oxygen of the air. The galvanization of wires usually adopted was a sufficient protection against ordinary impurities of the air even in thickly-populated and industrial neighbourhoods, but not in manufacturing or maritime districts. The Author regretted that steel wires had never been successfully cased with a protecting sheath of copper of good conductivity. It was therefore in such places absolutely necessary to use lead-covered steel wires or alloys of copper of considerable hardness—as for instance phosphor-bronze, which could withstand these destructive influences. That these wires had comparatively low conductivity was of small moment in overhead conductors, since the limit of working capacity of a telegraph circuit depended in large measure on its electrostatic capacity, which in the case of overhead conductors might be neglected in comparison with that of underground conductors. This circumstance was also in favour of the use of steel-wire conductors, in spite of their greater resistance, as in well-insulated overhead conductors the mechanical properties of the material were much more important than its conductivity. In so far as decrease in speed of working was concerned, this could be compensated for by using stronger batteries and correspondingly larger resistances in the instruments employed. For these reasons, since the time of the earliest of the more important projects which had been accomplished, overhead conductors had been made of iron, or later, of soft steel wire; while on the other hand, for all underground and submarine cables, copper wire of the highest attainable conductivity had been employed. He could not endorse the remark that the first cables insulated with gutta-percha were constructed with iron wires. The first telegraph lines with gutta percha insulation were those employed in Prussia between 1847 and 1850,¹ as he had mentioned on several occasions. Those underground lines contained copper wires $2\frac{1}{2}$ millimetres in diameter covered by packing with solid gutta percha.

Mr. L. WEILLER contributed the results of his experience in France on the improvement of electrical conductors. The first aerial conductor in that country was laid in 1848, between Paris and Rouen. It was of pure copper, and at the end of a few weeks stretched immoderately. At that time, France was in the midst of a revolution, and the great highways were patrolled by robbers rather

¹ Poggendorff Annalen, Bd. 79, p. 481; Mémoire sur la Télégraphie Électrique, présenté à l'Académie des Sciences, le 15 avril, 1850; Reprint of Papers, pp. 33 and 51.

Mr. Weiller. than by the police. The Telegraph-Administration neglecting to remove the wire which lay on the Rouen road, the stretching having thrown down the telegraph-posts, thieves saved them the trouble. Mr. Bergon, the manager of the Post and Telegraphic administration in France, had told Mr. Weiller that at the end of eight days there remained not a yard of wire in the air. This, with other considerations, decided the authorities to use iron wire in future. Since 1848, the manufacture of iron had so improved that it was a matter of course that wire made of that material should also be better. Until very recently, the telegraph administration ignored the conductivity of their wires. They took at haphazard, as a standard, iron wire 4 millimetres (0.157 inch) in diameter, having an electrical resistance of 10 ohms per kilometre; but this resistance varied greatly with the quality of the wire. Only recently had they imposed a minimum resistance in the Government contracts, though it must be acknowledged they had obtained for iron-wire a quite sufficient conductivity in proportion to the price. Swedish wire best fulfilled the conditions of conductivity imposed; but its excessive weight, the continuous increase in the number of aerial wires, and the growing employment of multiple telegraphy, necessitated at present the employment of a wire at once lighter and of superior conductivity. For this reason, attention was now being had to the substitution for iron wire of steel, or of wires made of copper or its alloys.

The Author had sufficiently explained how they had been able to-day to produce commercially, copper wires having nearly twice the conductivity of those formerly used. The reduction of the sub-oxide, and the elimination of the metalloids always found in combination with copper, were the sole causes of their having attained for copper a conductivity nearly equal to that of silver. Also the electrical resistance attributed by Matthiessen to copper wire, still used as a standard, was no longer exact. This resistance was, when formulated, 20.57 ohms per kilometre, at 0° Centigrade for a wire 1 millimetre in diameter, while at present, for the same conditions, it was only 20 ohms per kilometer, and by recent progress in electrolysis, it had been further reduced to 19.56 ohms, or scarcely more than that of pure silver. These latest conductors possessed, therefore, from 5 to 6 per cent. greater conductivity than the older ones, which by easy calculation could be shown to be equivalent, in the case of an Atlantic cable, to two or three words more per minute than the capacity of the present conductors. This would be in the future a fruitful source of economy in cables connecting Europe with the antipodes.

From a mechanical point of view, however, the progress realised Mr. Weiller. in copper wire, though very important, did not give sufficient results to warrant its employment aerially. Pure copper hardened little at the draw-plate by cold-drawing; it might be made to acquire sufficient mechanical strength, but its conductivity then lessened apparently, and it became rather more brittle. Furthermore, when it was quite pure, *i.e.*, contained merely traces of the sub-oxides, so slight that they could never be removed unless by substituting for them something else, it tended to expand or contract under the influence of heat or cold, and at the end of a few years to assume molecular deformation, which led to its deterioration or modified its electric qualities.

It was for this reason that attention had been paid to the removal from copper of its oxides, by means of phosphorus, and their replacement by small quantities of tin. This alloy, known as phosphor-bronze, had given, mechanically, wonderful results. By sacrificing its conductivity, a strength could be imparted to it equal to that of the best steel; but in that case there was no advantage in employing it in preference to steel or iron, which were much less costly. It was true that phosphor-bronze, like all its associates, resisted admirably the action of the weather which was not the case with iron or steel. Another advantage not to be despised in wire of phosphor-bronze was, that under its breaking-weight the molecular deformation acted by fibres, while in iron or steel wire it was granular. This fact to a certain extent accounted for the numerous failures of suspension-bridges made of iron wire which had ended by breaking under their own weight, although their sections were calculated for loads naturally much greater.

But if the qualities just attributed to phosphor-bronze made it of great value in purely mechanical applications, it was less so where electricity was concerned. It was known that phosphorus was an insulator rather than a conductor; also, that although this deoxidiser was only intended to act temporarily, traces of it always remained in the bronzes it deoxidised. Hence resulted either a great loss of conductivity, or, where only minute quantities of phosphorus were employed, a conductivity high but never homogeneous, by reason of the considerable variations imparted by traces of phosphorus to the conductivity of an alloy. This non-homogeneity of phosphor-bronze rendered the material unsuitable for telegraph lines. It was, therefore, necessary, as the Author had said, to look for a deoxidiser that was itself a conductor of electricity. Thus resulted the wires made of siliceous

Mr. Weiller. bronze. Such wire was now made in England, having a conductivity of from 97 to 99 per cent. of those of pure copper, possessing a tensile strength of from 28 to 29½ tons per square inch, and of extreme malleability. Such electrical and mechanical qualities were a powerful aid to the transformation of aerial lines, which became more and more necessary as their number increased, and as multiple-apparatus became improved.

The reduction of taxation had always been and would always be an important consideration to all governments, and the foregoing considerations indicated how this might be accomplished in respect of telegraph administration, by the employment of conductors capable of sending messages to double or treble the distance, while their capacity remained the same or even became increased. In this way it was not unreasonable to expect in the near future considerable reductions in international telegraph tariffs. There was another question, perhaps less generally important, but yet of considerable interest to the financial world, namely, the direct and easy communication between financial centres. Silicium-bronze would probably render a sure means of establishing such communication with a speed of transmission so high that exchange telegrams would always reach their destination in time to be useful.

It was not merely in aerial telegraphy, properly so called, that wires of high conductivity and great mechanical strength were called upon to render service. Their qualities rendered them eminently fitted to fulfil the special demands of military telegraphy. Every one knew with what scrupulous care were calculated to within a pound the weights, and to within a square inch the bulk, of the multitudinous impedimenta constituting the baggage of an army in the field. This precaution was indispensable, so as to shorten the string of vehicles which accompanied it, and constituted a great source of embarrassment to those in command. The carriages used in field-telegraphy carried a number of reels wound with iron wire, generally 2 millimetres (0·079 inch) in diameter. If for this wire were substituted silicium-bronze wire of 1 millimetre in diameter, it would be practicable to reduce the weight to one-fourth, or to carry a length four times as great.

From another point of view, if, in the insulated wires also laid from these carriages, the present core, composed of ordinary copper-wire of scarcely any resistance to traction, were replaced by one formed of strong silicium-bronze wire, the core itself would possess the necessary strength, and it would become possible to

reduce the thickness of the insulating medium, and consequently Mr. Weiller, the space occupied on the reels.

There had been essayed for submarine telegraphy the so-called light wires, less costly than the ordinary cables and allowing by reason of the diminution of bulk and weight, of the employment of laying-vessels of less size, or of a single vessel instead of several. Experiments had been made on a sufficiently large scale by the most eminent English engineers, especially by the late Sir William Siemens. The non-success of these trials was due to the inability of the hemp protection to withstand the strains of laying. Probably, if the necessary strength had been supplied by the core itself, and the covering been merely regarded as a protecting medium, success would have resulted.

For these reasons, Mr. L. Weiller was quite in agreement with the conclusions of the Author respecting conductors for aerial lines. But he differed from the opinion that for submarine cables the strength of the core was quite negligible. That was only so when the insulating coating had iron- or steel-wire protection; but how great would be the facility of laying and of transport, as well as the economy realised by the employment of a submarine cable, of which the conductor would at once transmit the current, and afford protection against mechanical strain.

11 December, 1883.

JAMES BRUNLEES, F.R.S.E., President,
in the Chair.

The discussion upon the Paper "On Electrical Conductors," by Mr. Preece, occupied the whole of this meeting.
