Electrical Equipments of the Columbus City and Interurban Railway Systems.

UNTIL July 1 of the present year the entire street railway system in the city of Columbus was operated by two independent companies, namely, the Columbus Railway & Light Company and the Central Market Street Railway Company. Since the date noted, however, the first-named company has been operating the Central Market system for the owners. The operating company owns about 300 cars of various designs and dimensions. With only a few exceptions each car is provided with two motors. There has recently been worked out an ingenious method for running the cars in trains in order to lessen the congestion on the principal streets, as well as to increase the carrying capacity in rush hours. The first car of each train is provided with a multiple-unit controller of the regular type employed for four motors. The wiring of this controller is identical with that of an ordinary four-motor equipment, with the exception that the leads for motors No. 3 and No. 4, instead of going to motors, are divided into a bus line extending the full length of the car and terminate in receptacles on each dash. On the rear car wires leading from the receptacle on the dashes are tapped in on the motor leads, and other than this addition no changes from the usual two-motor controller wiring is made. The chief advantage of the use of the two different kinds of controllers is that the extra expense of installing a multiple-unit controller on the rear car is avoided.

The Columbus Railway & Light Company has four distinct electric power services, namely, 550-580-volt, direct current for railway purposes, 115-230-volt direct current for Edison lighting system, 4,100-volt alternating current for lighting, and an independent insulated 550-volt power supply. The company owns four power houses, namely, Spring Street, known as Station No. 1; Gay Street, known as Station No. 2; Milo, known as Station No. 3, and a station formerly owned by the Central Market system, known as Station No. 4.

Most of the electricity for railway purposes is generated at Spring Street. Most of the electricity for lighting is generated at Gay Street. The generating apparatus at the Milo station is now held in reserve and is used only on peaks and in emergencies, a 500-kw National motor-generator set having been installed at this station for the purpose of taking current from the other stations and delivering direct current to the system in this district.

All of these stations are thoroughly tied together by alternating and direct-current tie lines, giving the greatest degree of flexibility and permitting of a number of combinations in the generation of electricity that assure economy and efficiency in the power supply and practically preclude the possibility of interruption to the railway, lighting or power service, through failure of lines or apparatus at any station.

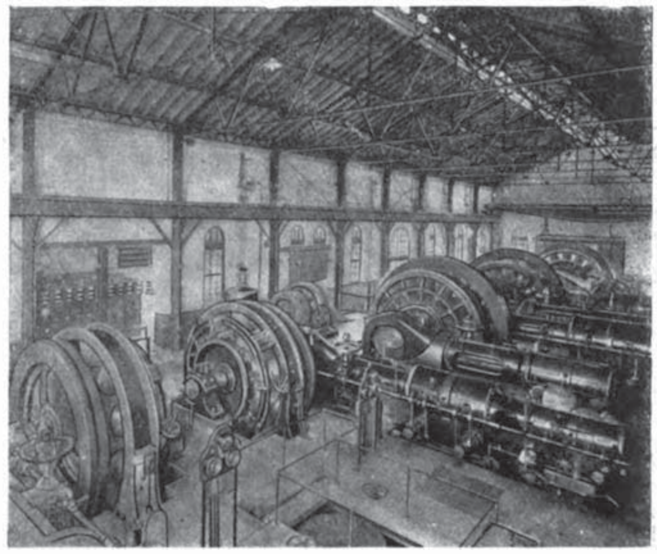

FIG. 2.—INTERIOR OF SPRINGFIELD STREET STATION OF COLUMBUS RAILWAY & LIGHT COMPANY.

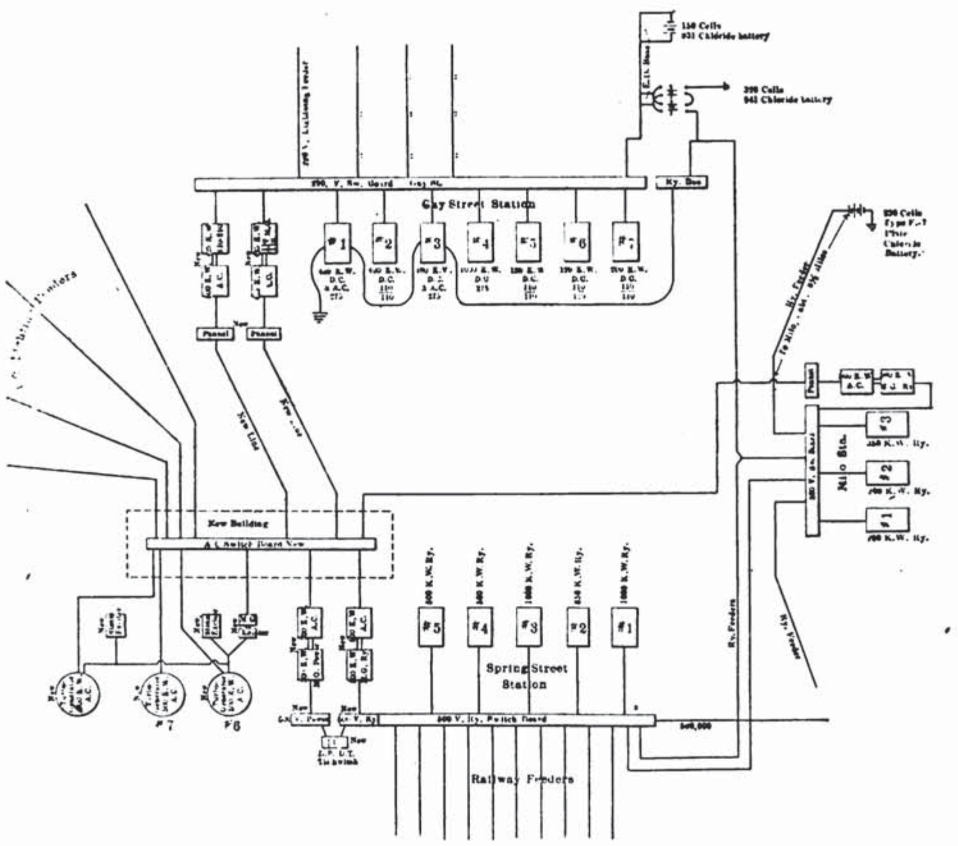

FIG. 1.—SCHEMATIC DIAGRAM OF STATION EQUIPMENTS OF COLUMBUS RAILWAY & LIGHT COMPANY.

As will be seen from the diagram of Fig. 1, the Spring Street station contains five railway units, two of which are 500-kw, two are 1,000-kw and one is a 840-kw unit. These machines handle the bulk of the railway load. There are also in this station two 500-kw Curtis turbo-generator sets which deliver alternating current at 4,100 volts. There is room for an additional 1,500-kw turbo-generator set. The high degree of flexibility previously referred to is greatly increased by the use of motor-generator sets in the various stations. In the Spring Street station there is one 500-kw General Electric motor-generator set and one 300-kw General Electric motor-generator set, which can be used either to deliver railway current to the railway feeders or alternating current to the lighting system, as conditions may require. There is also one 150-kw General Electric

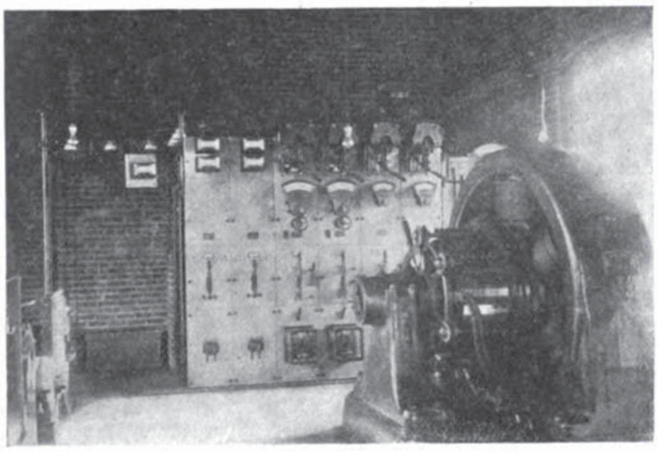

FIG. 3.—INTERIOR PLEASANT VALLEY SUB-STATION, COLUMBUS, NEWARK & ZANESVILLE.

booster set, which can be so connected as to boost through any feeder panel at this station. This booster is used chiefly on the park lines in summer. The railway units at this station are driven by Green-Wheelock engines.

The Gay Street station contains the following generating apparatus: Two 480-kw General Electric double-current machines, which can be used to deliver either direct or alternating current as required; one 400-kw General Electric 110-volt, direct-current machine and one 1,000-kw General Electric, 375-volt, direct-current machine for supplying electricity for the Edison lighting system. There are also three other units, two of them consisting of two 60-kw Edison bipolar machines and one consisting of two 100-kw Edison bipolar machines for use on the Edison system.

sets can, of course, be reversed so as to take direct current and deliver alternating current.

To further increase the flexibility and efficiency of the power supply there have been installed at the Gay Street station two storage batteries, one comprising a 320-cell "Chloride Accumu-

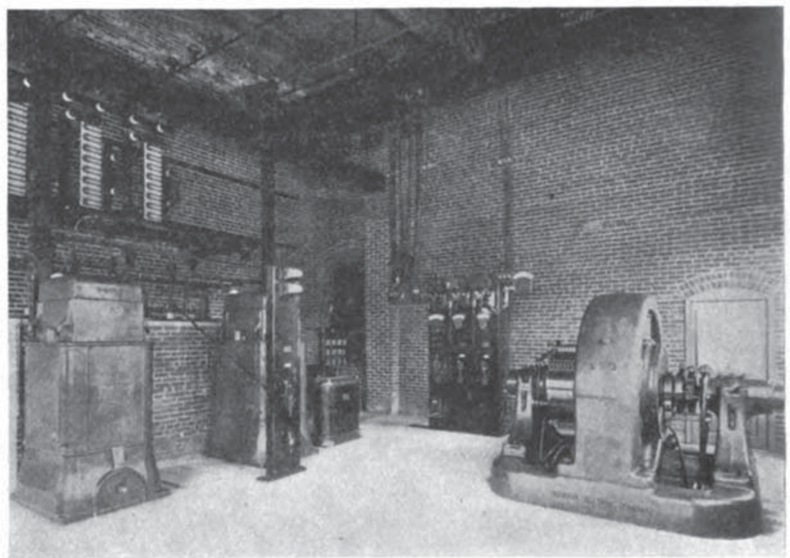

FIG. 5.—INTERIOR CHASELAND SUB-STATION, COLUMBUS, DELAWARE & MARION.

lator" battery, which may be used to deliver electrical energy at either 550 volts to the railway or 220 volts to the Edison lighting system. This is accomplished by operating the cells in series for railway work and in parallel sections for lighting. The battery in railway work has a capacity of 880 kw. There is also a smaller battery, consisting of 150 cells, used on the Edison lighting system and supplied by one 50-kw, two-unit motor-generator set. The possibilities that lie in this combination of direct-current and alternating-current generating apparatus, motor-generator sets and storage batteries in securing any kind of current required, smoothing out peaks, and, at the same time, maintaining a good load factor on all machines, will be very evident.

As stated, at the Milo station, the generating apparatus, which

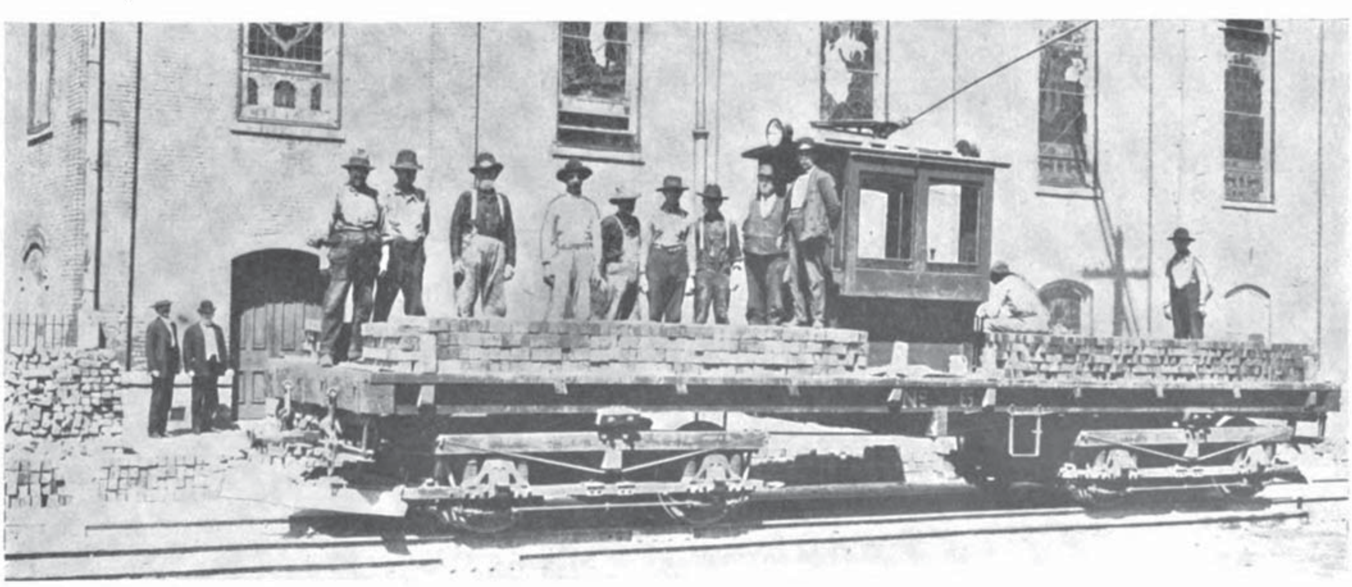

FIG. 4.—DELIVERING BRICK WITH RAIL CAR FOR PAVING BETWEEN TRACKS IN COLUMBUS.

In addition to the generating apparatus at this station there is one 500-kw, three-unit General Electric motor-generator set, the motor taking alternating current and driving the other two machines as generators, delivering 125-250 direct current to the Edison system. There is also one 500-kw General Electric two-unit motor-generator set, which is used in the same way. These

consists of two 200-kw and one 400-kw railway generators, is held in reserve, and the station is used principally as a sub-station, there having been installed a 500-kw motor-generator set supplied by the National Brake & Electric Company. This set is of the three-bearing type, and consists of a 750-hp, three-phase, 60-cycle synchronous motor receiving current at 4,100 volts and driving a 500-kw, direct-current generator, which generates current at 575 volts and 870 amp. This motor-generator set supplies the nearby territory and also feeds the line to Westerville. To improve the power situation on this Westerville line there is a 230-cell storage battery located about 8½ miles from Milo station, and which is used as a floating battery on the line.

The apparatus in the Central Market station consists of two 325-kw and one 250-kw Westinghouse railway generators. There is also at this station a 240-kw storage battery, which is fed from a motor booster set, and is used for taking care of load fluctuations at this power house.

In addition to the local electric railway system outlined above, which gives Columbus an unexcelled street railway service, eight electric railways radiate from the city in eight different directions, bringing it into intimate touch with the territory within

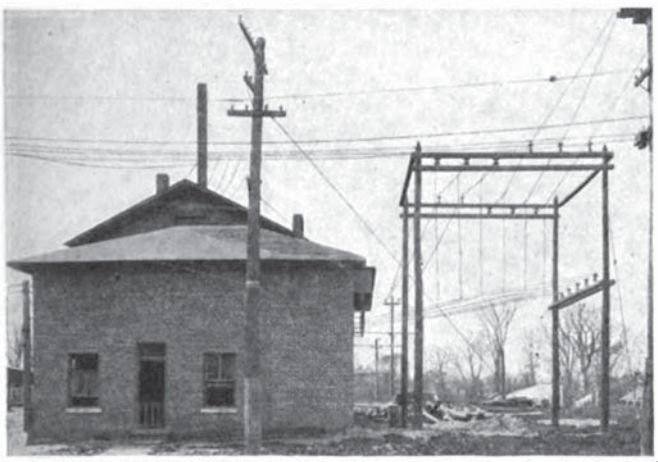

FIG. 6.—PROSPECT SUB-STATION, COLUMBUS, DELAWARE & MARION.

a distance of 75 miles, thereby rendering Columbus one of the principal interurban centers in the Central West.

Columbus is connected by through electric railway routes with Cincinnati and Indianapolis, and with only short links remaining to be built with Cleveland, Toledo, Detroit and Buffalo. The development of the interurban lines centering in Ohio's capital city has been so great that it is hard to realize the growth has taken place virtually within a period of four years. These lines give hourly passenger service, and are well built, well equipped

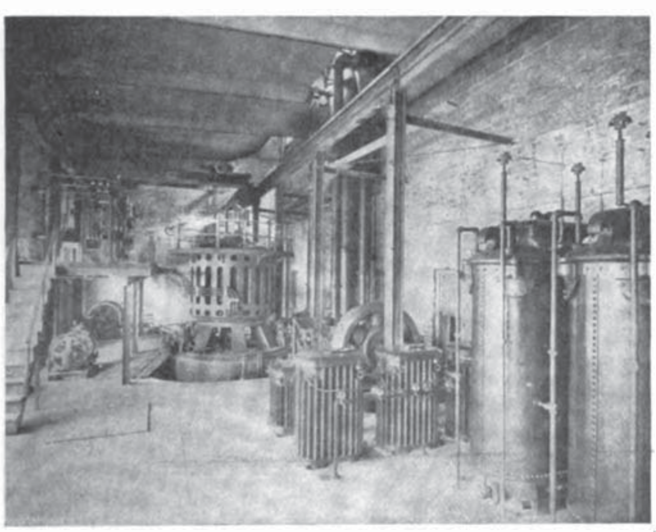

FIG. 7.—VERTICAL TURBINE IN STRATFORD STATION OF COLUMBUS, DELAWARE & MARION.

and well managed. In a multiplicity of ways this frequent and close connection between the country and the city has had an enormously stimulating influence upon the development not only of the capital city itself, but also of the country districts and towns as well. The early morning cars bring in many people employed in the commerce of the city, and the cars later in the day bring in retail and wholesale purchasers from all the surrounding country, while thousands of the city people use the interurban car in summer and in winter for pleasure and recreation, and as an important agency in their social life. Most of the lines maintain a freight and express service, bringing to the city the farm produce and products, and in exchange carrying to the farms and the country towns the manufactured articles and supplies furnished by the larger city.

The following are the interurban roads immediately centering in Columbus: Columbus, Delaware & Marion Railway Company; Scioto Valley Traction Company; Columbus, London & Springfield Railway Company; Columbus, Newark & Zanesville Electric Railway Company (controls the Columbus, Buckeye Lake & Newark Traction Company); Columbus, Grove

FIG. 8.—DOUBLE-TRACK CURVE, COLUMBUS, LONDON & SPRINGFIELD.

City & Southwestern Railway Company (operated by the Columbus, London & Springfield Railway Company); Columbus, Urbana & Western Railway Company; Columbus, New Albany & Johnstown Traction Company; Westerville and Arlington lines of the Columbus Railway & Light Company.

On each of the above-named roads four-motor equipments are employed exclusively. The 75-hp motor may be said to be the standard, although the Scioto Valley uses 100-hp motors. There is a decided tendency towards the adoption of multiple-unit

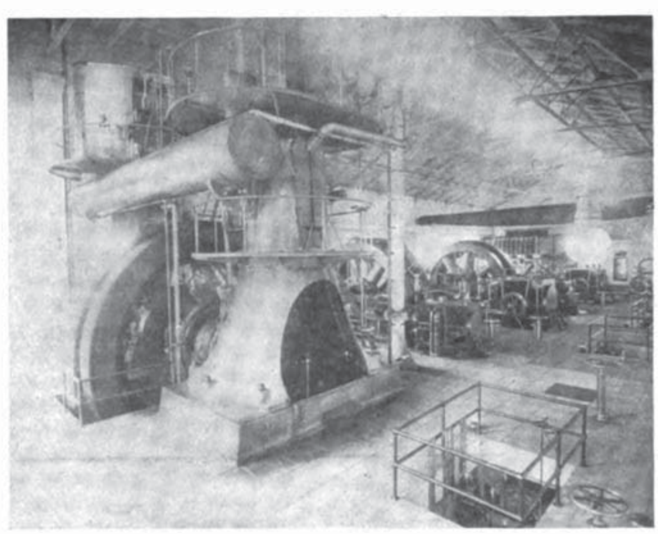

FIG. 9.—VERTICAL AND HORIZONTAL ENGINES IN HEBRON STATION OF COLUMBUS, NEWARK & ZANESVILLE.

controllers. In adopting these controllers probably the future operation of cars in trains has been considered, but evidently the avoidance of controller troubles has been the main consideration. The direct controller is generally conceded as being ill suited for controlling the larger types of motors. Flashing in the controller when the circuit is broken necessitates constant attention to the controller to keep it in operating condition. The

Scioto Valley, however, is using train operation in regular service on occasions of especially heavy traffic.

One of the large single generating stations connected with the above-named roads is that of the Scioto Valley Traction Company at Reese Station, where two 1,000-kw Bullock alternators, driven by Hamilton-Corliss engines, generate current at 375 volts, which electromotive force is raised to 27,000 for transmission to rotary converter sub-stations, which serve to feed direct current to the trolley line at 700 volts. The Columbus, Delaware & Marion Railway Company has a 2,000-kw Curtis turbo-generator now in service and is installing a second one.

The Scioto Valley system employs seven sub-stations between which the average distance is 10 miles, the longest transmission distance of the system being 41 miles. In these sub-stations there are used 18 150-kw Wagner oil-cooled transformers and six 150-kw General Electric oil-cooled transformers. The rotary converters are uniformly of 450 kw capacity, six being of the Bullock type and two of the General Electric type. The longest transmission by direct current in the Scioto Valley system is 12 miles.

Copper transmission lines are used by the great majority of roads, although considerable aluminum has been used during the past two or three years. The Scioto Valley Traction Company uses seven-strand aluminum of No. 2 capacity for its lines, and has obtained excellent results. One of the chief advantages found in aluminum is that sleet does not stick to it, in spite of the larger area of surface, and aluminum lines have gone through the most severe sleet storms without interruption while copper lines under similar conditions have broken down in many places. On the Scioto Valley transmission line 40-ft. poles are spaced 100 ft. apart, the cables being arranged in a triangle with 30-in. sides. The cables rest on 8-in. porcelain insulators, which are fastened on wooden pins. The circuits are transposed every two miles.

A recent study of the various transmission systems throughout Ohio has shown that the consolidation of interests and the grouping of systems which have been going on during the past two or three years have led to the abandonment of many of the smaller stations and the increasing of capacities of the larger ones, enabling electricity to be furnished over a number of connecting links from a single station. A few years back, when most of the interurban roads were promoted and built by separate groups of promoters, the practice was to build a separate power station for each road. Individual engineers followed their own ideas as to designs of stations and methods of generating and transmitting electricity, and the result of these numerous individual and disconnected efforts was that up to a year or two ago there were in Ohio a large number of comparatively small power stations, each supplying in its own way a single property regardless of conditions nearby.

Direct-current generation and transmission were used on the majority of the earlier lines, and as late as four or five years ago direct current was advocated and used on new roads of less than 30 to 35 miles. As a matter of fact, the direct-current scheme of transmission still has many advocates among the operators of the shorter lines, who, while they are paying somewhat more per kw-hour for electrical energy generated and have heavy investments in copper, which must some day be replaced, yet enjoy a comfortable feeling of security in times of high winds and severe storms, and they are inclined to view with sympathetic amusement the high-tension and sub-station troubles of their larger neighbors.

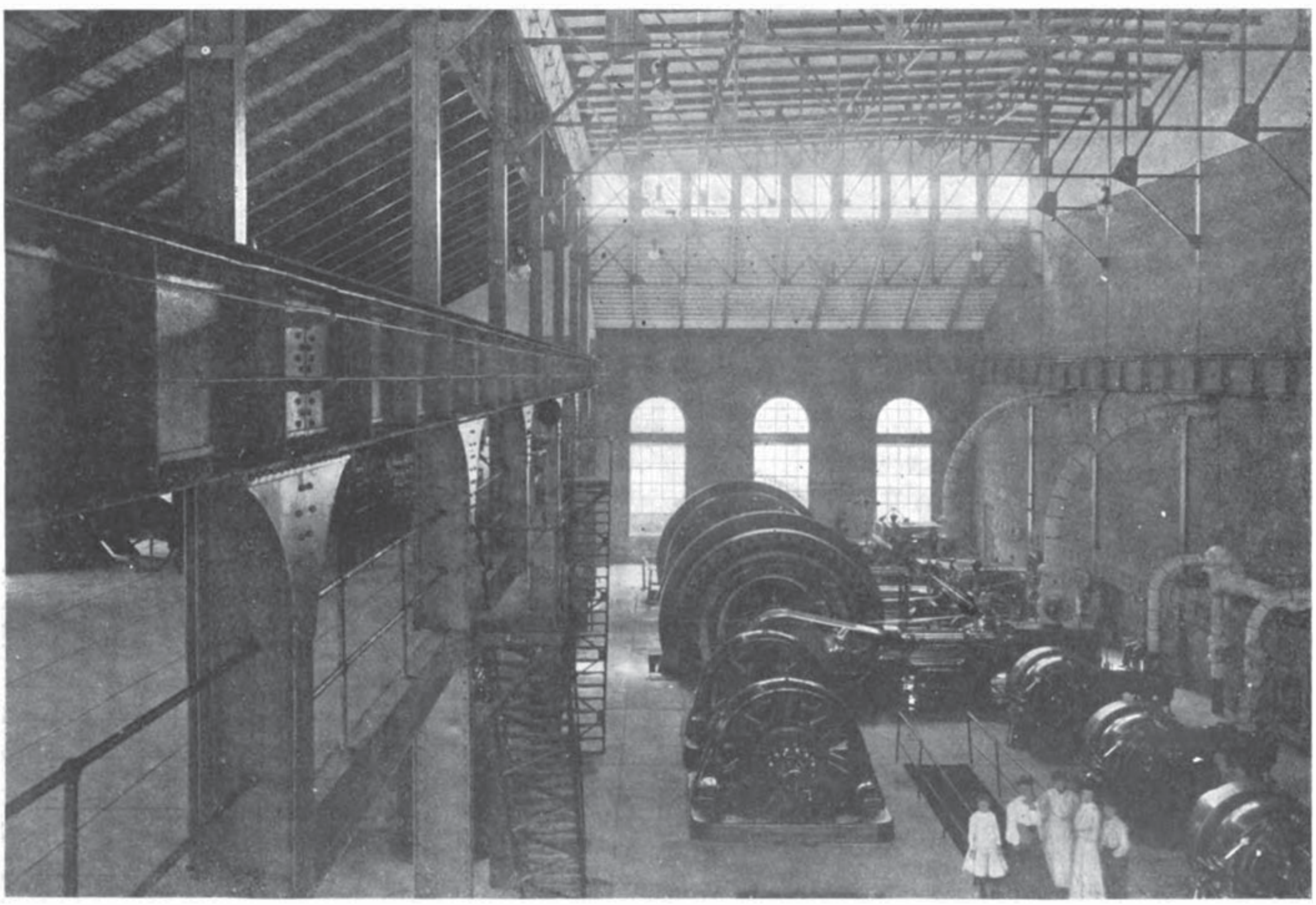

Fig. 10.—Interior Power Station, Scioto Valley Traction Company's Station at Reese.

Several of the earlier roads in Ohio using alternating-current transmission employed a potential of 10,000 to 13,000 volts, but later years have seen a growing tendency towards larger stations, larger units and higher voltages. Six years ago witnessed the building of the Toledo, Fremont & Norwalk Railway, now a part of the Lake Shore Electric Railways with a 2,000-kw station, 65 miles of road and 16,500 volts transmission. This was the most ambitious interurban project attempted in the district up to that time, and the layout represented the highest developments in the art. A little later came the Stark Electric and the Cleveland & Southwestern, with 22,000 volts and 24,000 volts transmission, respectively. Then came the Western Ohio with an 80-mile line, 3,300-kw station and 33,000-volt transmission lines. This high potential was looked upon with some skepticism at the time, but it has since been adopted by the Toledo Urban & Interurban, the Fort Wayne, Van Wert & Lima, Cincinnati Northern, Columbus, Delaware & Marion and the Cincinnati & Columbus.

The economy of the large plants and the advantages of centralization of power have become generally recognized and there are several small roads in the district that are buying their energy at a flat rate instead of producing it themselves. Thus, the Lake Shore Electric supplies the Sandusky, Norwalk & Mansfield; the Western Ohio supplies the Fort Wayne, Van Wert & Lima, and the Springfield, Troy & Piqua supplies the Springfield & Xenia and Springfield & South Charleston.

FIG. 11.—LINE ANCHORAGE AT POWER STATION, SCIOTO VALLEY.

The St. Mary's power station of the Western Ohio takes care of 177 miles of road. The Cleveland & Southwestern, with 135 miles of road, has a single station, and it is the intention to add 86 miles to its load. The Medway power station of the Indiana, Columbus & Eastern supplies about 165 miles, and a considerable mileage will be added to this. The Schoepf syndicate, in completing its system from Cincinnati to Toledo, plans to supply with three and possibly two stations, while its line from Indianapolis through Dayton and Columbus to Zanesville will eventually be taken care of by either two or three stations. In view of the centralization and consolidation plans now under way, it is quite possible that five years will see 3,000 miles of interurban roads in Ohio operated from ten and possibly fewer power stations where at present there are fifty interurban stations in the State.

Of seventeen large interurban roads in Ohio, three still use the direct-current system transmission. These three are among the smaller systems, and are independently owned and operated. One large road buys its energy while the others employ trans-

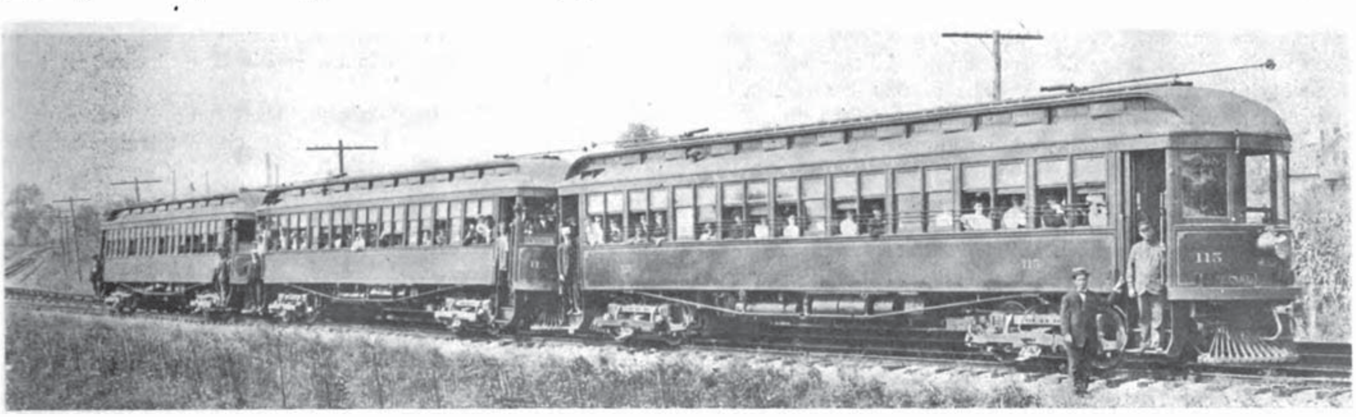

FIG. 12.—THREE-CAR TRAIN USED FOR HANDLING HEAVY TRAFFIC, SCIOTO VALLEY.

mission voltages ranging from 10,000 to 33,000 volts. Eight generate at low alternating voltage and step up to the desired transmission voltage. Five generate at the high voltage and transmit without the use of step-up transformers. A potential of 13,500 volts has been considered the maximum voltage at which electricity should be generated, but the Lake Shore Electric has one large unit generating at 16,500 volts. The roads using the higher voltages generate at a low voltage, usually about 400, and then step up. The longest transmission at this voltage is that of the Western Ohio, which transmits 95 miles from the station. The Lake Shore Electric supplies about 225 miles of road from its two stations. This line has a single stretch of 120 miles, and its stations, which are approximately the same size, are located at suitable distances from the ends of the line to distribute the loads between the two stations to best advantage. This company believes that two generating stations are better than one for a road of this length. The transmission lines are all tied in together and one station can assist the other in cases of emergency, even to the extent of handling the entire load

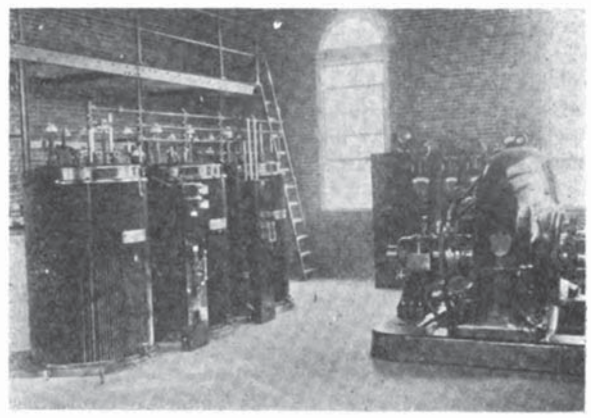

FIG. 13.—TYPICAL SUB-STATION, SCIOTO VALLEY.

if necessary. Of course, under normal conditions each station takes care of its half of the load, and the longest transmission is not more than 35 miles on the main line. The Western Ohio has its St. Mary's station practically in the center of its system, with lines radiating in four directions. The Cleveland & Southwestern station at Elyria is also well centered, transmission lines extending in three directions.

Sizes of units have increased with the growth of stations. In the earlier stations the 500-hp engine was looked upon as the most economical size. Later, in providing for additional equipments, many of the roads installed 1,000-hp units instead of two 500-hp, while in the new power houses on roads of 60 to 75 miles, two 1,000-hp units have been selected. New and additional equipments of more recent date have consisted of 1,250-hp engines in the cases of the Cincinnati & Columbus and the Toledo, Port Clinton & Lakeside, 1,500 hp for the Scioto Valley and 1,600-hp engines in the cases of the Lake Shore Electric and the Columbus, Buckeye Lake & Newark.

Steam turbines have been installed to some extent, and what are said to have been the first turbines used on electric roads were installed in Ohio. The first large installation of Westinghouse-Parsons turbines was that of the Cleveland & Southwestern, which has had two 1,250-kw units in use for more than three years. One of these turbines commenced operation December 20, 1903, and the other was started August 4, 1904. The station also has two large direct-current reciprocating units, which take steam from the same steam lines and supply to common bus-bars. Under average conditions the station generates electrical energy at about five and one-half mills per kw-hour. The two 1,250-kw turbines occupy one end of the engine room in the station while the other end is occupied by the two 500-kw reciprocating engines, and there is space in the turbine end for a third unit. The Canton-Akron Railway Company has a 2,000-kw Curtis turbine. The Northern Ohio Traction & Light Company has a 500-volt direct-current Curtis turbo-generator and is installing a large turbo-alternator. The Ohio Central Traction Company has a 150-kw DeLaval turbo-generator which has been in service for three years. The Lake Shore Electric Railway is installing a 2,000-kw Parsons turbine and is preparing to install an additional one.

It is interesting to note that the average rated capacity of the generating stations of the 17 interurban roads in Ohio is 24.1 kw per mile of track and 156.2 kw per car operated on an average schedule. Data on energy consumption also show interesting results. Thus by dividing the total station output for the year by the total car mileage it is found that the average for ten roads was exactly 3 kw-hours per car mile. The Western Ohio while operating at very high speed showed an energy consumption of 2.97 kw-hours per car-mile, showing the results of smaller motors than the average, and the advantage of liberal installations of feeders, bonding, sub-stations and general power conditions. The Scioto Valley, with ample power, plenty of feeders and good bonding, shows only 3.1 kw-hours per car-mile in spite of the use of 40-ton cars and 400 hp in motors to the car. Low grades and few stops also improve conditions for this road. The Dayton, Covington & Piqua, which had a low mark of 2.1, uses 35-hp motors, very light cars and its feeders and return circuits are ample.

Single-Phase Railway Equipment in Maryland.

The announcement that the Washington, Baltimore & Annapolis Railway has finally adopted the single-phase system and has placed contracts for the entire electrical equipment required for this line will attract considerable interest in engineering and railway circles, not only on account of the fact that this is one of the most important orders placed for alternating-current equipment in this country, but also because the original promoters of this line were the first to adopt the single-phase system. Some three years ago contracts were let for the construction of this line, but due to financial difficulties it was never built.

It will be interesting to compare the electrical equipment proposed at that time with the present equipment which has been ordered from the General Electric Company and which represents the latest practice in single-phase railway equipment. In the former plans for single-phase equipment between Baltimore and Washington it was proposed to use a trolley potential of 1,000 volts, current being delivered at this voltage at a frequency of 16⅔ cycles per second. The present contract calls for a trolley potential of 6,600 volts at a frequency of 25 cycles per second. On the cars a four-motor equipment was proposed, each motor having a capacity of 100 hp. The new car will be equipped with four motors arranged for either direct or alternating current, each motor having a capacity of 125 hp. While the first proposed motor equipments would have driven the cars at about 40 miles per hour, the new equipments, totaling 500 hp, will enable express trains on the road to attain a speed on tangent level track of 60 miles per hour.

The details of the new road have been carefully worked out by the Roberts & Abbot Engineering Company, of Cleveland, Ohio. Single-phase equipment was chosen only after the most careful engineering study had made it apparent that this system would prove most economical and best adapted to meet the special service conditions existing on this road.

Some 60 miles of road will be operated by the new company. The main line will be constructed between Baltimore and Washington, with a branch line, from a point on the main line near Odenton, extending to Annapolis. This station on the new line will be known as Academy Junction. Over the main line between Baltimore and Washington an express and local service will be established, express cars being operated under a fifteen-minute headway and making the run in 72 minutes. The road-bed will be double-tracked throughout, with sidings arranged at suitable intervals so that the locals may be sidetracked to enable the expresses to maintain schedules. The rolling stock equipment is to be very complete. Nineteen express cars, capable of making 60 miles per hour on a tangent level track, will be operated. In addition two work cars will be equipped, each sufficiently powerful to haul a train of five ordinary passenger coaches at 45 miles per hour, while four lower powered cars will be used for local service. These last-mentioned cars will run at a speed of 45 miles per hour. The express and work cars will each be equipped with four GEA-603 alternating-current-direct-current motor equipments with the Sprague-General Electric type M train control. The local cars will be similarly controlled, but will be driven by two instead of four motors.

Electrical energy for the new road will be purchased from the Potomac Electric Company at Washington, D. C., and will be delivered by that company at 6,600 volts, three-phase to a transformer sub-station located about three miles from Chesapeake Junction. In order to obtain a balanced load on the three-phase generators, the current as received at the sub-station will be changed from three-phase to two-phase by groups of two transformers connected three-phase on the 6,600-volt primary side and two-phase on the secondary side. Half of the transformers will have the secondaries wound for 6,600 volts and the other half for 33,000 volts. The 6,600-volt windings will all be connected in parallel on the same phase supplying single-phase current to the trolley as far as Academy Junction. The 33,000-volt secondary windings will all be connected in multiple on the second phase to the 33,000 volt transmission line, which will supply current to a step-down sub-station located at Academy Junction. The Chesapeake Junction sub-station will contain seven 800-kw water-cooled transformers, three with 33,000-volt secondaries and four with 6,600-volt secondaries, one of the latter transformers forming a reserve.

The sub-station at Academy Junction will be located adjacent to the car barns. For greater safety in inspecting and handling the cars all of the trolley circuits in the car barn will be arranged for 600-volt direct current, and for this purpose two 300-kw motor-generator sets will be installed in the transformer sub-station, changing the 6,600-volt alternating current to 600 volts direct current. The motor end of these motor-generator sets will be connected direct to the trolley circuits, one phase being led from the trolley coming from Chesapeake Junction and the other from the Academy Junction transformers. A feeder regulator will be placed in one phase so that the motor-generator sets will act as balancers, permitting the Academy Junction transformers connected on phase B to feed into the trolley line supplied by the Chesapeake Junction transpormers on phase "A." In addition to acting as balancers and to supplying current to the cars in the barns, the motor-generator sets will also supply direct current to the motors in the repair shops located at this point.

Government regulations within the District of Columbia prohibit the use of the track return so that within this section, the cars will be operated with a double trolley. This portion of the tracks, as well as that within the city of Baltimore, is at present operated by direct current, and the new cars are designed to operate on direct current over these sections of the line.

The present Washington, Baltimore & Annapolis Railway Company, which is constructing the line, is quite distinct from the initial corporation. The new company, under the head of its president, Mr. Geo. C. Bishop, has considerably broadened the former plans, land has been purchased for a wider right-of-way along the route, and new bridges are being built so that the road-bed will be excellent. The engineering work is in charge of the Roberts & Abbot Engineering Company, of Cleveland, Ohio, and contracts have been placed with the General Electric Company for the complete electrical equipment. The construction and operation of this road will be watched with great interest, as it is one of the largest and most important installations of the single-phase railway system ever undertaken.