TABLE No. 2.

COST OF LAYING 100 YARDS OF DOUBLE CONDUCTOR OF BARE COPPER CARRIED ON INSULATORS IN A CULVERT.

—	1	2	3	4	5	6
Area in square inches	0·25	0·5	1·0	2·0	2·55	3·00
Area in square millimetres	161·25	322·5	645	1290	1645	1935
Weight of Copper in lbs. per 100 yards	576	1153	2306	4612	6125	6918
Cost of Copper at 7¾d. per lb.	£18 15 0	£37 5 0	£74 10 0	£149 0 0	£190 0 0	£224 0 0
Laying	9 0 0	9 12 0	9 12 0	9 15 0	9 15 0	10 0 0
Insulators	0 4 6	0 4 6	0 4 6	0 4 6	0 4 6	0 4 6
Six Surface Boxes and Connections...	10 0 0	10 0 0	10 0 0	10 0 0	10 0 0	10 0 0
Culvert, 18 inches x 12 inches, for 2 lines Conductor in brickwork and Cement, replacing pavement...	53 8 0	53 8 0	53 8 0	53 8 0	53 8 0	53 8 0
Engineers and Superintendence	6 0 0	10 0 0	10 0 0	10 0 0	10 0 0	15 0 0
Total	£97 7 6	£120 9 6	£157 14 0	£232 7 6	£263 7 6	£312 12 6
Extra for Copper at 9½d. per lb.	3 5 0	8 10 0	17 0 0	34 0 0	43 10 0	51 0 0
Total	£100 12 6	£128 19 6	£174 14 6	£266 7 6	£306 7 6	£363 12 6
Cost of Copper per lb. laid complete	42d.	27d.	18·2d.	13·8d.	12d.	12·6d.
Current in ampères	90	180	360	720	910	1,080
Cost per ampère	1 2 3	0 14 5	0 9 8	0 7 5	0 6 9	0 6 8½
Cost per unit at 500 volts	**2 4 9**	**1 8 10**	**0 19 5**	**0 14 9**	**0 13 5**	**0 13 5**

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.

Taking area for area in conductors and cost per ampères, the cost was very much in favor of Mr Crompton's scheme, but it must be born in mind that 500 volts. was the maximum used in his mains, whereas in the Bitumen-Concrete System a very much higher potential was allowed, consequently to make a fair comparison between the two systems the cost per B.T. unit transmitted should be given instead of cost per ampère—for it was the total work given out which should be considered. Take, for instance, our two Water Supply Systems. Would it be fair to make a comparison of cost of laying these systems down at so much per gallon of water passed through the pipes, where in one the water was under a pressure of about 3 to 4 atmospheres and the other 50 atmospheres? In the tabulated statements referred to he had added the cost per B T. unit, taking 2,000 volts. for Table 1, and 500 for Table 2.

Mr Dymond: Why do you take 2,000 volts. for Table 1?

Mr. Fitzmaurice: Because the discussion to which these tabulated statements refer was on "The Battery *v.* Alternating Transformer Systems," and this was the voltage taken by Mr. Crompton himself for the latter system. It would be seen that the comparative costs, area for area, per B.T. unit was very much in favor of the Bitumen-Concrete System, but it was obvious that for the same output it would be only necessary in the 2,000 volt. circuit to provide a conductor one fourth the area of that in the Crompton, so that the comparative cost per unit per 100 yards would be considerably higher, but still in favor of the High Tension System. For example, in 8th column, Table 1, the cost of laying conductors 2 square inches in area was £601, or 8s. 4d. per unit, whereas under Table 2, 4th column, the total cost was £266 7s. 6d. or 14s. 9d. per unit. Turning to Table 1, column 6, the area of conductor was 0·5 square inches, or one-fourth that of area under column 4, Table 2, the cost of which was £187 10s., or equal to 10s. 5d. per unit against £266 7s. 6d. and 14s. 9d. respectively in the Crompton System. Before leaving the Crompton System, he would be glad if Mr. Whiffen could tell him the insulation resistance of that system, and to what extent it varied from summer to winter.

Mr. Whiffen: I am not in a position to afford the information.

Referring to the ideal system alluded to by the author, this no doubt would be so provided that the same stringent measures were enforced on the gas and water authorities as was the case with the electric light, telephones, and telegraphs, but, as a rule, very little attention was paid to the leakage from these mains until an explosion of ground occurred, and, as most of you are aware, if there was a possibility of shifting the blame to an electric discharge, it was done. Fortunately, Melbourne has not yet adopted the sewerage scheme for underground wires, otherwise there was a probability that it would have been accused of setting the sewers on fire lately. Before concluding, he would like to take one or two exceptions to the author's system of providing for the telephone or telegraph circuits, and in doing so would draw your attention to the last page of his paper, which read as follows:—"The two lower cases would be reserved for trunk lines, No. 1 for Post Office and No. 2 for Electric Light feeders, etc." If this system of conduits was adopted, he certainly thought No. 2 should give way to No. 4, for the reason that the danger of leakage from high tension mains to telephone circuits would be minimized, but, while agreeing with the author respecting the placing of telephone and telegraph wires in a drawing-in system of conduit, especially if the conduit itself afforded an insulation, yet where we had ample room the electric light and telephone and telegraph wires should be placed as far apart as was possible and not bunched, as proposed in his scheme, for he (the speaker) believed the induction in such a system would greatly interfere with the working of the Post Office lines.

Mr. Dymond considered that the author had treated his subject in such a fair manner that it was a difficult matter to glad if Mr. Whiffen could tell him the insulation resistance of that system, and to what extent it varied from summer to winter.

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Mr. Dymond considered that the author had treated his subject in such a fair manner that it was a difficult matter to discuss the paper, more especially as he had not touched the financial aspect of the question.

Mr. G. Fischer called attention to the following article which appeared in the *Electrical Engineer* of August 19th, 1891 :—

"THE MINNEAPOLIS STREET RAILWAY COMPANY'S UNDERGROUND CONDUIT SYSTEM.

"The electric system of the Minneapolis Street Railway and the St. Paul City Railway Companies is, without doubt, the most complete, and one of the most extensive, systems in the world The underground conduit system employed by the Minneapolis Street Railway Company for carrying its mains and feeders has several times been mentioned in our columns. A series of tests having recently been obtained from the Street Railway Company, we take pleasure in bringing the matter before our readers again.

"The novelty of the system employed throughout lies in the fact that there is not a wire in sight in the heart of the city, except the overhead trolley wire. The feeders, mains and track feeders are contained in a conduit underground, the trolley-wire connecting with the feeders by means of a sub-feeder through the hollow iron supporting poles. The conduit is located between the tracks, and is built as follows: Two-inch plank first treated by boiling in fernoline, is used for constructing a long trough of the desired size; this trough is so nailed together as to be continuous, and without joints from man-hole to man-hole, a distance of 408 feet. The trough is placed below the surface at such a depth that the top is six inches below the paving blocks. The conduit proper consists of a number of heavy paper tubes of the Interior Conduit and Insulation Company's make. The tubes employed are one-inch and one-inch-and-a-quarter, inside diameter, laid in the trough in ten-foot lengths, and separated from each other and the sides and the bottom of the trough by rings or spaces. The tubes are made continuous from man-hole to man-hole by use of a telescopic joint. After the tubes have been properly put in place, pitch, liquified by heat, is poured in, filling the interstices and leaving a series of highly-insulated raceways with a solid insulating filling, impervious to moisture, around them.

"The system is the first installation of underground conductors ever made in which bare copper wires were drawn into a conduit without other insulation than the conduit itself. There is at the present time about 60 miles of bare copper cable resting in the conduits, varying in size from 100,000 to 500,000 circular mils. The insulation resistance on the entire amount of tubing with overhead trolley and outlying feeders, as shown by actual test, is as high as 1,081,147 ohms.

"A large amount of this conduit has been in service since September, 1890, and has not developed a single fault. The most emphatic and reliable tribute to the excellent results of this new method is found in the additional order for 200,000 feet of tube recently fitted by the Interior Conduit and Insulation Company. The original order was for 400,000 feet.

"Some recent tests of the feeders in the conduits show an insulation resistance which is commendatory to the system, and speaks for itself:—

"Feeder A,	37,719,598	ohms.	Length,	3,122 feet.
" B,	18,649,094	"	"	5,172 "
" C,	2,251,122	"	"	8,048 "
" D,	10,288,096	"	"	9,082 "
" E,	1,790,898	"	"	7,219 "
" F,	1,815,078	"	"	8,048 "
" G,	1,488,031	"	"	5,172 "

"The drop in the potential at the terminal of the feeders employed in the conduit is 5 per cent., while in the other systems, where the overhead feeders are used, 10 per cent. and over is the result."

In reply to Mr. Whiffen, Mr Callender said that the question of the adoption of a bare conductor system, or a drawing-in one, such as the Callender-Webber, would really be decided on the question of costs. It was that when the sectional area of the conductor reached a certain size the bare copper system would have to be adopted, and the question to be decided was when the point is reached where the bare conductor becomes economical; in actual practice it was found that for sections up to 1 inch a drawing-in system is much cheaper. From 1 inch to 2 inches it is doubtful which is cheapest. Over 2 inches the bare copper is cheaper. Mr. Whiffen had treated the description of various drawing-in systems, and the Callender-Webber system in particular, as if they were only suitable for low tensions. This of course was not correct, the Callender-Webber system was equally suitable for either high or low tensions, and in this respect had, in common with all drawing-in systems, a great advantage over bare conductors, and, as most of the work in Australia must necessarily be high tension, this was an important point. Again, in a drawing-in system provision could be made for telephone and telegraph wires, if necessary. This was impossible in the Crompton system. Referring to Professor Threlfall's remarks, he did not consider that the conduit described was in anyway an improvement on the Crompton system, but was rather a retrograde step. It differed from the latter in several points, and in each of these points was distinctly inferior. The principal novelty was in the shape of the conductors, but it was difficult to see anything to be gained by the shapes as shown. The expense would be greater than for flat strips and it would also be more difficult to make joints. The joint described had no provision for expansion or contraction, and this would always be a source of trouble. Professor Threlfall appeared to have been under the impression that there was considerable difficulty in increasing the area of conductor in the Crompton system. As a matter of fact this difficulty did not exist, and this conduit is really nothing but an elaborate attempt to remedy an imaginary fault in present drawing-in systems.

In reply to Mr. Hinde, the author pointed out, that so far from the leakage from electric light mains being more serious than that from gas mains, the reverse was the case. And, in support of this, stated that no accident to life had ever been recorded in Great Britain, caused by leakage from an underground electric light main. It would be well if the gas companies could show as good a result. The amount of leakage from any extended system of gas mains was a most serious one, while the amount of leakage from a similar network of electric light mains was quite insignificant. Mr Callender then noticed the conduit described by Mr Fitzmaurice, and pointed out that the attempt to draw bare copper into pipes had always ended in failure, and he could not anticipate any better result from the conduit described. The conduit was, however, a fairly good one if used in conjunction with well insulated cables, but would be undoubtedly expensive.