laid with an up grade towards the engines, presumably with the idea of allowing any of the condensed steam to find its way back to the boilers. Coal for the boilers is obtained from trucks run into the station yard from the Darling Harbor lines, and is delivered from there into a hopper, thence through shoots at the bottom, into trucks which are run along a little tramway in front of each boiler. The ashes fall into a shoot under each furnace, and are delivered into a truck placed in the tunnel running the whole length of the battery. They run on rails through the tunnel to an ash pit, where the ashes are dumped and lifted by a bucket chain to a hopper, from whence they are delivered into a truck again and removed. The bucket chain is actuated by an electric motor. The boilers are fed with city water from a well, by means of either two three-throw electrically driven feed pumps, or by means of a steam pump. The electrically driven pumps are operated by General Electrical Company motors, shunt wound (thirty ampères, six hundred volts) and the steam pump is capable of delivering seven thousand gallons per hour, against the boiler pressure of one hundred and twenty lbs. per square inch. The circulating water for the condensers is obtained from Darling Harbor, through a tunnel which delivers it into a sump. From this sump it is drawn by centrifugal pumps, actuated by General Electric Company shunt wound motors to the condensers, returning to the harbor by an independent channel. All pumps are of Blake manufacture.

The electrical energy is conveyed from the generators to a switch-board, erected on a special gallery and fitted with the General Electric Company's standard type of generator and feeder panels. At present there are installed four generator panels, each provided with its complement of wattmeter, + and − switches, circuit breaker, ammeter, shunt rheostat, etc.; between each machine, and mounted near them, is an equalising switch. The remainder of the switch-board consists of a summation panel provided with a wattmeter, which integrates the output of whatever generators may be running. An intergrating ammeter for summation panel is also provided, reading up to eight thousand amperes. Two volt-meters are also provided on a swinging bracket. Panels are also provided for charging the two batteries of accumulators and discharging same, with the necessary switches, volt-meters, and circuit breakers. Twelve feeder panels are provided by means of which the energy from the machines running may be distributed to the various feeders. Each feeder panel is provided with a wattmeter, which, of course, measures the out-put on that feeder, an ammeter indicating the current, a switch and a circuit breaker, the latter being capable of regulation up to one thousand five hundred amperes; its object, of course, being to cut the current off automatically from any particular feeder when the current on it exceeds a certain pre-determined value. The number of feeder panels originally installed was twelve, but already, in order to provide for the necessary extension to Cook's River, Leichhardt, Balmain, Rushcutter's Bay, and Elizabeth Street, five more panels are being provided. A visit to the Power House itself will make it much more clear to the members the object and arrangement of the switch-board, which, being of a standard pattern well

known and well described, is not a worthy subject for any further explanation. In order to provide the necessary current for lighting, signals and other purposes when the plant is closed down, two sets of E.P.S. accumulators have been provided and fitted up in a special battery room. Each battery consists of two hundred and forty cells, in one case of three hundred and fifty ampere hours capacity, and in the other one hundred and fifty ampere hours capacity. These are charged as required from the generators, and a special switch is provided, so that they may be discharged or charged either in series or parallels of one-half or one-quarter, that is to say, at five hundred, two hundred and fifty, or one hundred and twenty-five volts. These batteries will also be used for testing purposes as required. A system of electric signals controlling all points and crossings at and around Redfern Station has also been designed, and these are operated from Signal Boxes at Redfern, and are interlocked with the points. They are worked electrically and lighted electrically, and are of local design; the batteries referred to above are used for their operation, and on the switch-board are means specially devised for indicating any faults in the connections, and such as would render the signals inoperative, it being a matter, of course of the greatest moment, that traffic should not at any time be impeded by a break down to the signalling system. So far, this system of signals has given the greatest satisfaction. The energy required for operating the North Sydney Tramways is mostly generated at Ultimo, and transmitted to North Sydney by the feeder cables mentioned above, but the increased traffic at North Sydney of late, has rendered it necessary to reinforce the supply from Ultimo by the operation of the plant installed at the North Sydney Power House, which has now been working for many years, consisting of three one-hundred kilowatt generators and one ninety kilowatt generator, all of the General Electric Co's. type. These are driven either by a Corliss compound engine, or by a Fowler engine as required. Storage batteries have been installed at two outlying spots, namely, Spit Road on the Mosman line, and Flat Rock Bridge on the Willoughby line, and a very large Tudor Battery is now being erected at Ridge Street Power House, the object in all cases being to maintain a steady and uniform potential for the system, and at the same time diminish the sudden peaky loads of the generators. The electrical energy for the operation of the Rose Bay line is at present generated at the Rushcutter's Bay Power House by means of two General Electric Co.'s one hundred and fifty kilowatt, 6-pole generators, driven by counter shafting and belting from the cable engines. Time however, will not permit of any further details of these plants, but the author hopes to have an opportunity later on of showing the members the various details of these smaller installations. The present Power House at Ultimo, will be by no means adequate to deal with the whole of the Sydney and Suburban Tramway system, and a scheme for the extension of the Power House has already been submitted to the Railway Commissioners. Part of this has already been put into operation, and only four months after the opening of the George Street line was a start made in preparing the foundations and settings for further boilers, which are to be of the water tube pattern, and although the present Power House may well claim to be one of the

largest and most up-to-date in the Southern Hemisphere, it is but a small edition of what it will be within, say, five years time. The machinery as installed there is quite of an up-to-date and standard American pattern, but the difficulties of the Sydney Tramways and the large distances to which the energy has to be transmitted, together with the very heavy loading which has been the result of so immensely popular a system, have all combined to show that the existing provision of plant can only cope with part of future requirements, and the necessary additions to the plant and Power House must necessarily be on a very large scale, and it may probably take the form of quite a different system of operation and apparatus. It might be mentioned, that in addition to the mechanical equipment of the Power House, a fairly complete equipment of electrical and chemical apparatus has been provided for testing and research purposes. The cost of generation of the energy cannot be definitely given at present, inasmuch as the continued alterations and increase in loading have been so rapid as to prevent the attainment of anything like settled conditions, but generally speaking, it may be stated that the cost of generation, distribution and operation of our electric tramway system in Sydney, compares very favourably with that in other parts of the world operating under somewhat similar conditions. The nature of the loading of the generators is practically the same as in other parts of the world, the load curve varying very considerably throughout the day. A specimen load curve is shown. The load of the Power House is at the present time such as to require almost continual operation of two sets of engines and dynamos in parallel. The load at busy times of the day, such as six o'clock, sometimes kicking to over four thousand amperes. An average potential of five hundred and fifty volts is maintained at the switchboard throughout the greater part of the day, but during the busy hours the potential is increased somewhat above this value.

III.—Utilisation.

The rolling stock provided varies considerably in design as far as the car bodies are concerned, but the electrical equipment, fittings, etc., comprise only three types up to the present. There are three types of locally built car bodies, namely, the enclosed or box car, as used on the Railway service; the combination type with cross seats, similar to the cars used in Brisbane; and what is called the bogie combination car, a large number of which are running on the Dulwich Hill service. All the car bodies with the exception of three at North Sydney, and sixteen large ones on the city side, which were built by the New York and Brill Companies, have been made locally, the majority by the Clyde Engineering Co. The detail of construction is so intricate as to be worthy of a paper in itself, and as the majority of the members probably ride daily on the various cars, there is no necessity to make further reference to their construction. The car bodies are mounted in some cases on bogies of the so-called maximum traction type, but all the enclosed cars and the Brisbane type have been mounted on either Peckham or Brill four-wheeled trucks of six feet six inch wheel base. Owing to the frequency and the sharpness of the curves on the Sydney lines, this large wheel base is a serious disadvantage, and the bogie

stock with a wheel base of four feet six inches is much better adapted for local requirements. The axles are in most cases three and three-quarter inches in diameter, of steel, and the wheels are in nearly all cases provided with steel tyres. Chilled wheels have been used but have not proved very successful, as most of the lines have the narrow groove, and the chilled flanges are very liable to chip away. The electrical equipments of the motor car consist at North Shore of G.E. 800 and G.E. 1,000 motor equipments, but in all cases on the city side, either G.E. 1,000 or Westinghouse 49 motors are used. The G.E. 1,000 motors, each capable of developing thirty-five horse power normally, are series wound and controlled by the well-known series parallel controller of the General Electric Co., K-10 type. The motors are slung on the trucks by a flexible suspension, and the power is transmitted from the amature to the axle by spur gearing running in grease. The pinions are of hammered steel and the spur wheels of cast steel, the teeth in all cases being milled from the solid. The armatures are four-turn and the speed reduction of the gearing is 4·6 to 1. Starting resistance, automatic circuit breaker, fuse, trolley base, pole, etc., lightning arrestor and various other details complete the equipment, which is nearly all carried underneath the car, with the exception of the switches, which are on the canopy. The W. 49 motor is practically equivalent, as regards output, to the G.E. 1,000, the difference between the two are details of manufacture, which space will not permit of describing. The system of controlling the speed is similar to that of the General Electric equipment, and is a practically universal method employed for series wound motors. The two systems are now being tried under similar conditions, with a view to determining the more efficient, and as the matter is still *sub judice* it is not possible for the author to quote any data at present. Each motor car is provided with air-brake gear and also the trailers. This air-brake is of the Standard Air-brake Co.'s. manufacture with a double acting compressor, operated by the axle of the motor car, the compressed air being stored in cells, either under the seats or under the car floor. This air is admitted to any desired extent by the driver's valve to a brake cylinder under each car, attached to the necessary brake beams, levers, etc. The standard air pressure is thirty-four lbs. per square inch, but the brake is not in any sense automatic, the release being obtained by allowing the air to escape from the brake cylinder. Owing to the great starting effort of series wound motors, the acceleration of electric cars is always very rapid, and by means of the air-brake, stoppages may be smoothly and quickly made although it is certain that the driver, having so ready a means at his command of stopping the car, frequently abuses it at the expense of the repair bill. Each of the motor cars of the enclosed type weigh seven-and-a-half tons, and the trailers attached thereto weigh about five-and-a-half tons, The seating capacity of an enclosed car and trailer is fifty-two per train. The bogie combination type, which is running on Dulwich Hill, has a seating capacity of forty-four, and a crush loading capacity of ninety to one hundred; and weighs ten tons eight hundred-weight. The large Brill and New York cars are run in coupled pairs, each being provided with two G.E. 1,000 motors, being operated at once by a special controller K-12 type. The weight of one of these trains is eleven tons ten-and-a-half hundred-weight,

and they are capable of moving three hundred to three hundred and fifty passengers at crush loading. The speed attainable on the cars varies of course with the conditions, and may be anything up to twenty-five miles per hour on the level. Of course this speed can seldom be attained in practice. The lighting of the cars is by incandescent lamps, in groups of two or three, arranged in a series of six usually, and controlled by necessary switch and fuse. The details of the equipment will be more readily seen by an inspection of them on Friday night at the car shed, and as they are of a standard pattern, and have been thoroughly well described many times previously, no further reference need be made to them.

The drivers have all been trained locally and recruited from the steam and cable trams, being either gripmen, drivers, firemen or conductors. The system of training them is very complete, and although they have their faults, like everybody else, still it is believed they compare more than favourably with the average motor car driver in any part of the world. Owing to the large amount of heavy grade and curve, the power consumed per car averages much higher than is found in cities with easy grades and straight tracks. The consumption per tram on the city side averages about fifteen to twelve-and-a-half kilowatts. Experiments are now being made with the General Electric Co.'s. pattern of electric brake, and a car so equipped is now running on the Dulwich Hill service, but there are not sufficient data available at present as to its merits for local requirements compared with the air brake. The cars are stored in specially designed car sheds at Ultimo and Newtown, and attached to the former there is a repair shop, fitted with a very fine equipment of the most modern American machine tools, which will repay a visit of inspection. The car sheds are provided with examining pits, and there is a large staff employed in the regular overhauling of the motors and equiqment. The Ultimo shed is capable of accomodating seventy cars approximately, and the Newtown shed, one hundred and twelve cars. All the necessary repairs of armatures, field coils, and every other part of the equipment are carried out by the Departmental staff, which also fits the equipment to new cars. Much more might be written on the details of this section of the subject, but as the paper has already extended beyond reasonable limits, further details must be reserved. Although, of course in the starting of such a large system, there are bound to be slight hitches and delays, the author ventures to think that on the whole the public is well satisfied with what it has already got in the way of an electric service, and looks forward with confidence to a successfully operated and adequate system; and although no doubt there has been apparent cause for complaint, owing to insufficiency of rolling stock, etc., it must never be forgotten, that at this distance from the base of supplies, and owing to the magnitude of the work, very many difficulties are encountered by those upon whose shoulders the burden has fallen, and of which the public can have no conception. The author feels confident however, that by the time the Electric Tramways of Sydney are in all respects an accomplished fact, that the public will have little cause for complaint, and much reason for gratification.

In conclusion, while the author is painfully aware that he has, for want of time, been unable to deal with the subject in such a minute way as to lend originality and value to this paper; he trusts

that it will to a certain extent accomplish his object, which was to collect for the benefit of the members of this Society, who have had little opportunity of getting any detail of the system, a few of the facts, and although it may not have many merits as an original production, still, if it has accomplished the author's intentions, and given the members any closer insight into the Electric Tramway system, it is all that is desired. Doubtless there are many points which will promote an interesting discussion.

The author wishes to record his thanks to the Railway Commissioners of New South Wales, for having kindly permitted the use of drawings, data and exhibits.