17 is adopted. A double cast iron box is prepared, cast in one piece, with an inner and an outer box, shown in plan and section, having their corresponding lids. The conductors are connected by copper bars as shown, and the whole joint then wrapped with semi-vulcanised material; the inner box is filled with molten bitumen, and the cover placed on, and then the outer box filled with the same material. For disconnecting the various portions of a large network, the type of box shown in Plate II, Fig. 18 is used. In this case the outer box only is filled with bitumen, and the joint at the lid is kept tight by an india-rubber washer as an additional precaution. A similar method is adopted for house services This system has been largely used in England and America for some years back, and has met with the most entire and unvarying success ever since its introduction, and, apart from the defects inherent in every solid system, leaves little to be desired in the way of efficiency and economy of construction.

The author will now turn to "Drawing-In" systems, and the first on his list is the system of Iron Pipe Conduits. This system may be divided into two branches representing the English and American methods; taking the American first, we find that a group of from ten to twenty or even more pipes, made of thin wrought iron and about 4 feet 6 inches in diameter, are laid in a solid bed of concrete and these pipes terminate in large brick man-holes at the corner of each "Block." Every endeavour is made to keep the conduits water and gas tight, but it must be acknowledged with very indifferent success. The man-holes are built of brick and cement and are sufficiently large to allow a man to work inside with a fair amount of comfort. A very general size is 4 ft. diameter by 8 feet deep, Plate II, Fig. 19. These large boxes at every street corner have been the scene of several very violent explosions, caused by leakage from the city gas mains accumulating and being fired, either by faulty cables or by actual contact with the flame when the lid has been removed for examining or adding to the cables. All classes of cables are run in the conduits—telegraph, telephone, and electric light—the upper row of tubes being generally reserved for the local distribution of electric light service mains. The cables used in conjunction with these pipes are of all classes—lead covered, vulcanite rubber, and all classes of rubber compounds, the most notable of which are okonite and kenite. Generally speaking, lead covered cables have been found most successful for telephone work, and the vulcanite rubbber and compound cables for electric lighting. Kenite and okonite are compounds of ozokerit, soapstone, and low grade rubber, with other substances, the exact mixture being kept secret, but they have both been found suitable for the climatic conditions of America.

The English method of laying an iron pipe conduit differs from the American in many important features. In the first place the pipes are of cast iron instead of wrought, Plate II, Fig. 20, they are laid directly in the ground without any concrete or other protection, and no attempt is made to keep them watertight. The pipes are simply laid with an ordinary socket joint, and, if possible, are so arranged as to have a fall to the drawing-in boxes. Man-holes and joint boxes are built at regular intervals, and these are usually constructed of brick or concrete, and are proportionately drained. The house service boxes are built in a similar manner, or else cast-iron boxes are used of the section shown in Plate II, Fig. 21. Into the conduit thus made, well insulated cables are drawn—usually one pair in each pipe. The success of the system depends on the quality of the insulated cable used, and it is only owing to the great perfection now reached by English cable manufacturers that the system is possible at all. The cables generally used in connection with these conduits are the highest class of vulcanised rubber, and, when properly laid down, failures are almost unknown. The chief drawback, and it is a serious one, is the great difficulty of making a reliable joint on vulcanised rubber cable. Perfect joints can be made in the factory, but it is a different thing to working in the open street, and the author believes all electrical engineers will corroborate this. A very ingenious method has been adopted by the Metropoliton Electric Supply Company for getting over this difficulty, which consists in making the cable in a series of short loops, the ends of which terminate in small fuse boxes inside each house. Each cable leaves the dynamo and forms a complete loop, or rather series of loops, and the main really consists of a series of short lengths of cable from house to house. By this means all joints are avoided, and a further advantage is that each house has a double line of cable to the station, and thus secures immunity from breakdown. The credit of this important improvement is due to Mr. Frank Bailey, of the Metropolitan Electric Light Company.

In this system of iron pipe conduits described (Plate II, Fig. 22), success depends, as has already been pointed out, on the insulation of the cable itself and on the perfection of the joints, if any. Another point to be considered is the question of the durability of iron pipes in the soil of a large city. The pipes actually required can be very light, as they have only to carry one or two comparatively small cables, but on account of the corrosive action of the soil it has been found necessary to use heavy sections, and this makes the system a very expensive one, and has to a large extent prevented its general adoption.

The Callender-Webber System is one which has been very extensively used in England, and has many points in common with the system last described, while differing from it in other important features. It is essentially a drawing-in system, and it was the first complete system of this class to be introduced in England. The chief points in which it differs from the last system are: First, the use of a pipe or conduit made of a bituminous concrete; and, secondly, in the use of vulcanised bitumen instead of vulcanised rubber for the insulation of the cables. In a word, the system depends on bitumen both for insulation and mechanical protection. The Callender-Webber conduit consists of multitubular cases of pipes usually of a rectangular section, and having from two to eight longitudinal ways as required. Plate II, Fig. 23. The material of which these cases are composed is a composition of Trinidad bitumen, desiccated wood, and special fine sand, and has many advantages for the work. It is strong mechanically, being considerably tougher than natural asphalt; it is a fairly good insulator, is easily moulded, and, lastly, can be produced at a moderate cost. The cases are usually made in lengths of 6 ft., and are laid and jointed in the following manner: The two cases required to be jointed are laid in position so that the ends are about 2 in. apart, mandrills are then placed in each hole, and bituminous concrete is run in all round the mandrills and shaped to the form of the case by special tools. The concrete sets quickly, and the mandrills are withdrawn, leaving a joint which is practically part of the case itself. Drawing-in boxes are provided at regular intervals, usually built of brick, and having cast iron frames with removable lids set in the paving (Plate II, Fig. 24.); service boxes are also built of brick or concrete as required. The cables used in connection with this system are insulated with a material called bitite, which consists of refined Trinidad bitumen, vulcanised by a special process, which renders it pliable and elastic, and to a great extent unaffected by changes of temperature. It can be easily and perfectly jointed, and in this particular has great advantages over vulcanised rubber. One cable only is drawn into each way or tube, and can easily be withdrawn if required. The cases can be made in any form desired, and, if necessary, can be bent on the work by being carefully heated in boiling water. Anyone who has had practical experience of main laying in a large city—where there is already a network of gas, water, hydraulic and telegraph pipes, not to speak of sewers—will realise what this means, and how great a convenience it is to be able to deviate from the straight line without specially prepared bends. The advantages of this system are: Firstly, the bitumen concrete is in itself a fair insulator, and, should a fault occur in the cable, it is less likely to be serious than an iron pipe; secondly, each cable being in a separate tube can be easily withdrawn, as there is no possibility of its becoming entangled with any other; thirdly, the material of which the cases are made, being composed of bitumen chiefly, is entirely unaffected by any acids or gases, and is one of the most durable materials known; fourthly, the first cost is moderate.

Earthenware pipes of various forms have been used in different places, chiefly in America, but have never met with much success. The material has not sufficient strength unless made very thick, and it then becomes too expensive. There is also great difficulty in making tight joints. The system was tried on a large scale in Philadelphia, and, after some years, was given up as a failure.

Creosoted wooden conduits have also been extensively used in America, and have been successful, but are not sufficiently permanent to justify their adoption on a large scale. The creosote gives off a volatile oil, which has an injurious effect on nearly all insulating materials, and which also attacks lead and rapidly deteriorates it.

We now come to the consideration of a totally different class of mains, viz.: Those which depend entirely on air for their insulation. There are several varieties of this system, but the most notable is that of Mr. Crompton, who indeed may be said to be inventor of this method of insulating mains.

The Crompton system of mains consists of bare copper conductors, stretched over glass or porcelain insulators in culverts, built underneath the footpath or roadway of a town. Plate II, Fig. 25. The conductors consist of one or more superimposed copper strips, each 1 in. wide by a ⅛ in. thick. Plate II, Fig. 26 and 27. The insulators are carried on stout oak bars let into the sides of the culvert at a distance of from ten to twenty yards apart. The insulators are usually of glass, corrugated to give greater service. A surface box is placed at each set of insulators to allow for examination and to facilitate drawing in new conductors. At intervals, as required, straining-up boxes are placed, which are shown in Plate II, Figs. 28 and 29. The ends of the conductors are held by two set screws in the bridge pieces. These pieces are held up against two transverse anchoring timbers, and are insulated from these timbers by glass insulators. The bottom timber is kept clear from the cement concrete underneath, so that water can drain away. The conductors are strained by hand, and are kept in position by the small set screws shown. Straining-up boxes are also provided at every change of direction. The house services are made by vulcanised rubber cables in iron pipes brought through the sides of the culvert, and the cable is simply clamped or soldered on to the main conductor. It is evident that the whole success of this system depends on a proper system of drainage being used.

Professor Kennedy's system differs from the Crompton, chiefly in the shape of the culvert which is made considerably shallower, being only 8 inches deep for a corresponding width. Plate, II, Figs. 30 and 31. It also differs in having a ledge on each side on which runs the wheels of a drawing-in carriage, shown in Figs. 25 and 26. The other details are much the same as in the Crompton.

Another system of bare conductors has been adopted by the St. James Electric Supply Company, which consists of cast iron troughing of a semi-circular form, carrying insulators of the shape shown in Plate II, Figs. 32 and 33, which carry one or more strips of copper. The copper strips are much wider than in the two previous systems, being 2 in. by 1-10th in., and are not strained in any way. The insulators are made of earthenware or terra cotta, and are placed at intervals of nine feet. A cast iron cover is bolted on and the joints made tight with red lead. The house services are made in the same manner as in the Crompton System. All of these systems have been the subject of much adverse criticism, and on their introduction were condemned by nearly all electrical engineers. They have, however, after several years of work completely proved that, in the hands of competent engineers, this system of mains is a decided success, and, for large conductors, are at least equal to any other. The entire credit of this class of main belongs undoubtedly to Mr. Crompton, who laid the first conductor on this system in Kensington about four or five years ago. All of these systems of bare copper mains are open to the same objection, viz., the great space occupied by them. This has been found so serious an objection in practice, that in actual experience it is found that, under the most favourable conditions, at least one quarter of the conductors must be laid on some other system. Another great objection, and one that will always tell against these systems, is the very heavy cost of building the necessary culverts, and the expense is practically the same for a small conductor as for a large one. This cost limits the application of this class of main to large conductors, and in practice it is found that the smallest size of conductor that can be economically laid on this system is one having a sectional area of not less than one square inch. The system is none the less valuable on that account as it can be easily used in combination with one of the drawing-in systems already described. The culvert being built where the section of copper is large enough to allow of its being done economically, and the smaller mains being laid on one of the other drawing-in systems. As a matter of fact, this is what is usually done, and the Callender-Webber system is generally used in combination with both the Crompton and the Kennedy systems.

There is one other method of laying electric conductors underground which has not been mentioned, but which is, without doubt, the ideal method, and that is the system of building a small subway or tunnel under each footpath in every street, this subway to serve to carry all, gas, water and hydraulic pipes, electric light mains and telegraph and telephone wires, and, in fact, to form a conduit for the complete underground service of a city. This system has been adopted in all the new streets recently opened up in London, and needless to say, has practically solved the question of underground distribution. But while the subway can easily be built in new streets, the enormous expense of excavating, building and removing the present pipes, make it practically impossible in any existing city; and the advantages to be gained by the adoption of such a system are not sufficiently great to justify the enormous expenditure of public money which it would entail.

Having considered, in detail, the leading systems of electric light mains, the author will now endeavour to look at the question from a practical point of view, and consider what would be the most suitable system to adopt for the underground mains of the City of Sydney. In considering this question we must necessarily also consider the question of telegraph and telephone wires, as the two questions are inseparable. The electric light service of a large city like Sydney will probably be a combination of various systems, and the report recently issued by the City Council on the subject may be taken as representing the probable nature of the different systems. The various classes of current to be conveyed for lighting purposes as set forth in that report, are:—

1st. High Tension, 2,000 to 3,000 volts, continuous current, for Arc Lighting.

2nd. High Tension Alternating Current, 2,000 to 3,000 volts, for Feeders for Private Lighting.

3rd. Low Tension Network of Mains for distribution of Private Lighting supply.

These represent the Lighting Mains, and then we have in addition to consider—

4th. Telegraph Wires.

5th. Telephone Wires.

6th. Fire Alarm, and other Municipal Service Wires.

Now let us consider the conditions required for each of these services.

First then we have the Arc Lighting wires; these wires will generally run in one or more simple loops, with a break at each lamp-post as required, and do not present any great difficulty.

2nd. The Alternating Current feeders, would in all probability run from the Central Lighting Station, without any break to a small sub-station, where the current would be transformed into low pressure, and thus fed into the distributing mains. These being simply trunk mains, would require no branches at all, and would be of comparatively small size.

3rd. The Distributing Network. The conductors for this network would be of much greater size than in either of the two preceding cases, and would require to be frequently tapped at points all along the line for house services.

4th. The Telephone service is perhaps the most difficult question of all, and in this there are really two classes of wires to be considered—first the Trunk Mains, and secondly the local distributing wires. The author does not consider the question of putting all the local distributing wires underground as possible, and shall only consider the question of trunk mains. These mains are usually groups of wires from 20 to 100 in number and are at present either run on insulators in the usual manner, or by means of lead covered cables suspended from a steel cable.

5th. The Telegraph service is practically the same question as the Telephone, and similar conditions will apply.

Now a conduit to successfully carry all these varying classes of cables, must fulfil certain conditions. It must possess mechanical strength, it must effectually protect each class of cable from contact with the others, and must allow of the necessary connections for house services being easily and quickly made, and, finally, must permit of all or any of the conductors being removed in case of accident or alterations.

Now it is perfectly certain that the system to meet all these conditions must necessarily be a "Drawing-In" one. By no other means can we attain a complete and satisfactory solution of the question. Any of the systems described would be adaptable for one or more of the services required, but a system of conduits, allowing for all cables to be withdrawn and added to as necessary, alone fulfils all the requirements.

The system of which the author has the most intimate knowledge is the Callender-Webber, and he proposes to show you how it adapts itself to the requirements of Sydney. A system of conduits of this description for Sydney would consist of a group of four cases, each with four or more tubes or ways of about 2 in. or 3 in. in diameter, which would be laid under the footpath on each side of the roadway. At every corner a brick box would be built to allow for distribution and connection.

The two lower cases would be reserved for the trunk lines. No. 1 for the Post Office service. No. 2 for the electric light feeders. The upper boxes would carry No. 3, the mains required for arc lighting, and No. 4 the distributing mains for low tension house service.

The telephone wires would be made up in cables as at present, and covered with a sheath of lead, but it would probably be found necessary to use complete metalic circuits, instead of the earth return as at present. From each distributing box, the wires required for service in the immediate neighbourhood, would be carried overhead on light iron poles, and as their number would be comparatively small, there would not be any great objection to them from an æsthetic point of view. In the event of a large fire, such as we have suffered from in Sydney during the last eighteen months, the overhead wires could be cut, without interfering with the service of the rest of the city, and the work of the fire brigades would be rendered much easier and safer

The high tension feeders in section two would run as already said from central station to sub-station without a break, and, therefore, the casing or conduit of bitumen, would run bodily through the distributing box without a break and contact between these mains and the telephone wires would be absolutely impossible.

For the Arc Lighting, and also for the private service mains, small service boxes would be built as required, surrounding the conduit, but only the actual section required to be tapped would be cut, the other sections running through the box unbroken. By these means we assure an absolute sheath of insulating material between each cable, and should any one cable breakdown it cannot possibly endanger any of the others. This is an important advantage possessed by the Callender-Webber system of conductors over a conduit of iron pipes.

Although some gentlemen may dissent from the views expressed, the author is aware we are all agreed on the importance of the subject, and especially so at the present time, when the air is full of schemes for electric lighting. Whether the work is done by the city authorities or by private enterprise matters little, but it is important that a comprehensive scheme should be adopted, and thus avoid the endless annoyance of continually opening up trenches in our principal thoroughfares.