

A SHORT DESCRIPTION OF THE ELECTRIC SUPPLY UNDERTAKING OF THE SYDNEY CITY COUNCIL.

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*(A Paper read before the Sydney University Engineering Society,
June 10th, 1914.)*

During the year 1904 the business of electricity supply for public lighting and private use was inaugurated.

The original installation consisted of a Central Generating Station connected by high tension cables with five distributing substations. The generating plant first installed was in the form of one 300 kilo-watt and two 600 kilo-watt, 5,000 volts, 3 phase, 50 cycle reciprocating engine driven alternators. The prime movers being Ferranti cross compound vertical inverted engines with Dick Kerr revolving field alternators mounted beside the fly-wheel on the main shaft. The exciters were rope driven from the main shaft. Condensing equipment comprised a surface condenser, Edwards' air pump, and centrifugal circulating pump for each engine. The air pumps were driven by direct current motors and the circulating pumps by 3-phase alternating current motors. A storage battery was also installed, rated at 1,260 ampere hours at the six hour discharge rate (i.e., 210 amperes). The battery included 56 cells, and was intended to operate at 100 volts. Two 415 volt, 3 phase, induction motor generator-booster sets were also installed for charging this battery. The purpose of the battery and auxiliaries was to provide energy to operate the air pumps and station emergency lighting and emergency field excitation. The switchboard controlling the 100 volt direct current supply was arranged so that the alternator fields could be excited from the battery if required. In ordinary use a motor generator was kept running to supply the demand, with the battery "floating."

The Boiler House plant originally provided consisted of five (5) Babcock and Wilcox water tube boilers rated at 10,000 pounds of water per hour each equivalent evaporation, and one separately fired superheater capable of dealing with the total output of these boilers and giving a superheat of 150°F.

The grate area of each boiler is 58 square feet, and the heating surface 3,240 square feet. The grate surface of the superheater is 33 square feet, and the heating surface 2,009 square feet. The boilers were designed to operate at 150 pounds per square inch gauge pressure. "Green's" economisers are used, delivering the feed water to the boilers at about 260°F. Weir steam-driven feed pumps are used, the exhaust from which is utilised in an enclosed feed water heater. The steam main is in duplicate, being so arranged that either saturated or superheated steam can be used.

Natural draught is used, the stack installed at the time being 200 feet in height and 11 feet average internal diameter. Under normal conditions this produces $\frac{3}{4}$ in. water gauge draught at the boiler damper.

The Generating Station is situated in Pymont, with a frontage on Pymont Street, and backing on to Darling Island railway yard. Condensing water was obtained from Darling Harbour through two underground conduits, each 4 feet by 4 feet internal dimensions, the one being used as intake and the other as outflow. The levels are such that the flow to and return from the station is obtained by gravitation. Two additional conduits were completed in 1913, as the original conduits proved inadequate for the complete plant then in view.

The Circulating Pumps are located in the basement of the engine room, close to the individual machines.

In the original scheme as mentioned five substations were included, all in the City, viz.:—

- One at Town Hall.
- „ Lang Park.
- „ Wilson Street (Woolloomooloo).
- „ Oxford Street (Darlinghurst).
- „ Athlone Place (now Mountain St.).

The energy in the form of 5,000-volt 3-phase current was distributed from the generating station by means of 3-core lead-covered cables drawn into cast iron pipes, the joints being made in special pits placed 80 yards apart. In two of the substations (Town Hall and Lang Park) the energy is converted by motor generators to 480 volts direct current and distributed on the 3-wire system at 480 and 240 volts. The area covered by the direct current system is approximately bounded on the north by Port Jackson, on the south by the Central Railway Station, on the east by Macquarie and College Streets, and on the west by Darling Harbour. The remaining districts were all supplied from static transformer stations where the energy was transformed from 5,000 volts to 415 volts 4-wire (240 volts to neutral).

The growth of the undertaking soon made the above plant inadequate, and in 1906 two additional 600 K.W. reciprocating engine-driven alternators were installed. These were Willans' engines direct coupled to Dick Kerr alternators. The arrangement of the auxiliaries was generally similar to that in the original three sets, but the exciters were carried on the end of the alternator shafts. The total capacity of the plant was thus increased to 2,700 kilo-watts. This did not meet the requirements for long, and in 1907 and 1908 additional plant was installed, consisting of two 2,000 K.W. Willans-Dick Kerr turbine alternators, running at 1,500 r.p.m.

To supply steam to this additional plant, four new boilers supplied by the Stirling Boiler Co. were installed, each capable of evaporating 20,000 pounds of water per hour under working conditions. Like the previous Babcock and Wilcox boilers, these were fitted with automatic stokers of the Babcock and Wilcox chain grate type, driven by 3-phase induction motors. An integral superheater capable of imparting 150° of superheat to the steam is fitted to each of these boilers. The grate surface of each boiler is 86 square feet, the water heating surface 5,750 square feet, and the superheating surface 425 square feet. The original smoke stack sufficed for this additional boiler capacity. The rapid increase in demand continued, and in 1911 two more Willans-Dick Kerr Turbo Alternators were installed, each of 4,000 K.W. capacity. This necessitated extensive additions to the generating station buildings, a second engine-room and boiler-house being built.

The new smoke stack is 217 feet in height and 13 feet 6 inches square at the base, tapering to 13 feet diameter at the top. Firebrick lining is carried to a height of 70 feet, and a firebrick partition is also built to allow access to one side of the stack without interfering with the operation of any plant connected to the other side. The height of the stack above the boiler downtake is 203 feet.

Six Babcock and Wilcox boilers, rated at 24,000 pounds per hour each from 200°F. to steam at 160 pounds per square inch and 150°F. superheat were installed at this time.

The particulars of these boilers are:—Grate surface 120 feet, water heating surface 6,182 square feet, superheating surface 1,320 square feet. Weir feed pumps and exhaust feed heater were also installed. As in all previous installations, Green's economisers were included.

In 1913 six additional boilers similar to the above, with the exception that the grate area was increased to 140 square feet, were installed with a duplicate smoke stack. An additional 4,000 K.W. set, duplicate of those installed in 1911, was completed in 1913. The latest extension, which will be completed in April, 1914, is a 5,000 K.W., A.E.G. turbine alterna-

tor of the "Curtis" type. Three of the original reciprocating sets have been sold (one 300 K.W. and two 600 K.W.), as with the larger units installed it was found uneconomical to operate the old sets. The space thus provided will be used for future extensions.

With the exception of the switches controlling the two 600 K.W. alternators, the whole of the high tension switchgear is now arranged in special chambers under the floor of the engine-room. The switches are opened and closed electrically, the control being operated from a bench board on a steel platform, standing about 10 feet above the engine-room floor level. The switches are arranged in three separate chambers. The central chamber contains two complete sets of busbars, one switch for each of the six turbine-driven alternators, five group switches, each controlling the supply to five feeders, and two switches controlling the supply to the step-up substation, a description of which follows. In one of the other chambers is arranged two groups of five feeder switches, and in the remaining chamber three groups of five feeder switches. In an entirely separate chamber from the three, the equipment of which has already been described, are placed the high tension switches, etc., controlling the supply to and the current leaving the step-up substation. This comprises a set of 5,000 volt busbars and a set of 10,000 volt busbars with five switches to each, controlling the supply to, and the current leaving five transformers which step up from about 5,000 to about 10,000 volts. Two of those transformers which stand in the engine-room are of 500 K.Ws. each, and three of 1,000 K.Ws. each.

The whole of the switchgear was supplied and fixed by the Australian General Electric Co., with the exception of the two switches controlling the two 600 K.W. alternators, which were supplied by Messrs. Ferranti Ltd.

Coal is delivered at the Power House by rail. The railway trucks are run into a special siding (double line), which lines pass over steel hoppers. The coal falls out of the coal waggons into these hoppers and passes from the hoppers into one or other of two conveyors, each of which delivers the coal into steel overhead bunkers, from which it falls by gravity into the hoppers forming part of the automatic stokers attached to the boilers. The railway waggons containing the coal are handled on the sidings by means of electric capstans. Each waggon is weighed on one or other of two weigh-bridges as it enters and leaves the sidings. The coal is also weighed or measured on its way from the overhead bunkers into the boiler hoppers. This is for the purpose of checking the performance of each boiler and the amount of coal used during each watch. The ashes are automatically discharged by the mechanical stokers into a space at the back of the grate, and

from there pass by gravity into a basement under the boiler-house floor. From this basement they are removed by conveyors and elevated into steel hoppers, from which they are discharged by gravity into the empty coal waggons.

The total area of the site in Pymont allotted to the Electric Light Department is 11,700 square yards. The engine-room covers 1,970, and the boiler-houses 2,900 square yards. The total boiler plant now installed is capable of an equivalent evaporation of 467,000 pounds of water from and at 212°F. The total generating plant by April, 1914, will have a capacity of 22,200 K.Ws. at continuous rating.

Keeping pace with the growth of the generating plant, the distribution system has been continuously extended. At the end of 1904 there were five substations in operation, at the end of 1907 eight, at the end of 1910 seventeen, and three pole transformers, and at the end of 1913 sixty-three substations and twenty pole transformers.

In 1910, on account of the increasing radius of supply it was found advisable to increase the pressure for the more distant suburbs to 10,000 volts. To meet this demand 1,000 K.Ws. of step-up transformers were installed and put into operation in 1911, and were used to supply energy to Botany and St. Peters. These soon became inadequate, and in 1912 3,000 K.Ws. of additional transformer capacity were installed at the generating station, raising the pressure to 10,500 volts. The districts at present supplied by this system include Randwick, Botany, Mascot, St. Peters, Marrickville, Canterbury, Drummoyne, Concord, Strathfield and Homebush, and a small part of Burwood.

Transmission from the generating station to the transforming stations is by lead-covered 3-core cables. All cables employed are constructed with the same insulation between conductors and the lead sheath as that between conductors.

In certain districts overhead 3-phase lines are used as a continuation of the lead cable system. The conductors are mounted at the angles of an equilateral triangle with 3-foot sides. Many substations are fed directly from the Generating Station, and several tie lines are run between substations. In the City area practically all low tension distributors are underground, but in the less congested suburban districts overhead construction is employed to a large extent.

Work was commenced on the first underground cable in Forbes Street, City, in January, 1904. and in 1913 the total street mileage of underground low tension feeders and distributors amounted to 49 miles, while the overhead mains covered a distance of 364 miles. The more recently installed high tension cables are drawn into fibre conduits, which are laid

in cement concrete; the standard 80 yard spacing of draw pits is, however, maintained. At the end of 1913 the total area of high tension cable leaving the generating station was 3 x 0.2 square inches 10,000 volt cable, and 3 x 2.45 square inches 5,000 volt cable, the individual cable varying from .05 to .15 square inch area. Of the 5,000 volt cables, eight—.15 square inch each—cross under the Harbour near the Pymont Bridge.

As previously mentioned, the two City substations contain motor generator converting machinery. In the original installation this comprised at Town Hall substation 300 K.Ws. of 5,000 volt induction motors direct coupled to 480-volt generators, and two 240-volt balancer sets of 150 kilo-watts each, and at Lang Park 650 K.W. of 480-volt sets and one 150 K.W. balancer. These machines were all supplied by Dick Kerr and Co. Repeated extensions have been made, and these substations now contain—Town Hall 4,950 K.Ws., and Lang Park 4,050 K.Ws. These comprise Dick Kerr synchronous and induction motor generator sets, Siemen Bros. Ltd. synchronous sets of 600 and 1,000 K.W. capacity, and a Bruce, Peebles, La Cour 1,000 K.W. motor converter. The installation of a 1,500 K.W. Siemen's rotary converter, which will be completed in May, 1914, will bring the capacity of the Town Hall substation up to 6,450 K.Ws.

The original switchgear was supplied by Messrs. Ferranti Limited, being of the old "cell" type. All recent additions, both high tension and direct current low tension, have been supplied by the General Electric Co. of America. The panels are all of blue Vermont marble, the low tension instrument being of Thompson astatic type, and the high tension horizontal edgewise type. The high tension switchgear is of the hand-operated remote control type oil switches with automatic overload release. Energy meters, knife switches, ammeters, and circuit breakers are fitted to all low tension panels. The circuit breakers are fitted with both overload and no voltage release on the generator panels, and overload release only on the feeder panels. In addition to the rotating machinery in the Town Hall substation there has been installed, completed in 1910, a Tudor Accumulator Co. storage battery, comprising 300 cells and a 600 K.W. charging booster. The battery is capable of delivering 2,000 amperes for three hours, or 4,000 amperes for one hour. Regulation is obtained by end cells, the switches being motor operated, controlled by push button switches on the low tension substation board. The Battery Room measures 84 feet x 49 feet approximately, and the booster and end cell switchroom 84 feet x 16 feet approximately. These rooms form the basement of the Department's offices and stores building.

Street lighting is provided by the Electric Light Department in the City and a number of the suburbs, both arc and

incandescent lamps being used. The original scheme, installed in 1904, comprised 343 open type Crompton arc lamps. At the end of 1912 the Crompton lamps were superseded by flame arc lamps. By the end of that year electric lighting of the City and the suburbs supplied by the City comprised 693 flame arcs, 36 enclosed arcs, and 1,120 metal filament incandescent lamps. In March, 1914, the respective numbers are approximately 1,100 arc lamps, 4,000 incandescent lamps. The incandescent lamps are connected in multiple across 240 volts, and are controlled from the substations by automatic time switches. The arcs are series multiple, eight being in series on 415 volts alternating current, and nine on 480 volts direct current. They are in general not controlled from the substation, but are tapped on to the network at convenient points. Automatic time switches control all circuits.

From Lang Park and Town Hall—the two direct current substations—there are run direct current 3-wire feeders to the number of 24, aggregating 53 square inches of copper conductor. By the middle of 1914 there will be 33 feeders of an aggregate area of 75.5 square inches. Single core concentric and triple concentric cables are used with a neutral conductor usually one-half the area of the outers.

Between Lang Park and Town Hall substations two pairs of direct current inter-connector cables are run, having a combined area of three square inches.

The network of direct current distributing cables is divided into sections, each section being fed by either one, two or three feeders. The sections are connected to each other by circuit breakers placed in pillars in the street. In case of a failure of insulation on any section, that section is automatically disconnected from the rest of the system by the circuit breakers in the streets.

A motor hiring scheme was put into operation in 1906, 116 motors being on hire at the end of that year to users of the Council's supply of electricity. At the end of 1913 there were 2,568 motors on hire from the Department.

The number of meters in use at the end of 1913 for lighting and power supply amounted to 14,000.

The charges adopted are as follows:—For lighting, a flat rate of 4½d. per unit, or, at the yearly option of the customer, a maximum demand rate of 5d. for the first hour and 2d. afterwards; for motors, lifts, heating and cooking, 1½d. a unit flat rate, or three-fifths of a penny per unit with a standing charge of 4s. per month per rated horse-power installed. This latter rate for power only applies to consumers who have one horse-power or more installed, and who agree to pay for energy and the standing charge at this rate for not less than six months continuously without reducing the rated horse-power.

Early in 1912 the headquarters of the Electric Light Department were removed from the temporary offices in the Queen Victoria Market into the Department's own building, entered from the Town Hall, but actually fronting on to Kent Street. This building contains under one roof—

1. On the ground floor the storage battery and apparatus connected with it.
2. On the first floor the new portion of the Town Hall substation, the meter-testing and repairing workshop and rooms for the outdoor foremen.
3. The motor and arc lamp repairing and testing workshop.
4. Departmental stores.
5. Departmental stores.
6. Departmental offices.

The building is designed and built to take two more floors when required. The total cost was about £40,000.

In addition to the City of Sydney the Electric Light Department supplies electricity to the public in 20 suburban municipalities, namely:—

Alexandria	Randwick
Annandale	Redfern
Botany	St. Peters
Darlington	Waterloo
Drummoyne	Woollahra
Erskineville	Strathfield
Glebe	Homebush
Marrickville	Concord
Mascot	Burwood
Paddington	Canterbury.

The organisation of the Department is on similar lines to most English electric supply undertakings, the principal exceptions being:—

(a) That the stores and materials are purchased by the Comptroller of Assets and issued by him as required; and (b) That all accounts are kept by the City Treasurer's Department.

The original scheme for the supply of electricity in Sydney was devised by Messrs. Preece and Cardew, of London. The undertaking was in the charge of Mr. Rooke from 1904 till he resigned the position of City Electrical Engineer in 1908. Since then it has been under my charge.

The architectural work has been carried out by the City Building Surveyor (Mr. Brodrick), and his Chief Assistant (Mr. Merriman).

The following table indicates the rates at which the Council's electricity supply business has grown, the figures being given for 31st December of each year:

	1904.	1905.	1906.	1907.	1908.
Capital expended ..	£151,894	£238,539	£280,463	£367,213	£435,105
Gross revenue	£4,060	£22,175	£40,983	£59,742	£87,006
Total load connected equivalent in 50 c.p. lamps }	16,850	59,650	112,400	174,066	236,966
H.P. of motors connected	451	1,415	3,639	5,872	8,290
Number of customers ..	86	519	946	1,600	2,219
Units of electricity sold per annum }	257,499	2,080,284	3,927,330	6,096,000	8,674,000
Average revenue per unit sold }	3.06	2.21	2.20	2.01	2.10
	1909.	1910.	1911.	1912.	1913.
Capital expended ..	£534,280	£708,888	£941,504	£1,240,280	£1,578,584
Gross revenue	£118,275	£144,734	£172,693	£216,814	£285,743
Total load connected equivalent in 50 c.p. lamps }	321,900	388,616	467,383	565,733	793,627
H.P. of motors connected	10,978	13,532	16,722	22,527	30,573
Number of customers ..	2,945	3,687	4,655	6,374	9,111
Units of electricity sold per annum }	11,914,720	14,398,918	17,768,210	22,701,056	31,986,843
Average revenue per unit sold }	2.10	2.13	2.05	2.06	1.93

It may be of interest to state the points at which, in my opinion, the system is defective:—

1. The boiler-house is entirely dependent on natural draught for the generation of steam; and though for many years I thought otherwise, I believe now that natural draught is not sufficiently elastic in the case of an electric supply undertaking, which has a considerable portion of its output

used for the lighting of private premises. In such a case, the maximum demand may occur in the shape of a peak, which may rise above the normal day-loading by several thousands, or even tens of thousands, of kilowatts. In Sydney, the "peak" is felt only during about three months of the year.

2. The site on which the generating station stands is too far from deep water. As a result of this, and of the Darling Island Railway Sidings intervening between the power-house site and the nearest deep water, the cost of providing a supply of circulating water for condensing is excessive; and owing to difficulties raised by the Harbour Trust and the Railway Commissioners, no provision has yet been made for getting coal direct from steamer or barge into the power-house. On account of this latter difficulty, considerations of economy have made compulsory the use of only Southern and Western coal.

3. A separate building has not been provided for the switchgear controlling the electric generators and the supply of electricity to the high tension feeders leaving the power-house; and experience in other places has shown that when the maximum rate of output exceeds a certain figure it is highly advisable to place the switchgear in a building entirely separate from the building housing the rest of the plant.

4. No provision has been made as yet for the limiting of the rush of current to a short circuit on the system if the short circuit occurs on the high tension system in the power-house, or on a portion of the mains near the power-house and in direct electrical connection with the generator busbars. The necessity for limiting the volume of short-circuit currents on alternating current systems in cases of short-circuit has been recognised only during the last three or four years, since it is only during the last five or six years that electrical energy has been generated at such a rate as to call for the use of plant generating energy of such a volume as to be absolutely destructive to any apparatus however carefully designed.

5. The generating voltage having been originally fixed at 5,000, admitted of an economical supply of energy only within a very limited radius; and it became advisable to increase beyond the generating voltage of 5,000 the voltage for transmission to the outlying portions of the metropolitan area in Sydney.

At the time, a secondary step-up voltage of 10,000 was decided on. It is now clear that this voltage was too low. A step-up voltage of 33,000 has now been decided on, and will be used as the standard in future for transmission to the outlying portions of the Metropolitan area. This will allow of electricity being supplied economically to any point within a radius of 20 to 30 miles.