Character of Metropolitan Service

Enormous Output of Electrical Energy in the New York District and Precautions Taken to Safeguard the Supply—Cities and Industries Depend on Central-Station Service—Tremendous Loads Thrown on System Suddenly

THE metropolitan district of New York includes not only the area within the corporate limits of the central city but also parts of the surrounding territory which are closely associated with the development of the metropolis. The city itself has an area of 183,555 acres and a population of 5,620,000, or 5.31 per cent of the entire population of the United States. Outside and within the metropolitan area are the counties of Nassau and Westchester in New York and the counties of Bergen, Essex, Hudson, Middlesex and Union in New Jersey. These have a combined population of approximately 2,500,000, giving to the metropolitan district almost 8 per cent of the entire population of the country. This district ranks first among the metropolitan districts of the United States in the value of its products.

The quantity of electricity generated in the New York district for all purposes in 1922 was fully six thousand million kilowatt-hours, with a peak load of approximately 1,500,000 kw. and a load factor hovering around 40 per cent. Of this amount the isolated plants in the hotels and some of the office buildings of New York City and those in the large industrial districts of New Jersey contribute over a thousand million kilowatt-hours yearly. The outputs and peaks of the public utility companies in 1922 are shown in Table I, in which no account has been taken of the outputs of the smaller generating companies in the boroughs of Richmond, Brooklyn and Queens or in the New Jersey districts.

TABLE I—OUTPUTS AND PEAKS OF METROPOLITAN UTILITY COMPANIES

Name of Utility Company	Output In Kw.-hr.	Peak Load in Kw.
New York Edison Co. and United Electric Light & Power Co.	1,659,269,781	497,577
Public Service Electric Co.	958,407,194	249,778
Brooklyn Edison Co.	516,987,870	164,495
New York & Queens Electric Light & Power Co.	120,011,093	35,300
Interborough Rapid Transit Co.	886,223,920	246,770
Brooklyn Rapid Transit Co.	413,992,125	118,800
Pennsylvania Railroad Co.	214,906,725	72,000
New York Central Railroad Co.	157,450,819	48,470

Leading Industries of New York

While it is universally known that New York is the largest city in the Western Hemisphere, it is not generally appreciated that its population is almost as large as that of the State of Ohio, the fourth most populous state in the Union. Brooklyn, for instance, has a larger population than the city of Philadelphia; Manhattan and Queens exceed Chicago by 40,000; the Bronx is as big as Baltimore, and Richmond is more populous than Nashville or Salt Lake City.

Industrially the city also leads. The essential facts concerning New York's manufacturing industries are shown in Table II.

New York leads the country in the production of many items in common use and manufactures a very large proportion of many others. This is particularly true of outfitting and apparel. For the women who make their own clothes, for instance, New York produces 95 per cent of all the paper patterns made in this country, and for the women who wear ready-made clothes New York produces nearly three-quarters of the country's entire output. The same is true of fur goods. New York also makes about one-half of the country's output of millinery and lace goods. In the city are cut and polished 90 per cent of the diamonds and other precious stones which are manufactured in this country. One-third of the country's jewelry is manufactured in New York and about 30 per cent of the nation's production of pianos.

For men New York makes four out of every ten ready-made suits of clothes, 46 per cent of furnishing goods, 40 per cent of the shirts and a quarter of the hats. It also supplies them with four out of every five tobacco pipes made in the country. New York is the greatest printing and publishing center of the country. It makes 29 per cent of the toys and games, a third of the mirrors, a quarter of the buttons, chewing gum and scientific instruments, and a large percentage of the patent medicines and compounds manufactured in the United States. In addition to all these is the fact that New York is now the financial center of the world.

Problem to Find Space for Wires

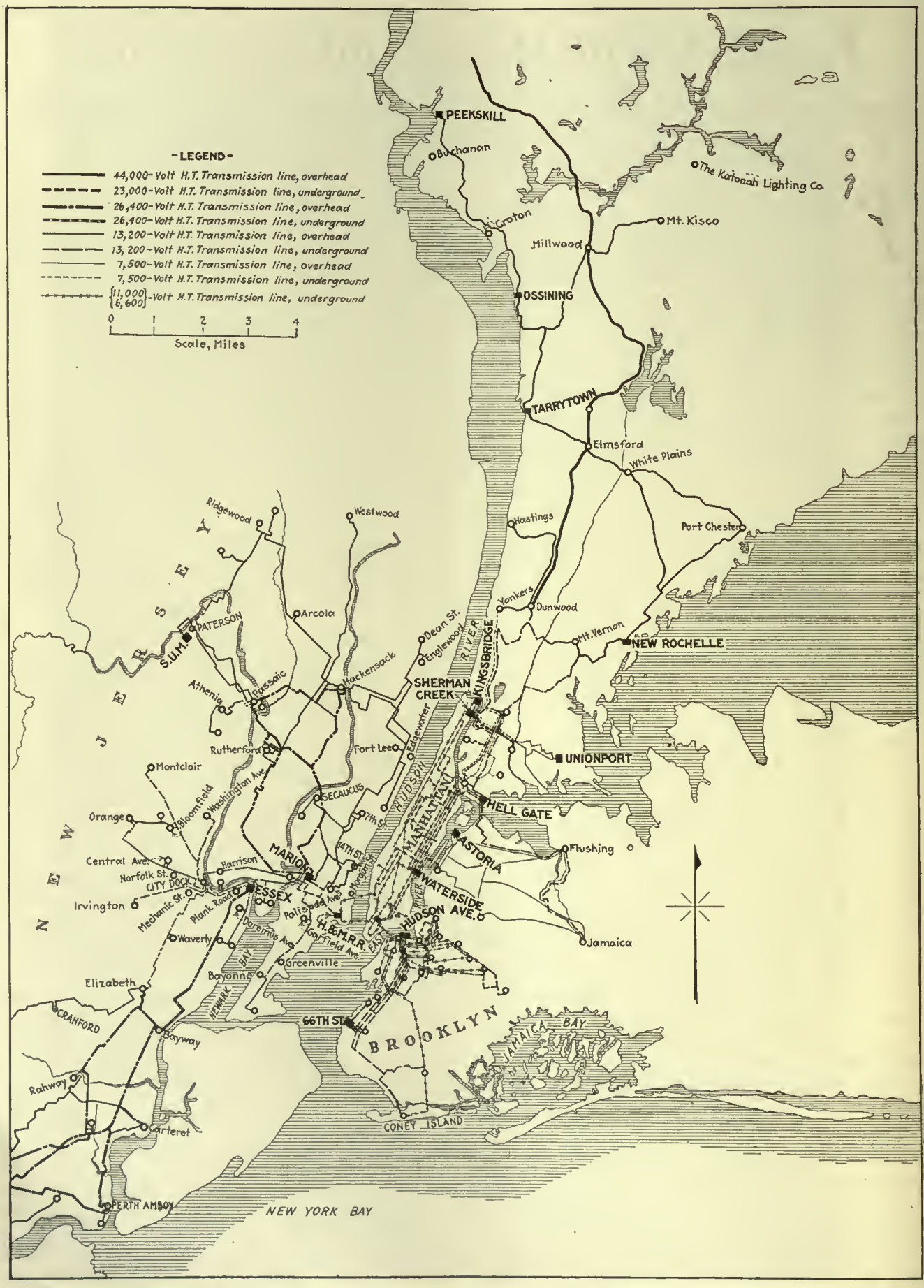
In a district the size of New York, with so many diversified and varied industries and with such a compact population working in skyscrapers and living in huge apartment houses, naturally electricity plays a very important part, more important than in any other city in the world. Without it the immense subway system of passenger transportation would be impossible, skyscrapers and large apartment houses and hotels would be largely uninhabitable, Broadway would become a village street, and a large part of industry would have to move elsewhere.

Having such a vital part in the life of the city, every precaution is taken to safeguard the supply of electricity and to provide for continuity of service. No overhead wires are permitted in the Borough of Manhattan, so that distribution of all electric service there is underground. So intensive is the use of electricity in many of the districts of Manhattan and so occupied are the streets with subways, pipes and ducts that the limit of capacity of many of the substations is fixed by the space available for underground cables in the streets. In the congested districts the situation is causing the operating companies much concern.

TABLE II—MANUFACTURING DATA FOR NEW YORK CITY

Number of establishments	32,590
Persons engaged in manufacturing industries	825,056
Capital	$3,038,557,492
Salaries and wages	1,131,994,192
Value of products	5,260,707,577
Value of raw material used in manufacture	2,801,619,388
Value added by manufacture	2,399,231,459

All of the generating stations in New York are interconnected, and the practice in Manhattan is to feed the substations from independent generating sources. More equipment could be installed in the generating stations of The New York Edison Company if sufficient space



Generating Stations and Substations in New York Metropolitan District

could be found in the streets for the copper feeders. As it is, lack of street space has limited the interconnections between generating stations and between generating stations and substations even though the distribution voltage has been raised from 6,600 to 11,000 and tie feeders between stations are being operated at 40,000 volts.

IMPORTANCE OF ELECTRIC SERVICE

The reasons why continuous electric service is imperative in the Borough of Manhattan will be apparent from the following considerations: The high-pressure pumping stations of the fire-protection system are absolutely dependent on central-station service for their operation not only in the Borough of Manhattan but in the Borough of Brooklyn as well. Any interruption lasting over three minutes is penalized at the rate of $400 a minute, but no penalty has so far been collected in either borough. The police and fire-alarm signaling systems, the ticker system, the telephone and telegraph systems of the Bell, Western Union and Postal companies, the trans-Atlantic cable companies, the newspapers, the garment and needle trades, 95 per cent of the passenger and freight elevators of the borough and the entire street-lighting system depend solely on the electric service of The New York Edison Company.

In order to provide a service which shall be at all times available great precautions must be taken. Coal shortage because of strikes or other reasons is guarded against by storage at Shadyside, N. J., and at the Hell Gate station, in addition to the overhead bunkers in the generating stations themselves in the case of the New York Edison and United companies. Space is available for more than 300,000 tons of coal, and during the recent coal crisis large cargoes of coal were imported from England. Taking into consideration the cost of the real estate and equipment and the cost of the coal in storage, the amount of working capital tied up in coal storage alone is not far short of $5,000,000 for the Edison company. In addition, to guard against any emergency or failure of generating equipment The New York Edison Company has electric storage batteries whose one-hour discharge rate is 471,000 amp. and from which 250,000 kw. can be pumped into the system for fifteen minutes.

The downtown section of New York is built skyward. There structures unequaled in height in any other section of the world are built wall to wall as compactly as possible. Each is a city in itself, with its vertical traction system in the shape of elevators, with a complete water supply and sewerage system and with power and lighting loads exceeding those furnished by many towns of like population. So high are these buildings that the streets resemble canyons more than thoroughfares, and electricity must be used for lighting the lower offices even during the day.

Such a condition is not without its effect on the electric light and power company, particularly when sudden storms sweep over the city. Every precaution is taken to have the power houses ready for such emergencies, and warnings are telephoned to operators when lowering clouds appear. The peaks thrown on the system are oftentimes of short duration, but to meet them means eternal vigilance and tremendous cost.

One such peak occurred at 4 p.m. on March 2, 1911, when an extra 52,000 kw. came on the system, which in five minutes was carrying a load of 75,000 kw., the extra load disappearing during the following ten minutes. The cause was a snow squall from the Northwest. On June 20, 1919, about 3 p.m., when the system was carrying 180,000 kw., a thunderstorm added 133,000 kw. to the load in about thirty minutes, and this extra load did not entirely disappear until 5 p.m. The total load overtopped the winter peak by 15,000 kw. In this case about 40,000 kw. was carried by the storage batteries for a few minutes. Similar in its effects to the thunderstorm peak, but not so troublesome, is the dark day. On Feb. 28, 1923, the load on the system increased from 120,000 kw. to 435,000 kw. in two and one-half hours, an increase of nearly 3,000 kw. per minute, and this load persisted for more than eight hours. One can readily appreciate the great reserve capacity required in an electric supply system capable of handling such tremendous loads on such short notice without any indication of distress.

MORE THAN A MILLION METERS INSTALLED IN CITY

The practice of selling electricity in New York differs somewhat from that which obtains in other cities in that dwellers in huge apartment houses are customers of the landlord rather than customers of the company. Thus the number of meters actually owned and installed by the utility companies represents less than the total number of users of electric service. There are in the Borough of Manhattan alone more than 150,000 sub-meters in apartment houses, service to which is supplied by the public utilities through a master meter.

The total number of meters connected to the circuits of the utility companies in the greater city was, at the end of March, 889,946, which, plus the sub-meters installed in apartment houses, brings the total number of electric meters in use to considerably over one million. As all of the distribution circuits on Manhattan are underground, and underground construction on Manhattan means blasting from solid rock, it will be appreciated that the cost of servicing a customer is high. Notwithstanding this fact, there is no minimum service charge for energy in Manhattan and the Bronx, and The New York Edison Company has on its circuits more than 50,000 customers whose annual bills for electrical energy are less than $10 a year.

The number of new meters which are being added to the circuits of the companies in Brooklyn, Queens and in the New Jersey district is very great. The Public Service Electric Company of New Jersey, for instance, connected 63,901 meters to its system last year, as compared with 45,912 in 1921, and of these 83 per cent were small meters for domestic service. The Brooklyn Edison Company in a smaller district during the same period added 63,657 new meters, a gain of 26 per cent over 1921. The ratio of growth in the Borough of Queens is even larger. the New York and Queens Electric Light & Power Company, which has almost 100,000 meters on its circuits, having increased their number during the last ten years 1,400 per cent.

EXPENDITURES FOR EXTENSIONS AND ADDITIONS

Of course, enormous expenditures have been made and are being made by the electric public utility companies to keep abreast of the demands made upon them for service. Since 1916 The New York Edison Company and its subsidiary, The United Elec'ric Light & Power Company, have expended more than $70,000,000 for additions and betterments to the system. This company, which has the largest gross income of all of the purely electric light and power companies of the country, will, at the present ratio of increase, which is

over 16 per cent, have a gross income of more than $60,000,000 this year. The Brooklyn Edison Company has increased its gross revenue in five years 135 per cent, and the gross earnings of the company for the four months ended April 30, 1923, showed an increase of $2,000,000 over the same period last year, or an annual rate of increase of $8,000 000. The gross earnings last year amounted to $19,129,000 against $16,000,000 in 1921. Since 1921 the capital of the company has been increased from $19,000,000 to $50,000,000.

The large increase in business reflects the fact that new construction in Brooklyn is going ahead at a pace equaled by few cities in the United States. During the first four months of the year the Brooklyn Edison Company added 22,000 new customers, and May showed no diminution in the rate at which new names were being added to the books. At the first of this year the expansion program of the Brooklyn Edison Company, to meet increasing demands for service, called for an expenditure of about $15,000,000, while $7,000,000 had been expended out of earnings for this purpose during the previous year. The expansion program includes a new 400,000-kw. steam station on the East River at Hudson Avenue. This station when completed will be one of the largest in the country.

Other features of the generating systems in the metropolitan district are given elsewhere in this issue.

Edison and United Companies' System

Manhattan Island Has the Most Concentrated Load of Diversified Character to Be Found in the United States—Service in the Bronx and Westchester and Connections with Railroads and with Brooklyn

By JOHN W. LIEB
Vice-President The New York Edison Company

THE starting of the historic Pearl Street station on Sept. 4, 1882, initiated the service of The New York Edison Company, as well as central-station electric service in the world as it is thought of today. Contemporary scientists predicted the failure of the undertaking, designating it as an absolute "ignis fatuus," but it proved to be a forerunner and established the basis of the highest type of central-station supply as it is now known. In the short period since the starting of the old Pearl Street station in New York the tremendous accomplishments of The New York Edison Company and The United Electric Light & Power Company have been recorded.

The territory directly served by these companies covers Manhattan and, together with its affiliated distributing company, the Borough of the Bronx. The electrical energy required in the city of Yonkers, served through the Yonkers Electric Light & Power Company, is also provided from the generating stations of the companies, as is a part of the energy required in the Borough of Queens and in Westchester County, which are served through allied companies, the New York & Queens Electric Light & Power Company and the Westchester Lighting Company. Thus the energy generated by the allied companies serves a territory extending from the southern tip of Manhattan Island to the Putnam County line, a distance of about 50 miles, and includes Yonkers, Westchester County and the Boroughs of Manhattan, Bronx and Queens as shown on the map of the metropolitan district.

The area of the territory served directly by The New York Edison Company and The United Electric Light & Power Company is approximately 40 square miles, with about 3,000,000 inhabitants, while the corresponding figures for the entire territory referred to are 550 square miles and about 3,800,000 inhabitants.

Five Generating Stations

The generating stations of the two companies comprise five stations of a total rated capacity of 635,000 kw., of which 405,700 kw. is 25-cycle alternating-current and 221,500 kw. is 60-cycle, with 7,800 kw. of direct-current generation. In order to care for the load of the coming winter there will be added a 35,000-kw., 25-cycle turbo-generator, making the total capacity of the stations 670,000 kw. Including the stations of the Third Avenue Railroad and the Hudson and Manhattan Railroad, which are operated by the companies under lease and are rated at 60,000 kw., there is in 1923 a total generating capacity, operated as a unit under the combined auspices, of 730,000 kw.

Waterside generating stations Nos. 1 and 2 are adjacent to each other on the East River between Thirty-eighth and Fortieth Streets. Waterside No. 1 commenced operation with large engine generator units, which have all been replaced by steam-turbine generator units, and it now has a total installation of ten units with an aggregate capacity of 174,000 kw. Two of the units are of 35,000 kw. capacity each, and all of them are 25-cycle except two small 60-cycle units aggregating 16,500 kw. The generating equipment of Waterside No. 2 comprises ten steam-turbine generator units of an aggregate capacity of 152,200 kw., of which all are 25-cycle except one 60-cycle unit of 14,000 kw. capacity. The Sherman Creek generating station of the United company, in Manhattan on the Harlem River at Two Hundred and First Street, contains eight steam-turbine generator units with an aggregate capacity of 151,000 kw., of which 40,000 kw. is 25-cycle and the remainder is 60-cycle. The Hell Gate generating station of the United company, on Long Island Sound at the foot of One Hundred and Thirty-fourth Street in the Bronx, with an ultimate capacity of 300,000 kw., has now installed two 35,000-kw., 25-cycle steam-turbine generators and two 40,000-kw., 60-cycle units. The original Duane Street generating station of 7,800 kw. capacity supplies direct current feeding into the Edison network in the business district near the southern end of Manhattan.

The Hell Gate generating station receives most of its coal from oceangoing ships and is equipped to unload such boats rapidly. Thus, during the recent extreme

shortage of coal, coal-laden boats from England went directly to the Hell Gate dock for unloading. This station is also equipped to receive coal by rail as well as by water. The other generating stations receive their coal by barge, the coal being brought to New York tidewater by rail, supplemented by the supply for the Shadyside storage yard.

The fuel supply for the generating stations is fortified by the large Shadyside coal storage yard, with a capacity of 240,000 tons, on the west bank of the Hudson River opposite Ninety-sixth Street, local storage capacity at the Hell Gate Station amounting to 60,000 tons, a total of 300,000 tons exclusive of the coal in process of utilization in the bunkers over the boilers of the several generating stations. In addition to this adequate provision for emergencies, the companies further participate in the storage facilities provided at the Consolidated Gas Company's plant at Astoria, with a capacity of 700,000 tons, located immediately opposite the Hell Gate station.

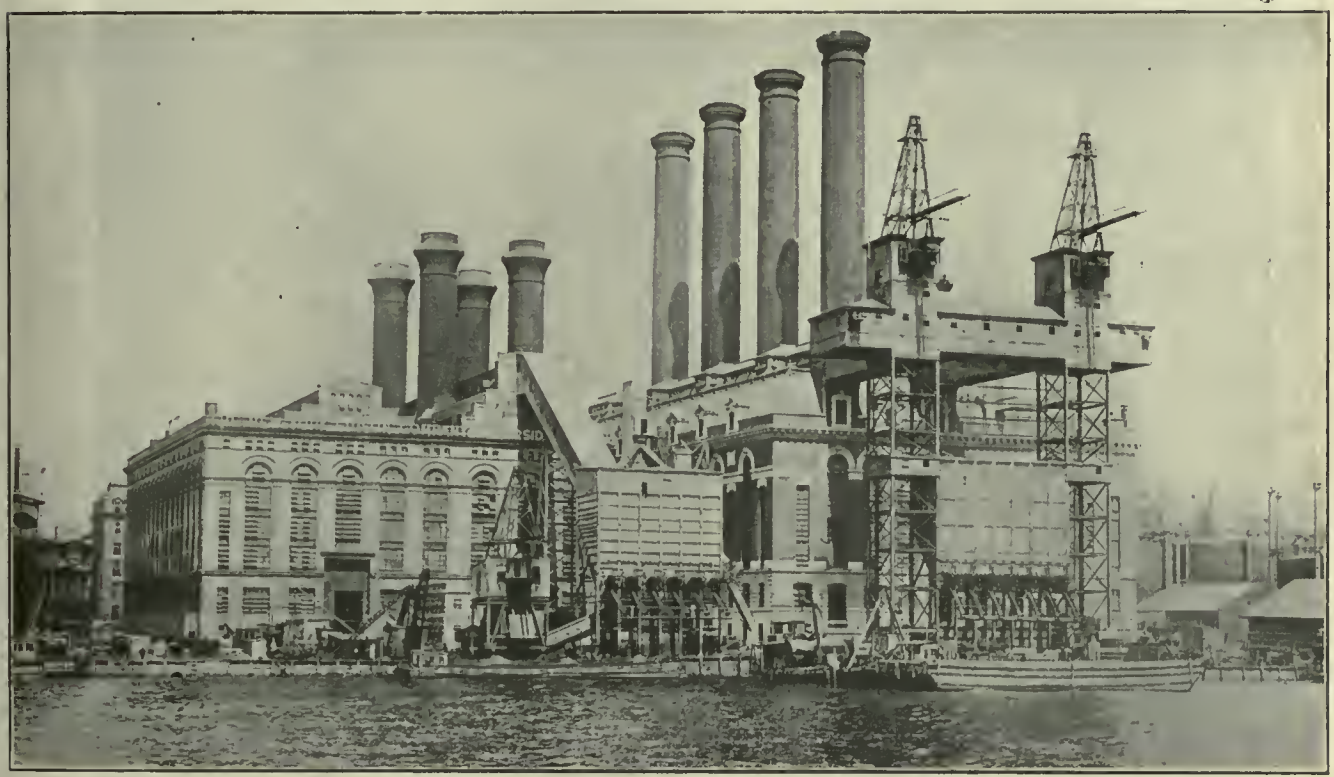
All of the generating stations are interconnected by tie cables of sufficient capacity to supply the loss in emergency of the largest unit in any station. Ties are also maintained through all substations to provide for the loss of at least one transmission cable.

The load dispatching of the entire system is supervised and directed by a system operator at the Waterside station. The system operator's room is equipped with a pilot board automatically indicating the position of all switches in all generating stations and all switches controlling high-tension feeders to substations and customers. A special telephone switchboard is installed with direct lines to all substations and generating stations and with trunks to several telephone exchanges. A Gamewell fire-alarm system is also provided for simultaneous instantaneous signaling between all substations and generating stations. All city fire alarms from the district supplied by the high-pressure pumping stations are also recorded at the system operator's room, and storm warnings are received by a "wireless detector."

The total demand on the Edison and United generating stations in 1922 was 525,000 kw., and the total output for that year was 1,665,000,000 kw.-hr.

It is interesting to note that in Manhattan sudden thunderstorms are sometimes accompanied by inky darkness, causing the midsummer load to rise to an amount almost equal to the previous winter's maximum. Thus the spare peak capacity usually found in central stations during the summer months is not available, a condition singular to Manhattan Island.

Energy is supplied to 25-cycle substations over radial feeders at 6,600 and 11,000 volts and to 60-cycle substations through parallel feeders at 7,800 and 13,200 volts. All transmission feeders operated by the Edison and United companies are carried underground. The supply to the Westchester Lighting Company is through two 45,000-volt underground feeders at 60 cycles (six single-conductor cables) from the Sherman Creek generating station to the New Rochelle substation, at which this energy is transformed to 13,200 volts for supply to other substations.



WATERSIDE STATION OF THE NEW YORK EDISON COMPANY

The northern end of Westchester County is also supplied from the Dunwoodie Avenue substation of the Yonkers Electric Light & Power Company via 45,000-volt overhead lines to the Elmsford substation. The New York, New Haven & Hartford Railroad Company is supplied by three-conductor, 25,000-volt underground cables at 25 cycles which tie in with the railroad's generating station at Cos Cob.

Tie connections for interchange of power are also maintained with the Interborough Rapid Transit Company at 11,000 volts, 25 cycles; with the Pennsylvania Railroad at the same voltage and frequency through the Jersey City Station of the Hudson & Manhattan Company; with the Brooklyn Rapid Transit Company at

Aerial Photograph of New York, Showing Location of Electric Generating Stations

6,600 volts, 25 cycles, and with the Brooklyn Edison Company at the same voltage and frequency and also at 13,200 volts, 60 cycles. The last-named connection is now being changed to operate at 26,000 volts.

High-tension energy is supplied in bulk to certain large customers, such as ice manufacturing companies, mostly at 7,800 volts or 13,200 volts, 60 cycles, through single or multiple loop feeders, with automatic switches in the customers' premises. This service is in all cases stepped down to not more than 440 volts by the customers' transformers. In the case of the pumping stations for supplying high-pressure water for city fire protection the energy is fed at 6,600 volts, 25 cycles, with two direct feeders from separate generating stations and two feeders from separate substations to each pumping station, the pump motors being operated direct at the 6,600-volt feeder pressure. This service, as will be appreciated, is of a highly important character, supplying water through a separate system of mains to the fire hydrants in the business sections of the city. It may be interesting to note that a very definite penalty clause for failure to supply energy is included in the contract.

MANHATTAN'S THIRTY-TWO SUBSTATIONS

The thirty-two substations serving the direct-current network in Manhattan have a total capacity of 380,000 kw. in 185 25-cycle synchronous converters, of which the largest units are of 4,200 kw. normal capacity. The conversion equipment is supplemented by storage batteries capable of supplying a discharge of 60,000 kw. for one hour. The output of these substations is distributed over 1,600 feeders connected to a network of 810 miles of service mains.

Part of this same territory is also served by 60-cycle low-tension distribution. This, together with the portion of Manhattan north of One Hundred and Thirty-sixth Street and the Bronx west of the Bronx River, is supplied by ten substations of a total capacity of 140,000 kva., the transformers used being mostly in sizes of 2,000 kva. and 3,000 kva. The 60-cycle distribution in Manhattan is at 3,000 volts, two-phase, three-wire, lighting being supplied across the outside legs. In the service fed from one substation this has now been changed to three-phase service and a low-voltage interconnected network has been put into service. In the Bronx the distribution is at 2,300 volts, two-phase, four-wire.

The system in Queens Borough, supplied by the six substations of the New York & Queens Electric Light & Power Company, with a total capacity of 90,000 kva., utilizes 2,300-4,000-volt, three-phase, four-wire distribution circuits, the high-tension feeders operating at 7,800 and 13,200 volts. Westchester County is served through thirteen substations of the Westchester Lighting Company, with a total capacity of 50,000 kva., the transmission voltage between substations being 13,200 and the distribution at 2,300 volts, two-phase. The city of Yonkers is supplied from the two substations of the Yonkers Electric Light & Power Company, the total capacity in step-down transformers being 15,000 kva., the transmission between stations at 13,200 volts and the distribution at 2,300/4,000 volts, six-phase, four-wire. The distribution from that portion of the Bronx east of the Bronx River is supplied from the Bronx Gas & Electric Company's substation at 2,300 volts, two-phase.

The foregoing can be considered a brief outline of the generating, transmission and substation features of the system of The New York Edison Company, The United Electric Light & Power Company and associated companies in the Bronx, Queens and Westchester Counties.

The districts other than Manhattan are largely similar to cities of the same population in the character of their load, composed of residential, business and power consumers. The load in Manhattan Island, however, an area of 21 square miles, represents the most concentrated diversified central-station load in the world, both from a standpoint of the population served (an average of 114,700 per square mile) and the density of the load itself.

As a result of the concentration of load and the restricted area the physical conditions affecting the distribution systems are peculiar. The load continues to increase year by year at a more or less uniform rate of from 12 to 15 per cent, and this means a continuing growth within a fixed area without reaching saturation.

The factors of building and population which cause the increase in central-station load carry with them also an increase in all other facilities such as transit, gas, water and steam, producing a progressive congestion of physical equipment within the fixed boundaries of the streets that makes the problem of construction of substations and installation and maintenance of distribution systems increasingly difficult because of space limitations and restrictions due to subsurface structures.

Coupled with the enormous concentration of load is the character of the load itself, which requires adequate and uninterrupted service at all times to newspapers, ticker service, telephone, telegraph and other wire communication systems, city lighting, fire service, hospitals, office buildings of great magnitude where the electric elevator service represents vertical transit facilities to innumerable tenants, and similar important service. The company-owned meters total in Manhattan Island alone approximately 350,000, to which should be added many thousands of customer-owned meters in individual buildings.

STREET LIGHTING SYSTEM

It may be of interest to add a word relative to the carefully planned street lighting throughout the city. The companies referred to supply approximately 50,000 street lamps of the multiple and series types of the high-efficiency "type C" form of Mazda incandescent lamp. The outstanding feature of the planning of the street lighting is the zoning of the districts and the allocation of lamps from 100-cp. size for suburban districts to the twin form of post carrying two 500-watt lamps for districts comparable with Fifth Avenue, Times Square, etc.

The lamp posts are of an ornamental type designed for the particular districts both as to height and form and are of types suitable for the residential districts, the business sections and the boulevards, parks and more highly developed avenues. The wide variation in the size of the "type C" incandescent lamp from 100 cp. to 750 watts enables application of illumination intensities, and, in combination with the proper post design, provides for a standardized equipment suitable for any desired street illumination.

From this brief summary a conception may be had of the conditions under which current is generated and distributed from the generating stations and substations on Manhattan Island and in the Bronx and the territories adjacent thereto served by the distributing systems of the companies allied with the Edison-United companies and from the standpoint of generation of current operated as a unified system.

Alternating Current in New York

Growth of Business Has Necessitated Additions to the Hell Gate Station of the United Electric Light & Power Company— Interesting Features of New Equipment

By FRANK W. SMITH
Vice-President and General Manager The United Electric Light & Power Company

FROM its Hell Gate generating station and its Sherman Creek station The United Electric Light & Power Company supplies electricity both to its allied companies and to the 82,150 customers on its lines. Because of the first class of service the United company may perhaps be considered in the nature of a "superpower company." Apropos of the second, it is interesting to note that of the total 82,150 customers supplied with United service on April 30 of this year 56,277 represent those residing in the Washington Heights section—that territory in Manhattan north of One Hundred and Thirty-fifth Street, which is exclusively supplied by the United company. Electric light and power facilities were first introduced in this district on Dec. 26, 1899. The remarkable strides taken in less than a quarter of a century are apparent in the fact that nearly four-fifths of the company's business is established in this new field.

The Hell Gate station was constructed for an ultimate capacity of 300,000 kw., and at the present writing equipment to one-half of this amount has been put into operation. At the Sherman Creek station the total capacity of 150,000 kw. has been utilized for some time. During the month of April 40,000,000 kw.-hr. was generated at Hell Gate, and the maximum load was 103,500 kw. At Sherman Creek during the same month 33,500,000 kw.-hr. was generated, with a maximum load of 94,000 kw. In comparison with these figures the following data for January, 1923, may be of interest: Hell Gate, 40,700,000 kw.-hr., with a maximum load of 110,000 kw. Sherman Creek, 39,327,000 kw.-hr. with a maximum load of 103,300 kw.

Additions to Hell Gate Station

A description of the new Hell Gate station appeared in the Electrical World for April 29, 1922. In that issue the departures from conventional practice were accentuated and described in some detail.

Among the features which make Hell Gate station stand out as an unusual plant are the following: The turbine room is next to the river, with the boiler room between it and the electrical galleries; alternating-current-driven auxiliaries are used, with one or two exceptions; phase isolation of all electrical equipment has been carried out; the ashes are sluiced by hydraulic means; the station equipment has been divided into four independent groups, and heat-balance control is provided. The arrangement of condenser circulating-water intakes and discharge, the use of boilers with superheaters only six tubes above the combustion chamber, the extensive equipment of motor-operated valves, the truck-type switchboards for station service and the coal-handling facilities are also worthy of note.

Oceangoing coal boats may land directly alongside the station for unloading by means of the coal towers. In addition, a direct siding from the New York, New Haven & Hartford Railroad permits the receipt of coal by rail—a feature possessed by Hell Gate alone among the generating stations in New York. The existence of two independent routes for bringing coal to the plant is of tremendous value in view of the absolute continuity of service that must be maintained on the system. The Hell Gate site possesses a further safeguard in this respect in having an outside storage capacity of approximately 100,000 tons, which insures about four weeks' operation at the ultimate load in case all the other sources of coal supply are cut off.

When the Hell Gate generating station was constructed it was planned to add further sections of equipment as the demand would warrant. This policy has been adhered to from the start. In line with this three new sections of electrical galleries are being added this year to the four sections already installed. These three sections of electrical galleries occupy an area of, roughly, 105 ft. x 94 ft. and are seven stories high.

The same system of compartments will be employed in these sections, and the same method of installing the ducts with paper forms will also be used. As described in a previous issue of the Electrical World, two of the first four sections of the electrical galleries were equipped for 25-cycle operation and two for 60-cycle. The three new sections will be equipped entirely for 60-cycle service, but two of the present 60-cycle sections will be reconnected for 25 cycles. The installation will then comprise four 25-cycle sections and three 60-cycle sections for the coming year. This reconnection does not involve any considerable expense as most of the apparatus is suitable for either frequency.

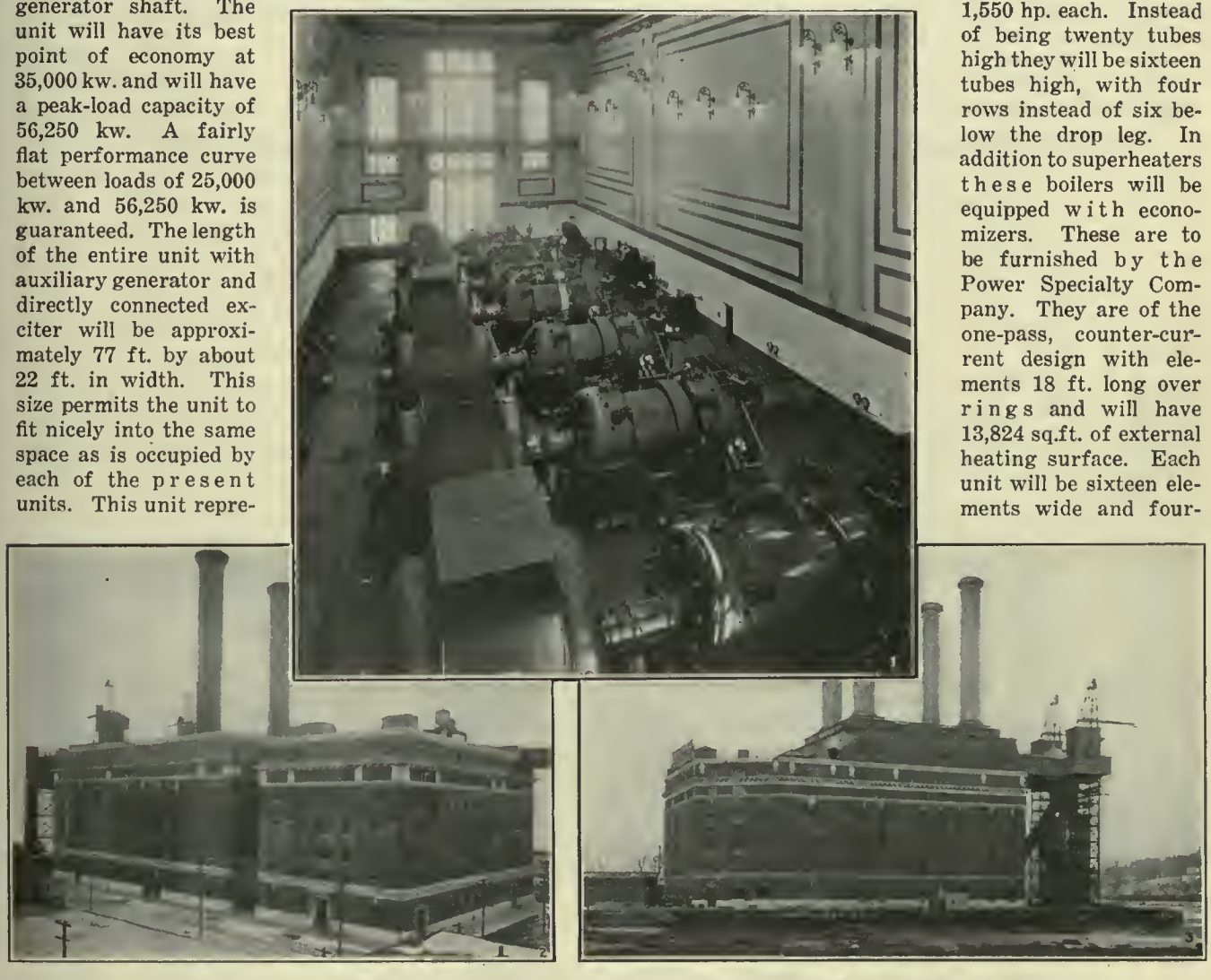
There have been purchased for the new sections ninety-nine Westinghouse circuit breakers of the same type and rupturing capacity—1,500,000 kva.—as was originally installed. These range in capacity from 3,000 amp. for the generators to 600 amp. for the feeders. The installation of this type of equipment in the present installation was an innovation, but the satisfactory service given made it advisable to continue the equipment along the same lines. In addition there have been purchased from the Metropolitan Device Corporation 120 porcelain-clad reactors of 3 per cent and 5 per cent reactance. This equipment also duplicates that installed originally.

50,000-Kw. Unit Purchased for 1924

For installation this year one General Electric 35,000-kw. turbine, similar in a general way to those now installed, has been bought. This turbine will exhaust into a Worthington condenser similar to that already in service. The circulating pumps, however, will be driven by two-speed motors instead of by the constant-speed motors used on all of the present circulating pumps.

A 50,000-kw. unit which is of especial interest has

been purchased from the Westinghouse Electric & Manufacturing Company for the 1924 installation. The turbine is to drive a 62,500-kva., 60-cycle, three-phase, 13,200-volt generator and will operate at 1,200 r.p.m. It is a single-cylinder unit, and in addition to the main generator it will be equipped with an auxiliary power generator of 2,000 kw., 2,500 kva., for auxiliary service at 60 cycles, three-phase, 2,400 volts. This auxiliary generator will be directly coupled to the main generator shaft, and a directly connected exciter will be on the end of the auxiliary generator shaft. The unit will have its best point of economy at 35,000 kw. and will have a peak-load capacity of 56,250 kw. A fairly flat performance curve between loads of 25,000 kw. and 56,250 kw. is guaranteed. The length of the entire unit with auxiliary generator and directly connected exciter will be approximately 77 ft. by about 22 ft. in width. This size permits the unit to fit nicely into the same space as is occupied by each of the present units. This unit represents the first 50,000-kw. single-cylinder unit which the Westinghouse company has contracted to make. Its design is of the impulse reaction type, consisting of one double Curtis wheel followed by the standard reaction intermediate blading and low-pressure blading of the so-called "Bauman" type, which permits the turbine to exhaust through one single-exhaust opening, there being three multiple passages through the Bauman blading to this single exhaust. It will be arranged for feed-water-heating purposes, the present plan being to provide for feed-water heating by four stage bleeding of the turbine, using the auxiliary generator to provide the necessary power incidental to the operation of the unit. It might also be noted that this is the first unit of this capacity to be equipped with a small generator on the main shaft for auxiliary power purposes.



HELL GATE AND SHERMAN CREEK STATIONS, SHOWING INTERIOR OF SHERMAN CREEK STATION

The present installation at Hell Gate consists of twelve 1,890-hp. Springfield boilers with no economizers but equipped with superheaters above the lower six rows of tubes. Under each boiler there are two fourteen-retort, seventeen-tuyère Taylor stokers discharging into a central ash pit. Although this installation is working satisfactorily, it was thought that further economies could be accomplished by a modification of it. Three new boilers have been purchased of the same general design but of 1,550 hp. each. Instead of being twenty tubes high they will be sixteen tubes high, with four rows instead of six below the drop leg. In addition to superheaters these boilers will be equipped with economizers. These are to be furnished by the Power Specialty Company. They are of the one-pass, counter-current design with elements 18 ft. long over rings and will have 13,824 sq.ft. of external heating surface. Each unit will be sixteen elements wide and fourteen rows high. The superheaters, instead of being placed in the original position, will be installed on the top of the first pass. Instead of a double stoker there will be a single fourteen-retort, thirty-three-tuyère Taylor stoker. These changes, of course, necessitate a different baffling arrangement.

The same method of disposing of ashes by a sluicing system will be maintained. On account of these boilers being fed from only one side it will not be necessary to purchase another coal lorry at this time.

An equipment of forced-draft and induced-draft fans similar to that of the original installation will be installed driven by B. T. S. General Electric motors. These motors have operated satisfactorily, and their purchase for this installation is economically sound.

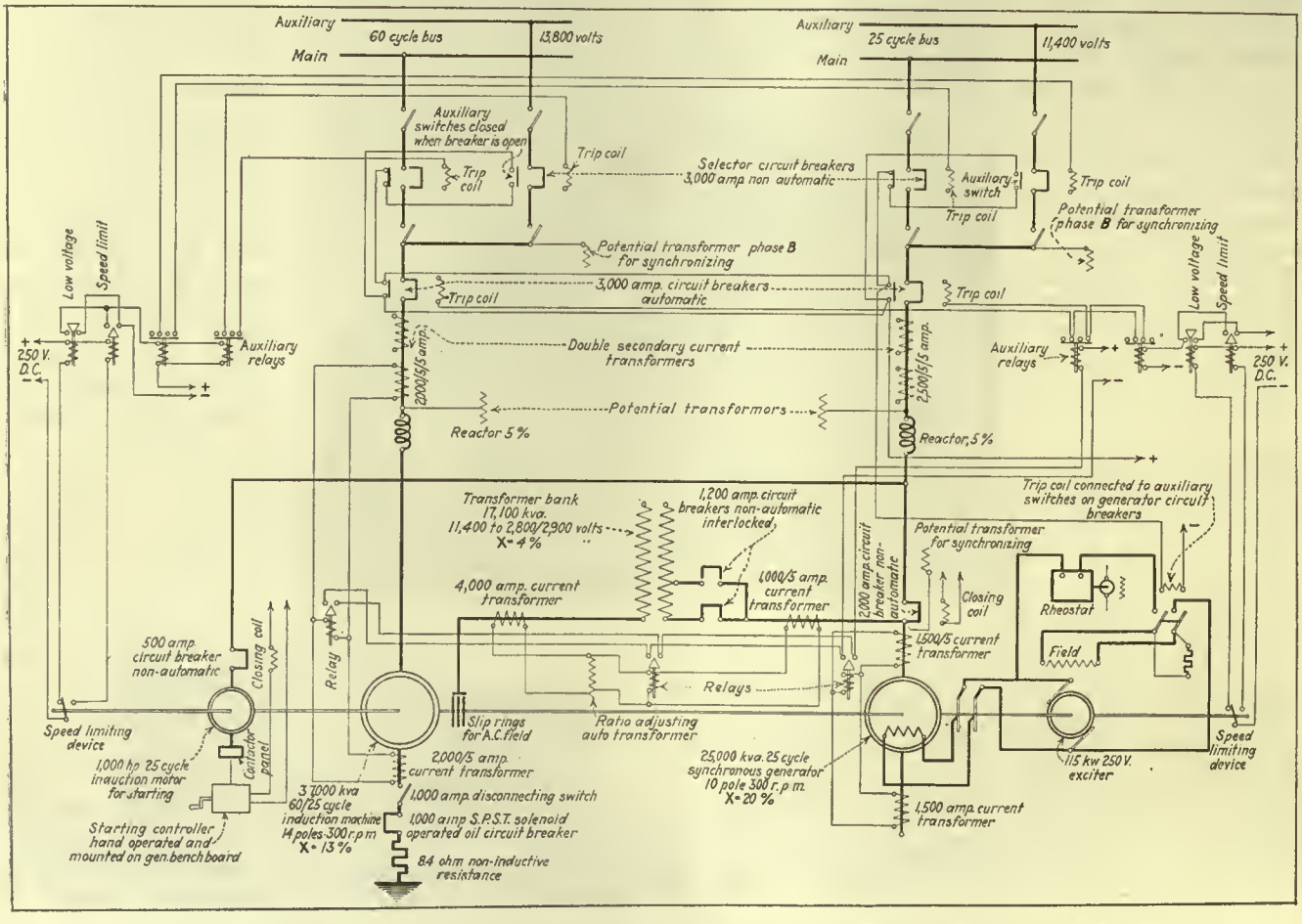
The present auxiliary power for the Hell Gate station is obtained from two banks of transformers fed from the main 60-cycle, 13,200-volt bus and stepping down to 2,300 volts, and from two 2,500-kva. turbo-generators generating at 2,300 volts. For the present year this will be sufficient. A further extension, however, is necessary to the truck switch installation. New switches have been purchased from the General Electric Company in sizes of 400, 1,200 and 2,000 amp.

An interesting addition to Hell Gate which is expected to be in operation during the coming fall is the installation of five 12,000-kva. oil-cooled outdoor-type transformers. These are the largest type of self-cooled transformers made. With their oil they weigh 42½ tons each, but in spite of this weight they will be shipped filled with oil to eliminate the drying out of coils after being received. They will be used to supply service to allied companies and will be installed at the extreme south end of the part of the property devoted to electrical galleries. They are delta-connected on the low-voltage side and star on the high and step up from 13,800 volts to 28,980 volts. They will have additional taps for approximate voltages of 27,600, 26,100, 24,700 and 23,000 for operation at full kilovolt-ampere capacity. They are of the core type with interleaved disk windings and will be equipped with conservators, ratio adjusters for the taps and temperature-indicating coils.

There will be installed for operation this year a 35,000-kw. induction synchronous-type frequency converter to be used for tying together the 25-cycle and the 60-cycle systems. Units of this type in large sizes have not previously been built, and its operation is looked forward to with interest. The set is to be furnished by the General Electric Company. It operates at 300 r.p.m. and consists of a 37,000-kva. wound-rotor induction motor having fourteen poles, a 13,800-volt, 60-cycle stator, and a 2,850-volt rotor wound for 25 cycles directly connected to a synchronous 25,000-kva., 25-cycle generator operating at 11,400 volts. On the same shaft are installed a six-pole, 115-kw., 250-volt exciter and a 1,600-hp., 11,400-volt, three-phase, 25-cycle starting motor. Between the slip rings of the main induction machine and the high-voltage 25-cycle bus is a 25-cycle, 17,100-kva. transformer stepping down from 11,400 volts to 2,850/2,950 volts.

The synchronous machine is a ten-pole generator having a synchronous speed of 300 r.p.m. The 60/25-cycle induction unit is wound for fourteen poles. At 60 cycles it would have a synchronous speed of 514 r.p.m. By holding the rotor speed down to 300 r.p.m. with the synchronous generator a slip of 214 r.p.m. is obtained in the induction machine, which gives 25 cycles at the collector rings of the rotor. The stator of the induction machine is connected to the 60-cycle line, and the rotor of the induction machine and the stator of the synchronous machine are both connected to the 25-cycle line. A transformer is required for connecting between the collector rings of the induction machine and the 25-cycle bus, because it is not practicable to build a high-voltage rotor for this machine, and this transformer also gives an opportunity for ratio adjustment for the control of current flow through the induction unit.

The induction machine will be excited from the 25-cycle side, the synchronous generator supplying this



LAYOUT FOR OPERATING A 35,000-KW. SYNCHRONOUS FREQUENCY CONVERTER USED TO TIE TOGETHER THE 25 AND 60 CYCLE SYSTEMS

excitation, so that the power factor on both the 25-cycle and the 60-cycle side of the set will be approximately unity, with full load on the set and power flowing in either direction. In order to provide this exciting kva. for the induction machine the synchronous generator is designed for 85 per cent power factor lagging load as a generator.

The induction machine furnishes an electromagnetic tie between the 25-cycle and the 60-cycle systems, similar to a transformer tie between the two parts of a system of one frequency. In other words, this machine forms a voltage tie between the systems in addition to being a power and frequency tie, and any variation or disturbance of voltage on one system will be transmitted to the other through this tie in a manner similar to that obtained through a transformer. The effectiveness of this voltage tie is dependent upon the reactance of the circuit through the induction machine between the two systems.

The flow of wattless current between the two systems may be controlled by adjusting the transformer ratio or by changing the bus voltage on either the 25-cycle or the 60-cycle system. For general operation these ratios will be adjusted to give unity power factor.

Phenomenal Growth in Brooklyn

Edison Company Erecting New Superpower Station, Changing Its Distribution System and Expanding Its Various Departments to Take Care of the Ever-Growing Demands

By M. S. SLOAN
President Brooklyn Edison Company, Inc.

THE progress of the Brooklyn Edison Company, Inc., has been rapid and consistent since the opening of the European War, and since the end of the war a large and steady average increase in business each year has been maintained. In 1922 this increasing business had reached a point where the company was justified in adopting a plan of expansion for the next five to ten years, conservatively predicated on past requirements, of a far greater scope than any previously contemplated in its history. A brief synopsis of this growth and the plan of expansion now in progress of execution is presented here.

The growth of the company's business is compactly shown in the tables, which cover the increases in customers, output, capacity, demand, gross revenue, domestic and industrial development.

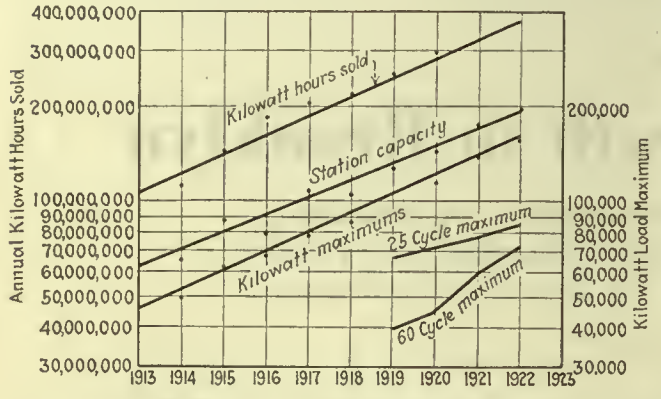
The diagram of output, maximum demand and capacity exhibited illustrates very clearly the basis of growth on which the present expansion is planned. The Brooklyn Edison Company, Inc., now has two generating stations in operation besides an interconnection with the plant of The United Electric Light & Power Company at Hell Gate in the Bronx. The largest of the two stations is on the East River at Gold Street; it has a capacity of 125,000 kw. of 25-cycle generators. The second station is at Sixty-sixth Street and New York Bay, having 65,000 kw. generating capacity at 62½ cycles. To meet the future requirements of capacity and economy, to standardize and simplify its type of service in phase and frequency, and further to decrease its cost of distribution and increase its efficiency, all tending to improve and lower its cost of general service, the company has financed and started a remarkably large and comprehensive program of construction and improvement, which when completed about the end of 1924 will have cost $23,000,000.

The basis of this development is the design and construction of what will be when completed the largest steam generating station in the world, at the foot of Hudson Avenue, Brooklyn, adjacent to the Brooklyn Navy Yard. This plant will be of 400,000 kw. to 500,000 kw. capacity, consisting of eight turbo-gen-

erators, three of which have been ordered. Each one of them will require a surface condenser of 70,000 sq.ft. cooling surface, supplied by two circulating pumps of 50,000 gal. each, or 100,000 gal. per minute total.

The station will be divided into four groups of two turbines each, each group being designed to be operated as a unit, the two turbines being served by eight boilers, each of 19,650 sq.ft. of heating surface, of which seven are required for normal operation of two units at maximum load, the eighth boiler being a spare.

The station is laid out on the most economical basis,



GROWTH OF THE BROOKLYN LOAD

the boiler room being adjacent to the waterfront, the turbine room next, and across a street the switch house, so that the least distance is required for handling coal and the most economical arrangement insured for transmitting the electric current from the generators to the switch house and thence to the transmission circuits.

The coal will be received in barges on the waterfront and hoisted by means of traveling towers on a coal trestle 112 ft. above the wharf, where it will be crushed and delivered to electric coal cars, which will be operated automatically and delivered to the bunkers over the boilers. From the bunkers the coal will be delivered by weighing lorries to hoppers of the individual stokers.

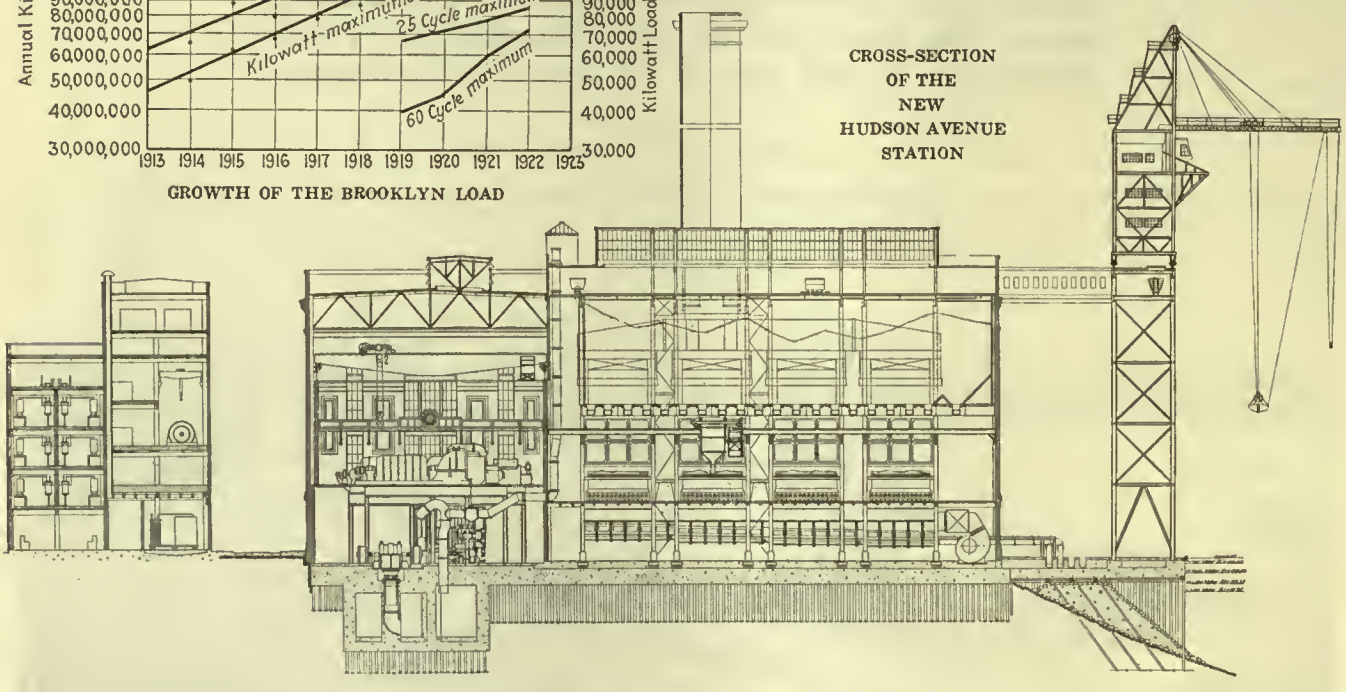
The bunkers will have a storage capacity of approximately 24,000 tons, which is six days' supply when full, based on normal steaming rate and the most economical load on the turbines. The ashes will be handled by means of hydraulic sluiceways under the ash pits of the boilers which lead to pipes under the surface of the wharf and thence to a pit on the dock, from which they will be dredged by locomotive crane into the ash scows and towed away to sea.

Steam will be received at the throttle of the turbo-generators at 265 lb. pressure, 200 deg. superheat. The electric current will be generated at 13,800 volts, stepped up to 27,600 volts in auto-transformers in the switch house and at this voltage transmitted to the 60-cycle substations of the company.

The turbo-generators have a guaranteed water rate of approximately 10 lb. per kilowatt-hour under the above conditions. It is confidently expected that the efficiency of this station will be approximately as follows:

	100,000 Kw., Full Load	75,000 Kw., Three-quarters Load	50,000 Kw Half Load
B.t.u. per kilowatt-hour	17,380	16,760	18,000
Total thermal efficiency, per cent	19.65	20.39	18.97
Lb. coal per kilowatt-hour	1.34	1.29	1.39
Lb. steam per kilowatt-hour	12.97	12.42	13.19

It will be noted from the foregoing that changes in the distribution system are also in progress. Originally the generation of energy by the Brooklyn Edison Company was two-phase at a frequency of.25 cycles. In 1912



CROSS-SECTION OF THE NEW HUDSON AVENUE STATION

about one-quarter of the energy was being distributed by alternating current, part directly at 25 cycles to large customers, and the rest at two-phase, 62½-cycle energy by means of a limited capacity in frequency changers. As the requirements and the refinements of the modern utilization of electricity have developed they have shown the desirability of three-phase and 60 cycles as the general characteristics of use, and in consequence, following the actual trend of the company's experience, an elaborate program has been adopted of changing to this phase arrangement and frequency. This program also includes a large extension of the alternating transmission system at much higher voltage than at present, for economic reasons as well as for those of physical limitations. It has proved desirable as well to change over certain portions of the low-tension direct-current distribution to alternating-current.

These changes are soundly predicated on the experience of the last ten years, during which the alternating distribution of energy increased from 25 to 45 per cent of the whole and during which the frequency-changer capacity increased from 18,500 kva. to 28,500 kva. of 62½ cycles, while 114,500 kva. of 62½-cycle substation transformers were also added.

Based broadly on these proved conditions and safely and conveniently to distribute through the streets of Brooklyn the greatly increased supply of energy from the new Hudson Avenue station, it has been necessary to increase the transmission voltage from 13,200 to 27,600, and the company is this year installing 80 miles of 350,000-circ.mil, 33,000-volt cable as an addition to its present 490 miles of transmission. The company's transmission cable in the past has always been conservatively rated, and studies now under way indicate that an appreciable portion of the existing cable installed for operation at 13,200 volts may, by rebuilding the joints, be safely operated at the new transmission voltage.

To utilize the output of Hudson Avenue station and to render available the higher transmission voltage, it has been necessary to purchase eighteen 10,000-kva. substation transformers, which will be installed during 1923. These transformers are of the oil-insulated, self-cooled type, as contrasted with the company's previous practice of using air-blast transformers of 5,500 kva. rating.

The rapid rate of growth of the company has now warranted a decision to change the distribution system from two-phase, 2,400 volts, to the almost universal standard three-phase, four-wire, 2,400-volt system, and accordingly two new substations now under construction are being developed as three-phase substations. Other substations in the process of reconstruction are being changed to three-phase, and during 1924 new substations and reconstructed old ones will be similarly changed to three-phase.

The relatively greater growth of the alternating-current territory has warranted the change in frequency from 62½ cycles to the standard 60 cycles. Both the change in frequency and the change in the number of phases will ultimately displace the present frequency changers from service, and the company is therefore installing this year a new 35,000-kva. frequency changer to interconnect the 25-cycle and 60-cycle systems. Provision has been made for the installation of a second such unit during 1924 or 1925 if occasion necessitates.

The pure economics of distribution, street congestion and the difficulty of obtaining adequate locations for direct-current substations have led to a policy of taking expansions within the direct-current district on the 60-cycle alternating-current service, and to this end a three-phase skeleton distribution network is being built throughout the direct-current territory. New business in the direct-current territory is now being taken on as alternating current, and during the year approximately 10,000 kva. of existing direct-current load will be transferred to the 60-cycle system. It should be noted that this change of direct-current to alternating-current customers is not being confined to the fringe of the substation territory but permeates the entire direct-current district. Only such customers are being changed as show a minimum cost of change-over, and the change-over, if extended in the future, will follow this general program. It is expected that some load on the premises of individual customers will remain on direct-current service for a number of years, even though the major load of the customer be transferred to alternating current.

The design, construction and extension program of 1923 is an extensive and arduous one and represents not so much fundamental change as an additional step in the maturing growth of the company. It has been the policy of the company to retain its existing standards and methods until modification should be clearly advisable and warranted and then to change in such manner as to give reasonable assurance of being in the line of development for some years to come. It is the expectation that the program for 1923 will give a large measure of flexibility and ease in making extensions and additions during the immediately succeeding years and that these extensions may be along lines standard not only with the Brooklyn Edison Company but in the industry as a whole.

In order to effect the many changes in the distribution system required in the program just described, marked developments have taken place in the application of mechanical appliances using air power for constructing

NEW OFFICE BUILDING OF THE BROOKLYN EDISON COMPANY TO HOUSE ALL DEPARTMENTS

services underground and in the use of trenching machines for the quick construction of duct excavations and the speedy repair of a street. All of these methods have shown not only a decreased unit cost but a decreased time of installation and better and quicker service.

This growth of the company and the expansion of its various departments to take care of this growth have rendered it necessary during the past few years to rent considerable space and to establish many of its offices outside the present main office building. To remedy this condition the construction of a general office building has been authorized, and this is now in process of erection at the corner of Willoughby and Pearl Streets.

This building will be twelve stories in height, giving approximately 150,000 sq.ft. of available area for office purposes, and will be ready for occupancy in the early fall of this year. At that time all the departments will be brought together under one roof with the exception of certain of those concerned with construction, stores and distribution functions, for which it is planned to

GROWTH OF BROOKLYN EDISON COMPANY, INC., 1918-1923

	Number or Amount 1918	Number or Amount 1922	Estimated Number or Amount Dec. 31, 1923	Change 1922 Over 1921		Change 1918 to 1923, 1923 Estimated	
				Number or Amount	Per Cent	Number or Amount	Per Cent
PROGRESS:							
Number of residential customers	58,663	197,513	251,172	49,543	33.5	192,509	328.2
Number of small atores and office customers	30,002	47,596	60,383	4,721	11.5	30,381	101.3
Number of wholesale customers	7,189	9,417	9,636	842	7.3	2,447	34.0
Total number of customers	95,854	254,526	321,191	55,106	46.6	225,337	235.1
Estimated number of families in Brooklyn (basis of five)	387,000	419,484	427,390	7,906	1.9	40,390	10.4
Residential customers as a per cent of number of families	15.2	47.1	58.8	11.1	....	43.6	.....
OUTPUT:							
Station output, kw.-hr.	282,424,822	493,006,436	570,000,000	75,077,073	18.0	287,575,178	101.8
Station capacity, kw.	104,750	189,500	*189,500	16,000	9.2	84,750	80.9
Maximum demand, kw.	86,000	164,495	188,681	26,695	19.4	102,681	119.4
Pounds of coal per kw.-hr.	2.5968	1.8854	1.8854	†0.2802	†12.9	†0.7114	†27.4
BUSINESS:							
Gross revenue	$8,854,302	$19,326,489	$23,000,000	$2,811,391	17.0	$14,145,689	159.7
Gross revenue per dollar of investment, cents	22	29	27	0	0	5	22.7
Kw.-hr. sold per capita of Brooklyn	113	181	210	23	14.5	97	85.8

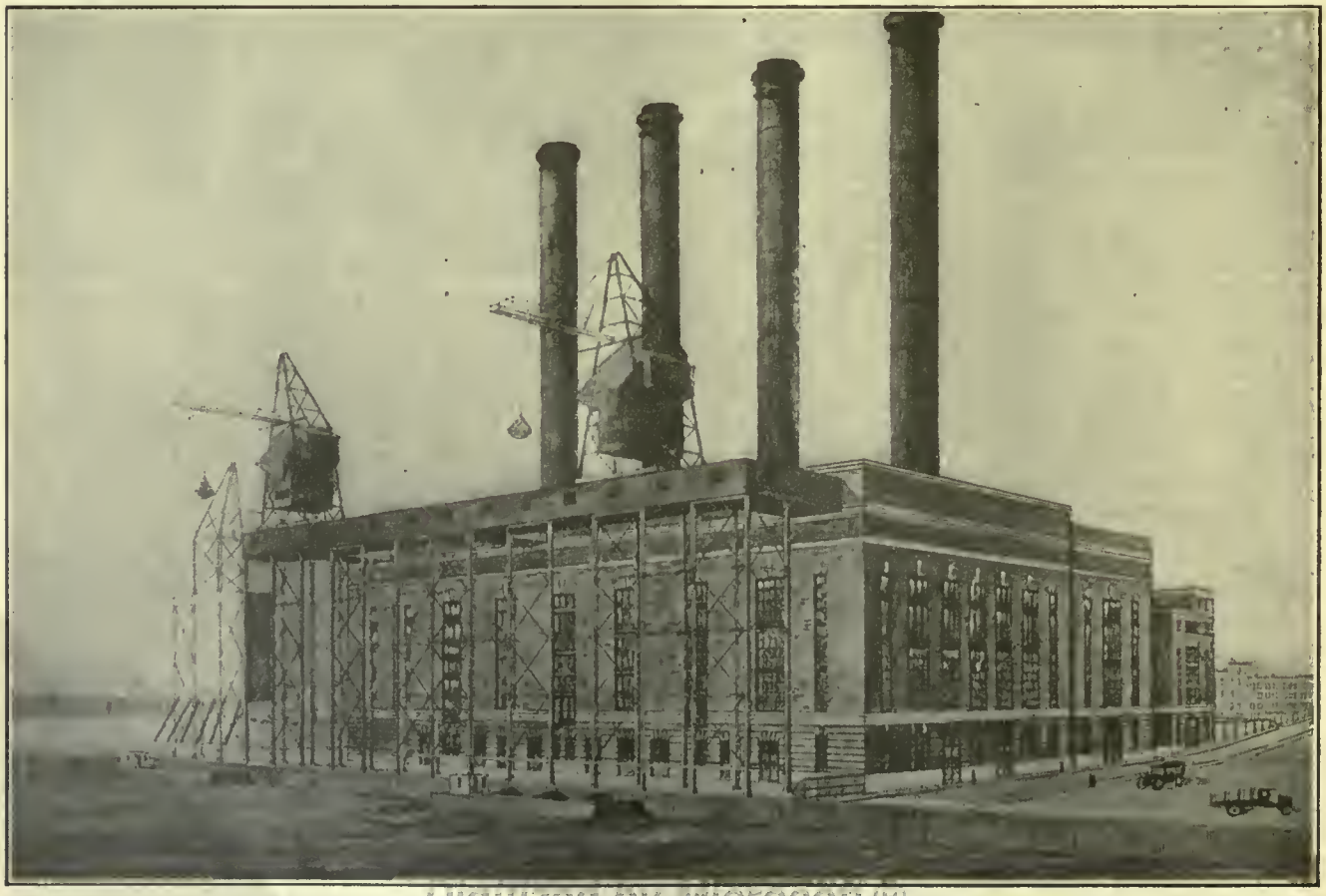
* Without Hudson Avenue. † Decrease.

erect a separate general service building at a convenient point in the near future. As the future growth of the company warrants, the general office building will be extended along Pearl Street as required.

Fuel oil will be used for generating the steam for heating the building. About 225,000 gal. of this oil will be used per year, and facilities for the storage of 35,000 gal. have been provided.

With all this increased and increasing business a strong and well-organized development is in operation for the continuous training and advantage of the company's personnel. These forces have increased from about two thousand in 1918 to nearly four thousand five hundred in 1923. The importance of surrounding this large number of individuals with proper conditions and opportunities is fully recognized, and the work is being carefully cultivated.

Within the past year a greatly improved educational training course has been established which has quadrupled the voluntary attendance as compared with previous years. This course, an employment division and a medical division are all in charge of the personnel bureau, which concerns itself entirely with the affairs of the employees in the company and their well-being. A medical examination is now required of all new employees, and free medical advice and regimen is open to all in the company. The employee and the job are studied with reference to each other, as well as the reward for excellence in the work, and an improved condition is beginning to show in the reduction of turnover. A self-governing club of the employees has been formed and is being developed by themselves with annual financial support from the company equal to what they raise by their own dues.

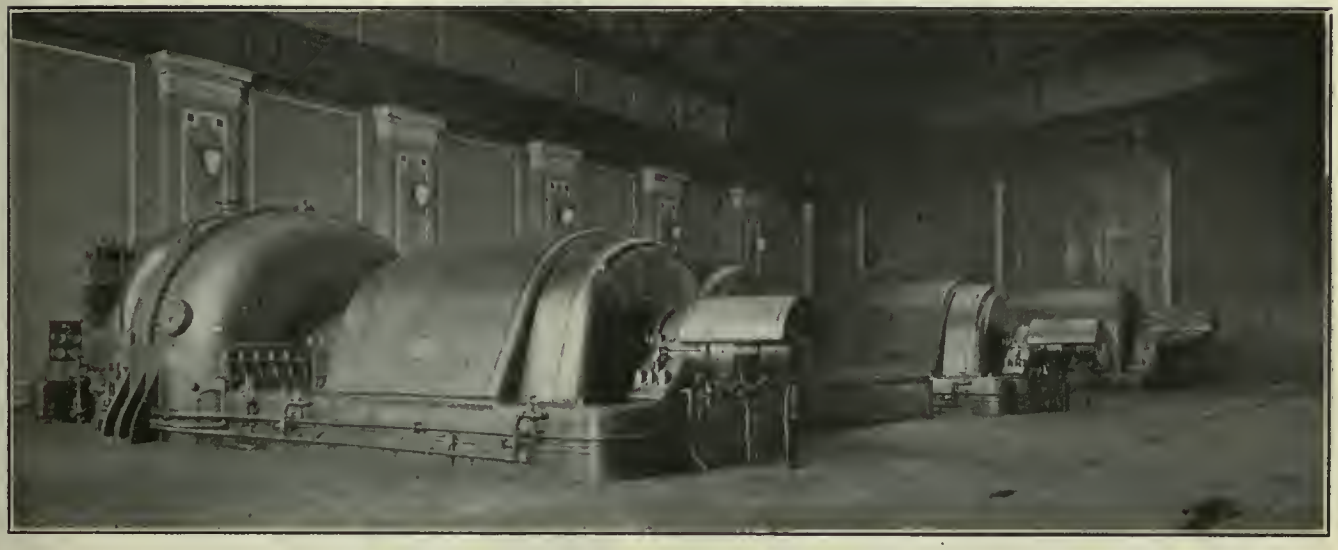


NEW HUDSON AVENUE GENERATING STATION AS IT WILL APPEAR WHEN COMPLETED

Diversified Service in New Jersey

Features of the Public Service Electric Company's System, Which Supplies Electricity to 202 Municipalities and Reaches the Large Industrial Centers Located Between New York and Philadelphia

By FARLEY OSGOOD
Vice-President and General Manager of the Public Service Electric Company



ESSEX STATION OF THE PUBLIC SERVICE ELECTRIC COMPANY

THE distinctive features that mark the operations of the Public Service Electric Company are, first, the wide extent of the territory served; second, the diversified characteristics of the communities within that territory, and, third, their rapid and continuing growth, both in population and industrially.

The area in which the company operates extends entirely across New Jersey, from the New York State line on the north to a point below Camden on the south and from the Hudson River and the waters adjoining New York Bay on the east to the Delaware River on the west. It embraces approximately 3,500 square miles, and electric service is supplied in twelve of the twenty-one counties of the state. In these counties live five out of every six of the state's inhabitants, while more than 90 per cent of the state's industrial activities are carried on therein. Probably no other electric utility in the nation serves so large a portion of the territory or of the population of the state in which it operates.

Two hundred and two different muncipalities, ranging in size from Newark, with more than 425,000 people, to communities of a few hundred, and including five cities with more than 100,000, five others with more than 50,000, ten others with more than 25,000, and sixteen others with more than 10,000, are supplied with light and power.

In their characteristics these communities are widely different. They range from great manufacturing centers, such as Newark, Jersey City, Paterson, Trenton, Perth Amboy and Camden, to purely residential towns of many classes, like Montclair, the Oranges and the hundreds of attractive suburbs in Bergen, Hudson, Essex and Union Counties in the northern section and in Burlington, Camden and Gloucester Counties to the south.

The social and industrial quality of the territory is to a large extent molded by its proximity to the great metropolitan cities of New York and Philadelphia. Sixty-six per cent of the total population served by Public Service live within 20 miles of the New York City Hall. Another 9 per cent live within 20 miles of the Philadelphia City Hall. Much of Public Service territory is within easier reach of the business center of New York than are many parts of New York itself.

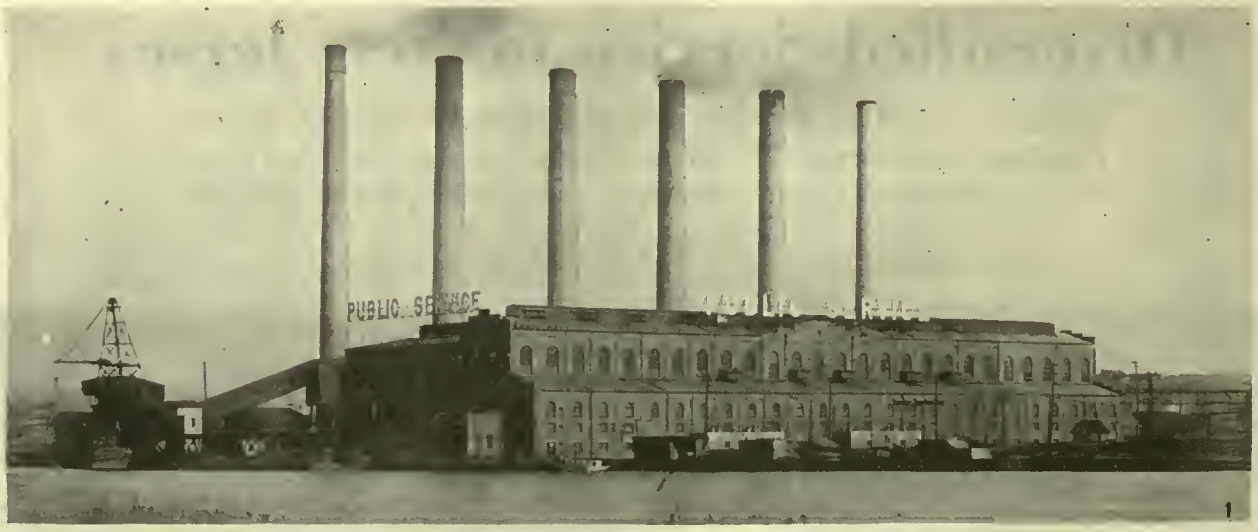
Nearly 75 per cent of the total population embraced in the twelve New Jersey counties served by the Public Service Electric Company live in six counties adjacent to New York City, although the combined area of the six is but 26 per cent of the total area served.

There is, then, in the northern part of the section of the state served by the company a territory about 20 miles in width, extending eastwardly from the banks of the Hudson and adjoining waters, with a high density of population; a territory extending 10 or 12 miles eastwardly from the Delaware with a lesser but still high density of population, and between them a territory of comparatively low density, and there is at the same time a concentration of industrial activities in these areas of dense population.

Astonishing Growth of Population

The growth of all this community has been, and still is, remarkable. For the last twenty years there has been an accretion of population in the twelve counties served by the Public Service company of nearly 60,000 a year, and during this period the rate of population increase has been greater than that of New York City and much greater than that of Philadelphia.

Marion and Essex Stations and Typical Branch Office and Substation



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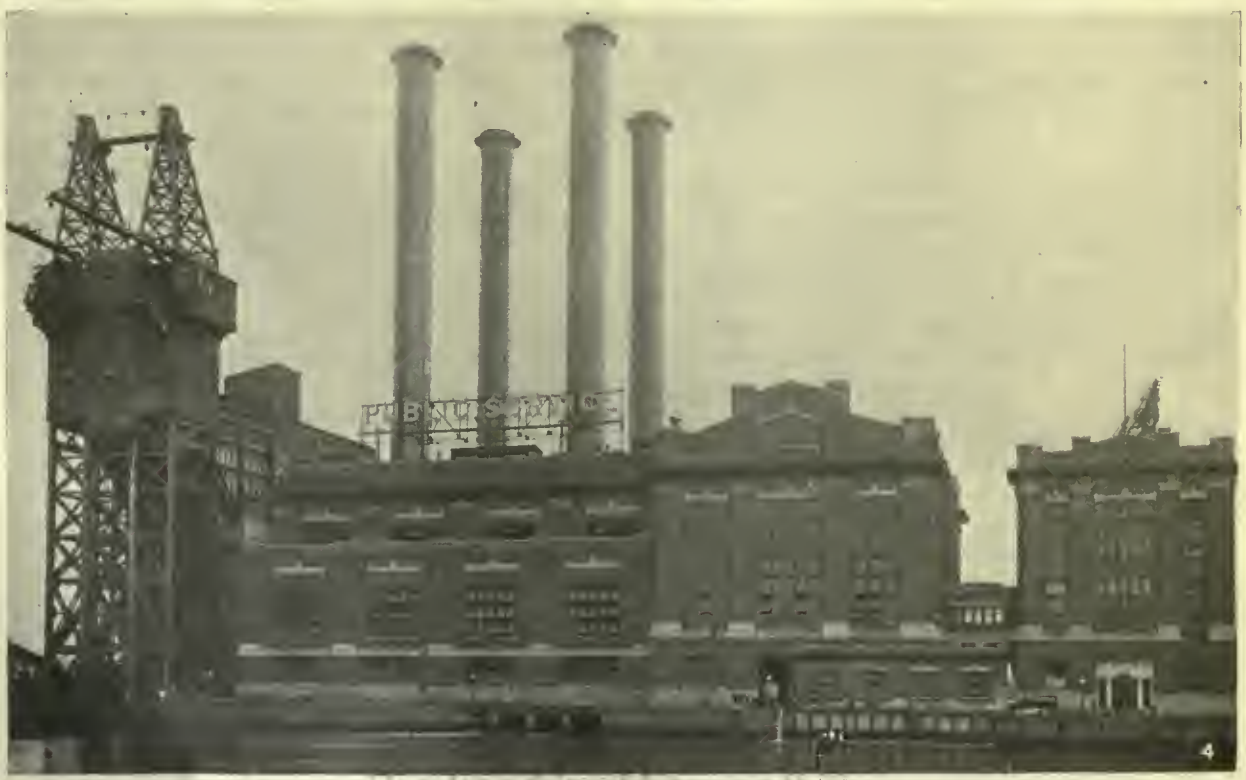

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There has been an equally astonishing growth in manufacture. From the standpoint of the central-station man, this may best be expressed in terms of primary horsepower used in industry. The United States industrial census shows that between 1904 and 1919—the latest census was taken in the latter year—there was for New Jersey an increase of 87 per cent in the horsepower of industrial prime movers, and for the electric generators included in this total an increase of 297 per cent.

This increase came in very large part from extension in the sale of electric station energy, since we find from the census figures that while electric horsepower generated by the user increased 180 per cent in the ten years, that purchased by the user increased 852 per cent, or at the ratio of more than four to one.

The picture of the industrial and population conditions which is presented in the foregoing paragraphs is essential to an understanding of the operations of the company itself.

Nearly a Billion Kilowatt-Hours a Year

In 1922 the company generated, to meet the light and power requirements, including those of the Public Service Railway Company, which operates a system embracing nearly 900 miles of track and which carried in 1922 some 410,000,000 passengers, 939,413,040 kw.-hr., with a load factor of approximately 44 per cent.

This total of nearly a billion kilowatt-hours was produced in fourteen generating stations. The conditions existing in the territory which has already been described indicate, in general, the distribution of load, and the general arrangement of both generation and distribution systems follows conditions of load.

The northern and central sections are very completely tied together, and energy generated in any of the stations in these sections can be distributed throughout the entire area. The southern section, extending from Princeton, near Trenton, to below Camden, is operated independently.

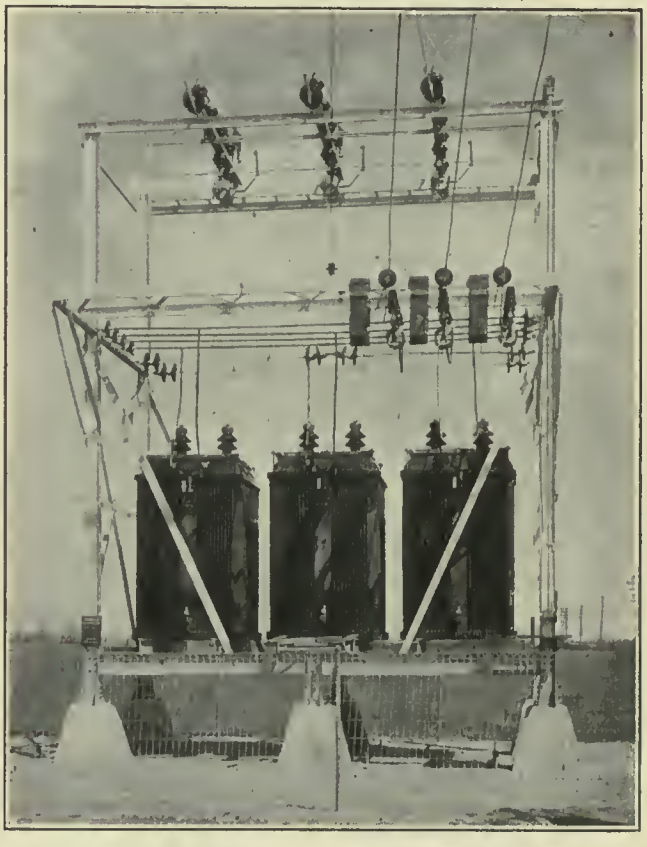
The total generating capacity of the fourteen stations is 290,900 kva., of which Essex station can furnish 85,000, Marion 90,500, Perth Amboy 22,500, and Burlington 37,500. Essex, Marion and Perth Amboy stations are in the northern and central sections. In addition, there are in this section stations of much less capacity and older design at Paterson, Secaucus, Edgewater, Hoboken, Crawford, Plainsboro, Red Bank and Newark.

The Burlington station is in the southern section and is reinforced by smaller stations at Trenton and Camden. To provide a further supply of energy when necessary, a tie with the lines of the Philadelphia Electric Company has recently been made at Camden.

The Essex station is the most modern of those operated by the company, and many of its engineering features are of interest. It is located at Point-No-Point on the Passaic River, about 2½ miles from the center of Newark, and contains at the present time one 35,000-kva. and two 25,000-kva. units, all operating at 13,200 volts, 60-cycle, three-phase.

The Passaic River at the point where this station is situated is of sufficient depth to permit coal and other material to be received by water. In addition, a spur from the Central Railroad of New Jersey provides for receipt of coal and supplies by rail. Coal received by water is handled by means of two towers erected on docks in front of the plant and capable of handling from barges 200 tons of coal per hour. Coal received by rail is handled by a system of horizontal and inclined belts and a skip hoist with a capacity of 90 tons an hour. Coal from both barges and cars is carried to bunkers at the top of the building adjacent to the boiler house. A bunker, of a capacity varying from 1,700 tons to 2,400 tons, is provided for each eight boilers. Each has a bottom dump, and coal is carried from bunker to boiler in weighing lorry cranes.

There are at present sixteen 1,370-hp. boilers, operating under forced and induced draft and equipped with modern underfeed stokers. Twelve of the sixteen are equipped with economizers. The entire switching equipment is of the remote-control type and with the bus layout is flexible enough to prevent interruptions to service as the result of switch or bus failures. An electrically operated load dispatcher's board indicates diagrammatically the exact load conditions in the system network of which Essex is a part and is of great value to the load dispatchers under the conditions of complicated and frequent operating changes that prevail.

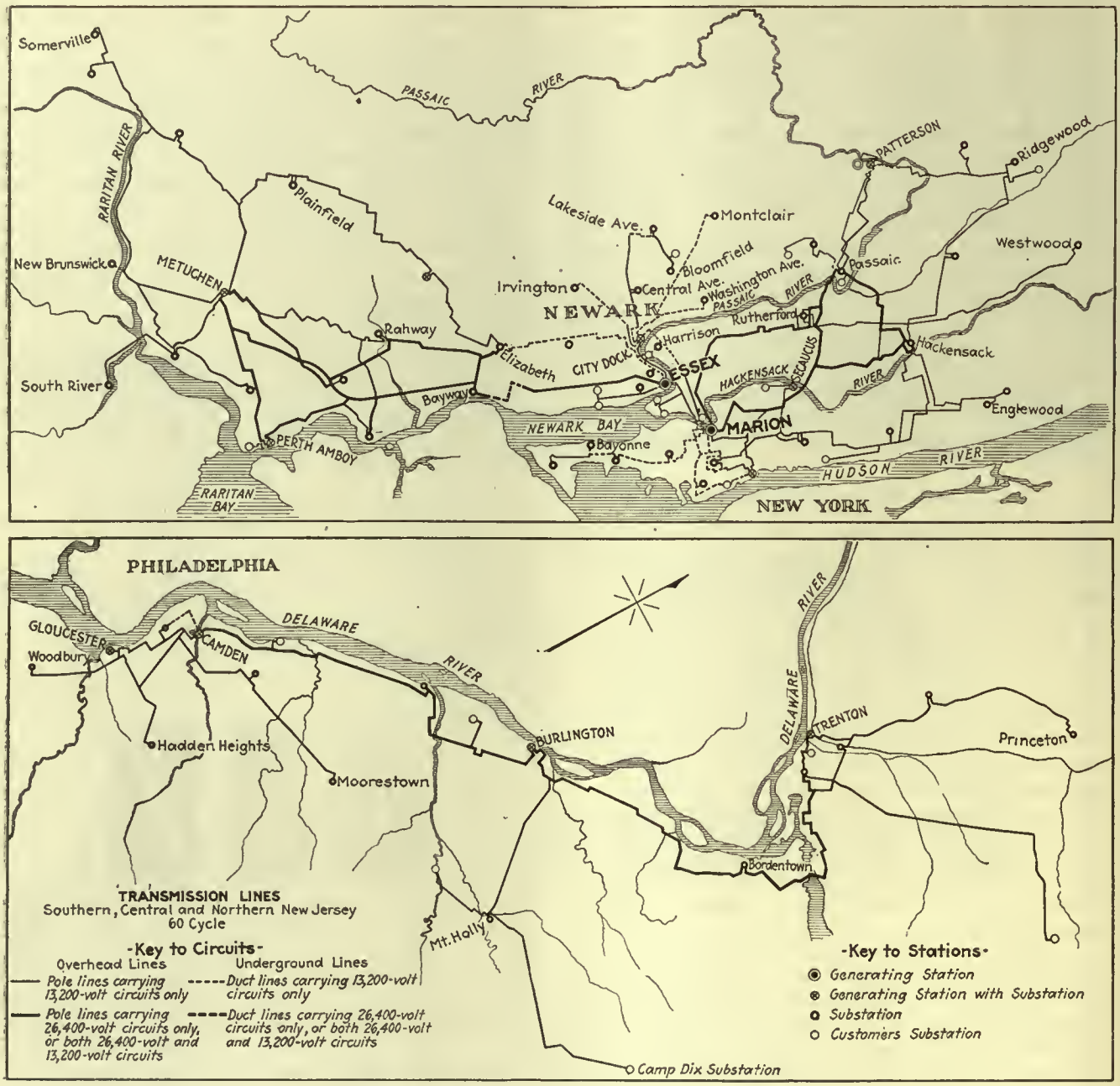


OUTDOOR SUBSTATION PUBLIC SERVICE ELECTRIC COMPANY

The architectural design of this station, both interior and exterior, is pleasing, the turbine room being a welcome departure from usual engine-room conditions.

Transmission from Essex station is, for near-by substations and plants of large consumers, at 13,200 volts. To more remote points it is, in order to cut down line losses, at 26,400 volts.

Extensions and improvements at the Essex station now under way will increase its capacity to 190,900 kva. An addition to the station is now being completed to house three 35,300-kva. turbo-generators, two of which will be in service during the summer of this year and the third in March, 1924. The boiler plant is at the same time being increased by eight 1,800-hp. boilers.



MAP OF TERRITORY SERVED BY PUBLIC SERVICE ELECTRIC COMPANY

The company has recently purchased twenty acres of land adjoining its station property, on which a high-tension substation is to be erected. This additional space will also be used to increase coal-storage capacity, a spur from the Pennsylvania Railroad permitting the use of the 600 coal cars now owned by the company for transportation of coal from the mines directly to the station.

The Marion station is built on the banks of the Hackensack River, on the outskirts of Jersey City. Its largest unit at the present time is a 20,000-kva. horizontal machine, constituting a part of the 60-cycle capacity. Of the station's total capacity of 90,500 kva., 28,000 kva. is furnished by 25-cycle generators furnishing energy for railway use.

The station's boiler plant consists of fifty 600-hp. boilers, thirty of which are equipped with Roney and twenty with underfeed stokers. Coal, from both barge and cars, is handled by means of a gantry crane and horizontal and inclined belt conveyors and by the use of this apparatus may be placed either in overhead bunkers or in storage under the crane.

Extensions and improvements at Marion now in process include the installation of a new 25,000-kva., 60-cycle turbo-generator, a 12,500-kva., 60-25-cycle frequency changer to be used in connection with the 25-cycle load, and a new switch house to take care of the increased number of feeders going out from the station.

The Perth Amboy station, on the Raritan River at Perth Amboy, has a generating capacity of 22,500 kva. in horizontal turbo-generators, with eight 600-hp. boilers fired with chain-grate stokers. Coal is received by water and by means of an unloading tower and an inclined belt conveyor is unloaded into overhead bunkers. The Perth Amboy and Essex stations are tied together by a 26,400-volt transmission line.

The Burlington station is at Burlington on the Delaware River, at about equal distance from Trenton and Camden. It has a capacity of 37,500 kva. in three

horizontal turbo-generators of 12,500 kva. capacity each. Its eight 600-hp. and two 1,500-hp. boilers are fired by underfeed stokers. Coal is received at this station by rail and handled by a skip hoist and inclined belts.

The 1922 peak load for the company's generating stations came in December, when 249,778 kw. was carried.

THE TRANSMISSION SYSTEM

The company's transmission system consists of approximately 957 miles of line, operating in part at 13,200 volts and in part at 26,400 volts, interconnecting the fourteen generating stations and the seventy substations of the company and supplying energy to such large customer installations as are fed directly from the generating stations. The seventy substations have a static transformer capacity of 572,875 kva. and a rotary converter capacity of 120,884 kw., exclusive of that of street-lighting transformers through which are fed 50,500 street lamps.

In the large cities a considerable length of underground cable, both 13,200-volt and 26,400-volt, is in use, while at many points in the transmission system where conditions do not warrant underground construction and where open wire-circuits cannot be used to advantage aërial cable, the cable being of the same type used underground, has been installed with exceptionally good results, interruptions to service having proved negligible.

The system's substations operate at 13,200 volts, and where it is necessary to step down energy from the 26,400-volt lines the company's practice is to install an outdoor type of substation. A typical station of this class is the Bayway substation in the factory district of Elizabethport. Here are installed two 3,750-kva. water-cooled units placed on concrete foundations immediately under the high-voltage buses. High-tension oil switches, aluminum-cell arresters and buses are all carried on steel framework set on concrete foundations out of doors.

In most cases the transformers step down the energy to 2,400 volts on the secondary side, automatic feed regulators, a switchboard, a 2,400-volt double bus and 2,400 electrically operated oil switches being housed indoors. In cases where it is desired to have the transmission transformers deliver energy to station and substation buses connected with incoming and outgoing feeders operating at 13,200 volts the transformation is at the ratio of two to one, giving a secondary voltage of 13,200. A large number of the substations are operated with a primary voltage of 13,200, stepped down to 2,400.

Until 1922 the company's standard of distribution was 2,400-volt, two-phase, four-wire service to customers being furnished at 2,400 volts, or through transformers at 220/110 volts, three-wire, except in the case of about twenty large users, supplied with three-phase service at 13,200 volts or 26,400 volts. In 1922, however, a new standard was adopted, and for a large part of the system a change was made to three-phase. four-wire, with 4,150 volts between phase wires and 2,400 volts to neutral wires, which are in all cases solidly grounded at the substation. The change involved much work, both in the substations and in installations of line transformers, but resulted in an increase of distribution line capacity of about one-half and a reduction in line loss of 67 per cent.

All of the company's three-phase and about 85 per cent of its single and two-phase circuits are equipped with automatic potential regulators, installed in substations, to assure adequate and uniform voltage to users.

A DECADE'S GROWTH IN DEMAND

Increase in demand has during the last ten years been little short of astounding. As was to be expected in a community of the character, war industries greatly increased industrial requirements both for power and light. Conditions following the war slackened in some degree the demand, which has, however, during the last sixteen months been renewed to a greater degree than ever before.

In 1910 the per capita consumption of energy for other than street-railway purposes in the territory amounted to 46.5 kw.-hr. per year, and the company had in service a meter for each 30.9 inhabitants. In 1922 per capita consumption was 205.2 and a meter was in service for each 7.5 inhabitants. In 1910 the kilowatt-hours sold, exclusive of energy generated for street-railway purposes, amounted to 89,742,689 and meters in service were 63,186. In 1922 kilowatt-hours sold amounted to 534,465,033 and meters in service to 344,309—a gain of 495 per cent in energy sold and of 445 per cent in number of meters in service. In the first four months of this year the gain in meters has broken all records for the same season of the year.

The development of the section of New Jersey served by the company is going on with increased momentum. Within a short time New York and New Jersey will be connected by a tunnel which will greatly increase ease of communication. A bridge to connect Philadelphia and Camden is under construction, and its completion will make the greater residential and industrial development of that portion of New Jersey surrounding Camden a certainty. The two states are now at work on the development of the port of New York, which lies largely within New Jersey waters. The port of Newark is already making a successful bid for increased business, while to further close the gap between New York and New Jersey projects for bridging the Hudson have gained substantial backing.

A survey of power requirements in the Public Service Electric Company's territory indicates for a number of years to come an increase in load demand upon the company of at least 30,000 kw. a year.

The company is laying its plans to keep pace with, or proceed a little in advance of, the needs of its territory. Within the last few months the Public Service Electric Power Company was organized by the Public Service Corporation of New Jersey, the parent company of the Public Service group of utilities, to construct and lease for 999 years to the Public Service Electric Company a new generating station with an initial capacity of 207,000 kva., to be enlarged within a comparatively few years to more than double this capacity. Within a short time construction work on this new plant will begin. The five units which will constitute the first installation will be two 45,000-kva. and three 39,000-kva. turbo-generators, all 13,200-volt, three-phase, 60-cycle.

The Public Service Electric Company feels that the industry is entering upon a phase of development in the use of electricity that is to be of stupendous importance both to the people of the country and to those within the industry itself, and that what is taking place in New Jersey is indicative of a general movement.