# DISCUSSION.

Mr Whiffen considered that the author had given a most able and unbiassed explanation of the various systems of underground electric mains. He (the speaker) represented the Crompton bare copper system, which was specially designed for carrying currents of low potential but of large quantity through crowded thoroughfares with best possible insulation. It had been severely tested on as large a scale as any other system and proved its efficiency. He was willing to give credit to the Ferranti tubes, which had astonished everyone and had proved a great success, but these being high tension mains did not come into the same category as the bare copper system. In Melbourne they talked very largely about carrying the electric mains underground, but when it came to the question of cost they acted very differently. This was only putting off the evil day, as conductors carrying the enormous currents now in use must ultimately be placed underground, and this course was now being pursued in New York. The author had put forward various systems as being suitable, but the point to determine was which possessed the greatest advantages for the City of Sydney. In the Callender System the insulation was mechanical, whereas with the bare copper it was ærial; the best that could be obtained. Another point was, that in a busy city the practicability of examining or jointing the mains was a serious matter, and the bare copper system certainly offered much less difficulty than any other system, as, with man-holes arranged at regular intervals, the mains could very easily be tapped, but was that the case with the Callender system. He believed there would yet be a system expounded in Sydney which would be on the bare copper principle with some modifications. The greater proportion of the electric lighting in London was carried out on the bare copper system and he considered that there was some analogy between that city and Sydney, and what was suitable for one should surely apply to the other. Although America had gone ahead so largely with high tension currents, still some of its cities, notably New York, Boston, and Baltimore, were rapidly going back to the continuous low-tension system.

Professor Threlfall endorsed the author's remarks regarding the difficulties which beset engineers in deciding on the dimensions of conduits, as it was almost impossible to obtain reliable information as to the probable load which was likely to be put upon the conductors within any reasonable number of years. He had had this matter before him for some time, in reference to the lighting of the city of Sydney, but so far had been quite unable to even roughly estimate what the demand for light was likely to be. As far as he could judge, where conductors carried large quantity currents the bare copper was the best system. In 1884, Mr Crompton had shown a considerable amount of enterprise in the introduction of his system, and in spite of the doleful prognostications at that time it had proved itself very successful, but before adopting this or any similar system in Sydney there was one very important point which required serious consideration. The atmospheric conditions ruling in London and Sydney were totally different, for although the yearly rainfall in the latter city was only about twice that of the former, still there were times when it fell with tropical violence, and might possibly flood the conduits and thus break down the insulation. He was at present engaged in some experiments on a bare copper system of his own design, and he thought that as much as four tons might be laid in one length, thus reducing the cost of laying and the possibility of less resistance on account of the reduced number of joints.

Mr. A. W. Tournay-Hinde considered that the future success of electrical distribution from central stations depended very largely upon the use of reliable underground mains. The author's paper, coming as it did at the present time, was of paramount interest, it moreover showed that much time had been spent by various investigators on the subject. Present dynamo design left very little room for improvements, various kinds of lamps could now be obtained for transforming electrical energy into light, though perhaps not quite so efficient as they might be in the near future. The principal trouble, if such it might be called, appeared to exist in the transmission of electrical energy by underground conductors. In saying this, he did not refer to the actual transmission of the energy, but to the successful insulation of the mains. Undoubtedly there were many systems in every day practical use, but he did not think that it could yet be said that electric light mains and services could be run and handled with the same facility as those conveying our water and gas. What appeared to be wanting was something that should be able to insulate the electric current as effectually as iron might be said to insulate water. It was doubtless true that iron pipes deteriorated from the effects of rust, that gas pipes were more or less permeable to gas, but the leakage of water or gas did not involve the same risks that a similar leakage of electricity would. Many of our dielectrics were more or less injured in the course of time from the prolonged effects of a current passing through them, for it must be borne in mind that, though nominally called insulators, there appeared to be no substance through which the current could not pass, although the quantity might be infinitely small. Although he had no partiality to any particular system, it would appear that those systems that used bare conductors supported on glass insulators presented some advantages under certain conditions over those in which the insulating medium continuously covered the conductor. It might be inferred that the principal leakage in a bare conductor system should be over the surface of the glass insulator, which could not be kept absolutely dry in the chemical sense of the term; here the current in passing did but little harm to the glass insulator, as the extremely thin film of moisture on its surface bore the brunt of the current's action, and this film, moreover, was continually being replaced from the atmosphere. It had occurred to him that, as there must unavoidably be, no matter with what system, a certain small current leakage from main to main, that it might be within the realms of possibility to utilize this leakage for the purpose of improving the insulation. To accomplish this end he would suggest, taking for an example a continuously covered cable, that perhaps there could be found scme substance or substances which, if placed next the metallic surface of the positive conductor and outside the insulating covering of the negative, might, from electrolytic action, produced by the current passing from main to main, coat the inside of the insulation on one main and the outside of it on the other with a substance that would offer a high resistance to the current, and thus improve the insulation instead of tending to break it down. Wherever along a main a fault occurred this action would take place more rapidly, and by doing so would help to correct it. If an alternating current were on the mains, it would be necessary to arrange that one phase or alteration should exceed the other in current value, somewhat after the fashion of Messrs. Lowrie and Hall's system at Notting Hill, where, he believed, the same effect was in use for the purpose of actuating the consumers' meters. He must ask your lenience in putting this before you in a rather crude form, but he had not had time or opportunity at his disposal to investigate it as thoroughly as he might have wished. If something of this kind could be done, or something of a similar nature, it would undoubtedly improve the quality of our underground conductors. Fresh discoveries were cropping up every day, and he trusted that it would not be long before we should have at our disposal underground electric light mains and services, if anything, better, cheaper, and handier to use and work than those of any other means of transmitting light and power.

Mr. J. S. Fitzmaurice considered that the author had very graphically explained the various systems in use, but one great feature in the Ferranti Mains was omitted, and that was the comparative safety of this over other systems. At Deptford it was originally intended to ground the outer tube so as to render the system absolutely safe, but, owing to the telephones also being grounded, this was prohibited. To overcome the difficulty the outer tube was insulated and one terminal of the dynamo was grounded, so that for a person to make a short circuit contact, it would have to be made with the inner tube, which would necessitate cutting through the outer tube and insulation Before deciding on any underground system, many important points had to be considered, but the most salient one was insulation. The want of this essential feature in underground conduits had been the cause of nearly all the failures. Any system which provided an insulated conduit was much more desirable than one depending principally on the insulation of cables. The Iron-pipe Drawing-in System, alluded to by the author as being used in England, appeared to be very faulty, inasmuch that no attempt was made to keep the conduits water or gas tight, but merely depending on the insulation of cables. In a system such as this and, in fact, the American Iron-pipe System also, it was essential that the very best workmanship must be displayed in the jointing of cables, otherwise the whole system was likely to fail, through no fault of the cable manufacturers. As an instance of this, *the first cables laid in subways in New York were found to possess an insulation resistance of but little over 100,000 ohms, whereas the insulation resistance of same cable at the factory was over 2,000 megohms per mile. There were about 40 joints in these conductors. After being cut and fresh ones made by an expert jointer the resistance rose to over 1,500 megohms. The method adopted by the Metropolitan Electric Supply Company to overcome the difficulty of jointing as referred to by the author, was no doubt a very good one, but it appeared to him (the speaker) to be only suitable for trans-

* "Electrical World," p. 172, 1890.

former-feeder-circuits, or circuits where the conductors were of small sectional area. To adopt this method for a low-tension system would be very expensive, owing to the large sectional area and quantity of conductor required. He would like the author to state under what systems this looping method was adopted.

Mr. Callender: Mr Fitzmaurice is quite correct in what he states. This system is principally used for transformer-feeder circuits.

Mr. Fitzmaurice: In the Callender-Webber Conduit, insulation to a certain degree had been provided for, but Major-General Webber, in a paper read before the British Association of Newcastle, in September, 1889, said "That although the substance of which the Callender-Webber casing is made is di-electric, yet no reliance is placed on it, even as an assistant to the insulation." It would be seen by these remarks, and also the models exhibited by the author, that in this system dependence was only placed on the insulation of cables. It was a system, however, that had proved successful in England, and there was no reason why it should not be so in Sydney if properly laid down. Its flexibility, strength, and facility for laying should certainly be some recommendation for its adoption. There was one system omitted by the author, which was in use in America, and one that would appeal to electrical engineers as a very common sense method. He alluded to the underground system of the Interior Conduit Company of New York. Unlike the Crompton Conduit, this system could be used for high or low tension currents, while it possessed the same advantage in using bare conductors. He was indebted to the manufacturers for the description and method of construction of this conduit, which was as follows:—" A light, cast-iron interlocking box or trough is first laid in the trench and a series of telescopically-formed tubes of any given number, length and diameter are then racked together within the iron boxing, so as to be held apart a uniform distance by the insulating supports.

The interstices between the individual tubes and the boxing are then filled in with an insulating compound, composed for the most part of coal-tar pitch. This is poured in in a liquid state and quickly solidifies, thus presenting a substantial body composed of a highly insulated material, throughout which are the clear, straight duct interiors as shown in Plate III. and Figs. 1, 2, 3, 4. The telescopically formed ducts, Fig. 2, in this system are an important feature; they consist of two tubes fitting within the other, and are supplied in 10ft. lengths, and at the moment of laying the inner tube is coated with an insulating compound or cement and then telescoped into the exterior tube to just one half of its length, thus each and every duct so formed of two complete tubes, cemented with a superior insulating compound, becomes to all intents and purposes a continuous unbroken tube without sleeves or joints, and possessed of very high insulating properties. The Manhole, Plates III. and V., Figs. 2, 5 and 6, is a simple construction of brick and preferably cemented to protect it from the exudation of the soil. The iron boxing entering the manhole is forked and expanded vertically for the purpose of separating, and therefore providing greater space around the duct ends for more convenient manipulations. The end of each section entering the manhole is provided with a cast-iron head, on the face of which are short pipe projections, which are carried across the manhole to the opposite face-plate by sectional iron pipes, enclosing a section of the insulating tube. These sectional pipes are adapted for easy and quick removal, in order to render the conductors readily accessible. Thus the continuity of each duct is preserved even across the manhole itself, permitting the same to be left open with impunity in all kinds of weather. A mud-pan is provided for keeping out the filth of the street. Lamp-posts, feeder-posts, elbows and other branch connections are provided, and are so constructed to be nothing more or less than minor extensions of the system in its every feature. They are iron boxing or piping, Plate VI., Figs. 7 and 8, filled with insulating compound and joined to the conduit proper by suitably constructed elbow extensions, thus providing for the drawing in of conductors from the nearest manhole to the top or extreme terminal of the post or other branch. This system appeared to possess every feature required in an underground conduit, as it was claimed to be air, gas and water-tight, and that the saving of of the expense of using highly insulated wires would, in a plant of material size, amount to a sum more than sufficient to pay the entire cost of this conduit. With the Crompton System, the maximum voltage used was 500, and the author stated that it was evident the success of this system depended on a proper system of drainage being used. This in itself, would not be sufficient, for unless the culverts were properly ventilated the dust accumulating on insulators would absorb the moisture and consequently ground the circuit. The cost of building these culverts must necessarily be large, especially if adopted in this colony, where this class of labor was so high. He had not been able to obtain any later quotations, but in a paper read by Mr. Crompton, in 1888, before the Society of Telegraph Engineers and Electricians, two tabulated statements were given, showing the comparative cost of laying 100 yards of double conductor underneath the footway of a London street. Table 1 being insulated wires laid in a cast-iron trough and set in bitumen. Table 2, Crompton's Bare Wire System.

## TABLE No. 1.

### COST OF LAYING 100 YARDS OF DOUBLE CONDUCTOR UNDERNEATH THE FOOTWAY OF A LONDON STREET.

| — | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| | Single. No. 16. | 7/16 | 19/10 | 19/15 | 19/12 | 37/10 | Two Sets. 37/10 | Four Sets. 37/10 | Six Sets. 37/10 |
| Area, square inch ... ... ... | ·0032 | ·0225 | 0·773 | ·1613 | 0·25 | 0·5 | 1·0 | 2·0 | 3·0 |
| Area, square millemetre ... .. | 2·08 | 14.6 | 50 | 104 | 161·25 | 322 | 645 | 1,290 | 1,935 |
| Weight per 100 yards run lb. | 7½ | 53½ | 183¼ | 392 | 576 | 1,153 | 2,306 | 4,612 | 6,918 |
| Cost of Copper at 7¾d. ... ... | £0 10 | 1 14 6 | 5 18 0 | 12 13 0 | 18 15 0 | 37 5 0 | 74 10 0 | 149 0 0 | 224 0 0 |
| Cost of Insulation ... ... ... | 1 3 2 | 4 8 6 | 11 2 0 | 24 17 0 | 35 17 0 | 70 15 0 | 141 10 0 | 283 0 0 | 424 0 0 |
| Total cost of cables ... | £1 8 0 | 6 3 0 | 17 0 0 | 37 10 0 | 54 12 0 | 108 0 0 | 216 0 0 | 432 0 0 | 648 0 0 |
| Casing, Bitumen, and Cement ... | 5 3 0 | 5 5 0 | 8 0 0 | 12 10 0 | 12 10 0 | 16 0 0 | 22 0 0 | 40 0 0 | 55 0 0 |
| Labour laying .. ... ... | 3 0 0 | 4 0 0 | 5 0 0 | 5 0 0 | 6 0 0 | 10 0 0 | 18 0 0 | 35 0 0 | 50 0 0 |
| Trenching and Repairing ... ... | 25 0 0 | 25 0 0 | 25 0 0 | 25 0 0 | 25 0 0 | 25 0 0 | 25 0 0 | 30 0 0 | 35 0 0 |
| Surface Boxes and Connection ... | 5 0 0 | 7 0 0 | 10 0 0 | 10 0 0 | 10 0 0 | 10 0 0 | 10 0 0 | 10 0 0 | 10 0 0 |
| Engineer and Superintendent ... | 3 0 0 | 4 0 0 | 5 0 0 | 5 0 0 | 6 0 0 | 10 0 0 | 10 0 0 | 20 0 0 | 25 0 0 |
| Total ... ... ... | £42 11 0 | 51 8 0 | 70 0 0 | 95 0 0 | 114 2 0 | 179 0 0 | 301 0 0 | 567 0 0 | 823 0 0 |
| Add extra, if Copper at 9½d. ... | 0 1 1 | 0 8 0 | 1 7 0 | 2 17 0 | 3 5 0 | 8 10 0 | 17 0 0 | 34 0 0 | 51 0 0 |
| | £42 12 1 | 51 16 0 | 71 7 0 | 97 17 0 | 117 7 0 | 187 10 0 | 318 0 0 | 601 0 0 | 874 0 0 |
| Cost of Copper per lb , laid complete | 5 13 6 | 0 19 4 | 0 7 9 | 0 5 0 | 0 4 1 | 0 3 3½ | 0 2 8¾ | 0 2 7¼ | 0 2 6¼ |
| Current in ampières ... ... | 1·2 | 8·1 | 28 | 58 | 90 | 180 | 360 | 720 | 1,080 |
| Cost per ampère ... ... ... | 35 10 0 | 6 8 0 | 2 10 6 | 1 13 9 | 1 6 0 | 1 1 0 | 0 17 6 | 0 16 8 | 0 16 1 |
| **Cost per unit at 2,000 volts ...** | **17 15 0** | **3 4 0** | **1 5 6** | **0 16 10** | **0 13 0** | **0 10 5** | **0 8 10** | **0 8 4** | **0 8 1** |