Electrification

of the

ST. CLAIR TUNNEL

Grand Trunk Railway System

ELECTRIFICATION

of the

ST. CLAIR TUNNEL

An Illustrated Technical Description

by

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FOREWORD

THE question of the electrification of the St. Clair Tunnel has been under consideration by the Grand Trunk Railway officials for some years, and various plans for its accomplishment were submitted from time to time. During the analysis of these plans a conference was held between Messrs. C. M. Hays, Second Vice-President; E. H. Fitzhugh, Third Vice-President, and Mr. Bion J. Arnold, which conference resulted in the work being referred by Mr. Fitzhugh to Mr. Arnold for a report. This report, covering the general question of electrification, was submitted. It contained detailed estimates of cost of installation and operation of the various systems that might be used in connection with the work. The report was accepted by Mr. Fitzhugh, and Mr. Arnold was commissioned to prepare specifications for the equipment. The specifications stipulated, in addition to various guarantees regarding efficiencies of different parts of the system, and of the system as a whole, that the installation when completed should be capable of hauling a 1,000-ton train through the tunnel, from terminal to terminal, in 15 minutes, and that in so doing the maximum speed should not exceed 25 miles per hour, and the minimum speed, when ascending a 2 per cent grade, should not be less than 10 miles per hour. Tenders were submitted by the companies, that were prepared to undertake the work as specified, and after careful analysis the decision was made to adopt the single-phase alternating current system, using an overhead working conductor, this being the first decision providing for the application of the single-phase system to heavy steam road service. The contract was awarded some months later to the Westinghouse Electric & Manufacturing Company and provided that it be responsible for the installation and successful operation of the entire equipment. The equipment has been in continuous operation since May 17, 1908, handling the entire train service of the St. Clair Tunnel Company, this service being the heaviest railway service handled by electricity in the world.

TECHNICAL DATA

ELECTRIFICATION OF THE ST. CLAIR TUNNEL.

General:

Length of zone electrified, approximately (miles)	4
Length of single track, approximately (miles)	12
Length of tunnel (feet)	6,032
Maximum grade(per cent)	2
Normal weight of train (tons)	1,000

Locomotives:

Number of units per locomotive	2
Number of complete locomotives	3
Weight of complete locomotives (tons)	135
Normal motor capacity (h.p.)	1,500
Normal drawbar pull (pounds)	50,000
Maximum speed (miles per hour)	35
Minimum speed, up 2% grade with 1,000-ton train (miles pr hr)	10

Pumping Stations:

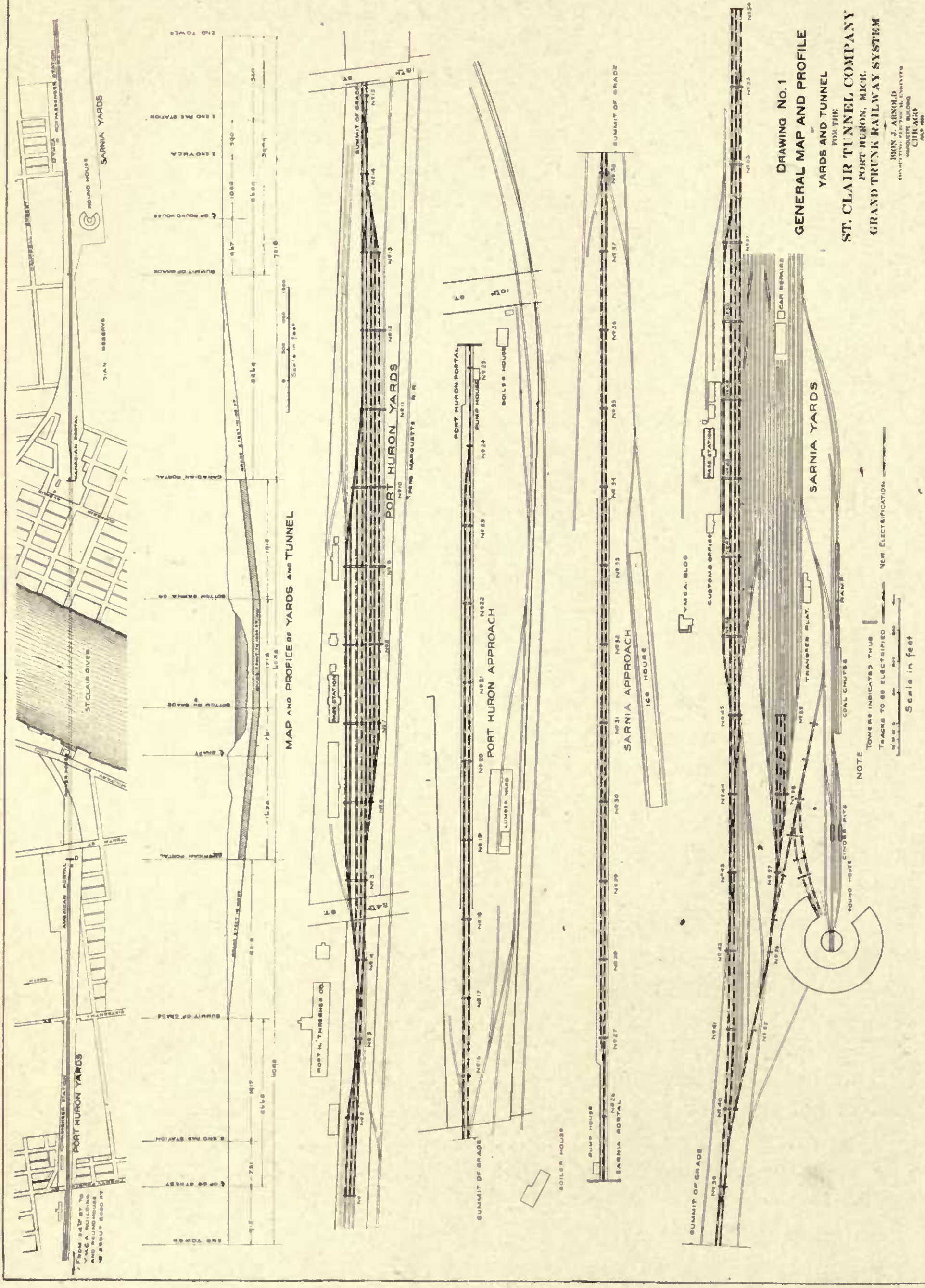
Location—	Sarnia.	Port Huron.
Number of pumping units	2	2
Capacity of units (gal. per min.)	5,500	4,000
Capacity of driving motors (h.p.)	200	100
Voltage of motors (volts)	3,300	3,300

Electrical Distribution System:

System adopted	Single phase.
Type of construction	Single catenary, supported by structural steel bridges.
Normal voltage (volts)	3,300

Power Plant:

Number of turbo-generators	2
Normal capacity of each generator (kw.)	1,250
Generator voltage (volts)	3,300
Generator frequency (cycles per sec.)	25
Generator speed (r. p. m.)	1,500
Number of boilers	4
Nominal capacity of each boiler (h.p.)	400
Capacity of coal bunkers (tons)	750
Capacity of hand-power crane (tons)	15



MAP OF YARDS AND PROFILE OF TUNNEL AND APPROACHES.

I—*The Tunnel*

The St. Clair Tunnel was opened for traffic in 1890 by the St. Clair Tunnel Company, organized as a subsidiary company to the Grand Trunk Railway System. The tunnel, located under the St. Clair River, is the connecting link between the terminal of the Western Division at Port Huron, Michigan, and the terminal of the Eastern Division at Sarnia, Ontario. The length of the tunnel from portal to portal is 6,032 feet. The open tunnel approaches are of considerable magnitude, that on the Port Huron side being slightly over 2,500 feet in length, while that on the Sarnia side is nearly 3,300 feet in length, the total distance between the American and the Canadian summits being 12,000 feet, or about 2¼ miles. The grade on the tunnel approaches and the inclined sections of the tunnel is 2 per cent, while the flat middle section of the tunnel, about 1,700 feet in length, has a grade of 0.1 per cent downward toward the east, just enough to provide for the proper drainage of any seepage water.

A single track extends through the tunnel, while a double track is laid in both of the tunnel approaches. The necessary tracks for handling the freight and passenger traffic are provided in the yards at Port Huron and Sarnia. The map and profile of the zone operated by the St. Clair Tunnel Company is shown in an accompanying illustration. The tracks in the yards and on the tunnel approaches are shown to a large scale in the same drawing.

The tunnel shell consists of cast iron rings built up in sections, the inside diameter being about 19 feet. The hydraulic shield was used in advancing the bore from each of the tunnel portals, by which means the

SARNIA APPROACH TO TUNNEL.

entire work of construction was carried on with reasonable expedition. A vertical shaft was sunk near the bank of the river on both the American and Canadian sides.

The disposal of the rainfall on the tunnel approaches required particular attention. The areas of the Port Huron and Sarnia approaches are approximately 11 and 13 acres respectively. Water precipitated on these areas during a rainfall is discharged into waste ditches on the bank above by means of pumps of large capacity. Retaining levees have been constructed, so arranged as to impound a large proportion of the water falling on the approaches. By this method the pumps have to handle only the water falling on the central portion of the approach during the rainstorm. Later the impounded water is discharged into the pump sump by valves provided for the purpose.

As is evident, this pumping service is of great importance in the operation of the tunnel, as, should the tunnel become flooded with water, entire interruption of the traffic would ensue. For the operation of the steam drainage pumps, boiler plants were provided at each portal, and attendants were constantly on duty, it being necessary to keep up steam during a large part of the year in order to take care at a moment's notice of any rainfall that might occur.

Four steam locomotives of special design had been in commission since the construction of the tunnel for handling the freight and passenger traffic. They were designed to provide the necessary high tractive effort required to operate the trains over the grades in the tunnel and on the approaches, and arranged to burn anthracite coal, in order to minimize the inconvenience due to excessive smoke in the tunnel. These locomotives have given good account of themselves, and have handled the traffic in a satisfactory way throughout their service. Their maximum tractive effort limited the weight of the trains handled to about 760 tons, and even with this load the speed up the 2 per cent grade was often very slow. With the constantly increasing traffic, at times the capacity of the tunnel with its steam equipment was taxed in handling the tonnage delivered to the Tunnel Company by the adjacent divisions of the Grand Trunk Railway System, and it was thought desirable to make such changes in the operation of the tunnel as would increase its possible capacity for handling traffic, and at the same time obviate the danger and inconvenience due to the presence of the locomotive gases in the tunnel.

II—Proposed Systems for Increasing Capacity

The advantage of the use of electric locomotives, on account of the freedom from smoke and the attendant discomfort, together with the possible greater economy in operation, led finally to the decision to provide an electrical equipment to handle the tunnel service, this equipment to provide for the operation of the trains through the tunnel by means of electric locomotives; the handling of the drainage and seepage water by means of electric pumps; the lighting of the passenger stations, the tunnel and the roundhouses by electricity, as well as furnishing a certain amount of power to the roundhouses; also, provision was made for a limited amount of outside lighting in the form of arc lamps. The different electrical systems available for such service were considered, and estimates as to the relative cost and efficiency of the various systems were prepared and submitted to the Tunnel Company. These estimates covered the direct current system both with and without battery, as well as estimates on the alternating current systems. Complete specifications were prepared, covering both the direct and alternating current systems, and propositions on these received and considered. Decision was finally made in favor of alternating current, using a 3-phase system for the distribution of power required for pumping and for shop motors with single phase distribution for locomotives and lighting.

III—Service Conditions and Requirements

The St. Clair Tunnel Company is operated as an independent division of the railroad, the trains being delivered by the Western Division in the yards at Port Huron, and taken by the tunnel locomotives through the tunnel, and delivered to the Eastern Division at the yards in Sarnia, the westbound trains being handled in the reverse order. The steam locomotives operating on the divisions adjacent to the tunnel are never operated through the tunnel.

In order to increase the capacity of the tunnel, it was desirable to provide for the maximum practicable tractive effort in the new locomotives.

The capacity limit was determined by the maximum pull to which it was deemed wise to subject the drawbars on the mixed rolling stock that must be handled, without danger of breaking trains in two. For this reason the locomotives were specified of sufficient capacity to develop a drawbar pull of 50,000 pounds, when operating at a speed of 10 miles per hour. It was estimated that such a locomotive would be able to make the complete trip through the tunnel from terminal to terminal with a 1,000-ton train in fifteen minutes, or four 1,000-ton trains per hour, which would provide a capacity for traffic about three times larger than the actual maximum demands up to the present time.

It was estimated that the pumping service, for which adequate provision must be made, would require the installation at the Sarnia portal of two pumps each of capacity of 5,500 gallons per minute, and at the Port Huron portal the installation of two pumps each with a capacity of 4,000 gallons per minute. To provide absolute continuity of service, duplicate pumping equipments were provided in each portal, as well as duplicate feeder lines leading from the power plant to the pump houses. As noted above, the pumps must always be in readiness for operation day and night throughout the entire year, which in case of electrical pumps simply necessitates the presence in the pump house of a pump operator and the continuous operation of the power plant.

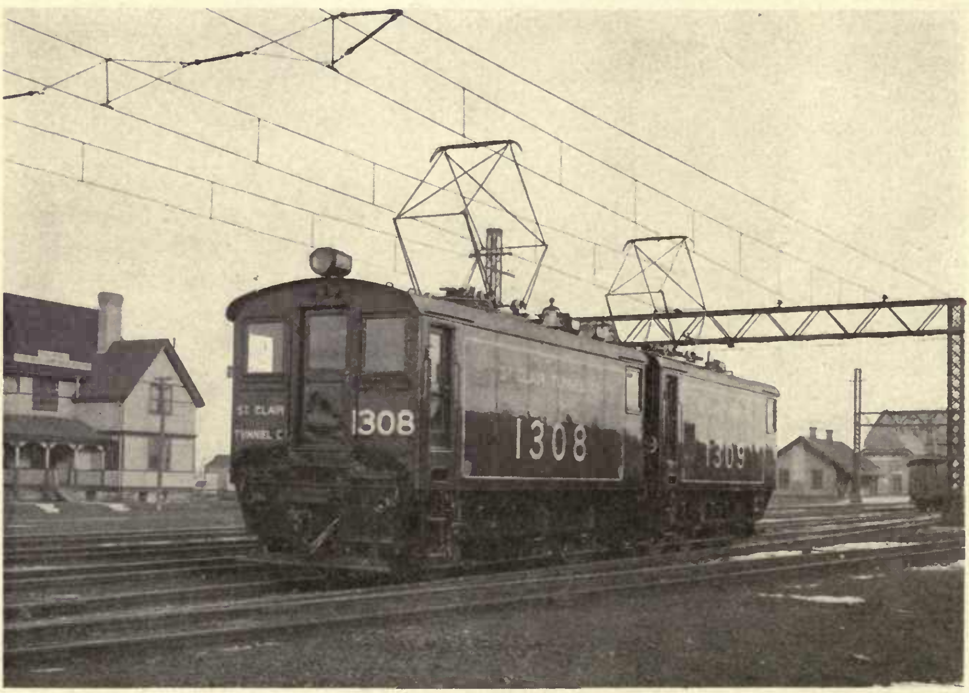
The lighting service to be provided for is of minor importance in so far as the amount of power required at both Sarnia and Port Huron is concerned, this being somewhat less than 100 kw. The power requirement for motors in the roundhouses at Port Huron and Sarnia is about 100 kw. for both shops.

To furnish electrical energy for the service outlined above, provision must be made in the power plant for supplying single phase current for the electrical locomotives, 3-phase current for the pumping service, and 3-phase and single phase current both for the power and lighting service at various points throughout Port Huron and Sarnia, as well as for a small amount of arc lighting.

IV—The Electrification Equipment

LOCOMOTIVES:

Three locomotives have been provided for this service, each consisting of two half-units, each half-unit mounted on three pairs of axles driven through gears by three single phase motors with a nominal rating of 250 h.p. each, the nominal horse power of the complete locomotive unit being 1,500. In so far as the electric motors have a very liberal overload rating, it is easily possible to develop 2,000 h.p., and on occasion in excess of this, in one locomotive. The half-units are duplicate in every respect, and as the



LOCOMOTIVE IN SARNIA YARDS.

multiple unit system of control is used, they can be operated when coupled together with the same facility that a single phase half-unit can be operated.

As previously stated, the locomotives are designed to develop a drawbar pull of 50,000 pounds at the comparatively low speed of ten miles per hour. The locomotives are powerful enough to start a 1,000-ton train on a 2 per cent grade in case this should be necessary. At a test made on a half-unit, using a dynometer car, it was found that a single half-unit developed 43,000 pounds drawbar pull before slipping the wheels. This was done on a comparatively dry rail, with a liberal use of sand. On this basis it would be possible to develop about 86,000 pounds drawbar pull with a complete locomotive. The maximum speed of the locomotives is 35 miles per hour. However, it is not the intention of the Tunnel Company to operate the locomotives at a speed in excess of 30 miles per hour. Speed indicators are provided, which indicate on a large dial located in the locomotive cab near the engine driver's seat the speed at which the locomotive is running, and at the same time record the speed throughout the length of the run. This assists the locomotive driver in keeping the speed of trains within prescribed limits at all times, and furnishes records of the exact speed of the trains throughout all trips, for the inspection of the superintendent of the tunnel.

The locomotive cab is rectangular in section, constructed of sheet metal supported by structural steel shapes. Inside of the cab are located practically all of the apparatus used in connection with the locomotive, with the exception of the motors and the brake rigging. Included in this apparatus is a single phase transformer used for reducing the voltage from 3,300 to a voltage suitable for application to the motor. The transformer, as well as the motors, are air-cooled, the supply of air being furnished by an electrically driven blower, also located in the locomotive cab. The blower is driven by a single phase motor, the current being supplied at 100 volts by a tap from the main transformer. With the moderate supply of cooling air furnished by the blower fan, both transformers and motors are able to operate at full capacity with comparatively little increase in temperature above that of the surrounding air. The air for the cooling is taken through a suitably designed shutter located in the side of the locomotive cab, and is distributed through sheet metal ducts installed under the cab floor to the three motors under the cab, and to the transformer. From the latter the air passes either through an opening in the floor of the cab into the open air, or, if desired, into the interior of the cab. In the latter case an appreciable amount of heat can be secured from the main transformer for utilization in heating the cab during cold weather.

Motor driven air compressors are also located in the cab. The air brake equipment is of the standard type used for electric cars and locomotives, with the exception of the motors, which are single phase. They are operated by means of an electric controller, which serves to keep the normal air pressure at about 100 pounds. The compressed air is used for the purpose of operating both the automatic and straight air equipment on locomotive and train, and in addition for a variety of minor purposes in and about the locomotive. All of the contactor switches used in controlling the operation of the locomotives are air operated, the air valves being operated by direct current electrical control. This is also true of ringing the bell, blowing the whistle, raising and lowering the trolley, and the application of sand to the tracks.

Speed control of the locomotive is effected by varying the voltage at the terminals of the motors. This is obtained by making connection with various transformer taps by means of the air operated, electrically controlled contactor switches. Electric control of the contactors is effected through the master controller, which in the electric locomotive replaces the throttle valve in the steam locomotive. The current for the master controller is furnished by a small storage battery operating at about 20 volts, the battery in turn being charged by means of a small motor-generator set provided for the purpose. The electric controller has 21 points in all, 17 of which are running points. This provides for an increase in the speed of the locomotive from the lowest running speed to the maximum speed by very slight gradations, thus making it possible to maintain a practically constant drawbar pull, while the locomotive is accelerating the train. This is very desirable, in so far as the minimum variation in the drawbar pull while handling the train through the tunnel decreases the liability of breaking the train in two. Particular attention was given this phase of the train operation in designing the locomotive, and the resulting remarkable decrease in the number of breaks-in-two since the operation with electric locomotives has been inaugurated is a source of great satisfaction.

On the master controller is also located the reverse lever, which controls through the electrically operated solenoids the air operated contactors used in reversing the motor connections. Here also are located the push buttons, which serve to raise and lower the trolley, operate the front and rear sanders, reset the circuit breaker, and ring the bell. The ringing of the bell and the application of sand by means of the front and rear sanders are also controlled by foot pedals, thus making it possible for the operator to perform these functions while his two hands are employed in operating the master controller and the air.

The balance of the equipment of each locomotive, consisting of the sand boxes, the seats for the drivers, ammeters, voltmeters, wattmeters, the banks of contactors, the preventive resistance coils, circuit breakers, auxiliary storage battery and motor generator set for charging it, are all installed in a compact manner inside of the cab, and are supported on structural steel work.

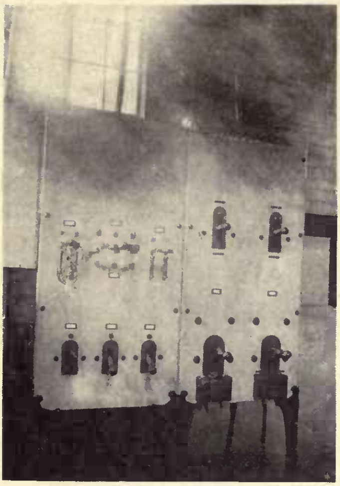
Each half-unit is arranged for operation in either direction; air valves, a master controller and ammeter being located at each end of the cab. By means of cable couplings, the control system of two or more half-units can be thrown in parallel, thus providing for the operation of any number of half-units from any master controller. In this way the two half-units are generally operated in the handling of freight trains through the tunnel. The passenger traffic can ordinarily be taken care of by a single half-unit.

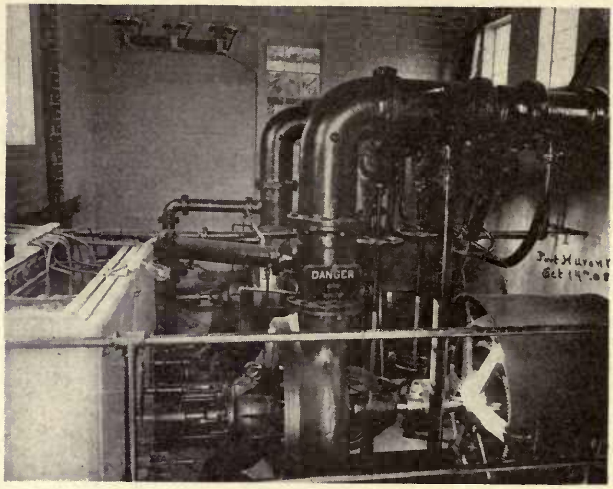
The current is collected from the trolley wires suspended at a distance of 22 feet from the track by means of a sliding bow pantograph trolley. In so far as the trolley wire extends throughout the length of the tunnel, no additional provision has to be made for the collection of current while the locomotive is passing through the tunnel. Electric headlights are provided, as well as lights for the illumination of the interior of the cab and the dials of the indicating instruments. The heating of the cabs is provided for by means of standard electric heaters. Heat is also available for drying the sand stored in sand boxes. In general, the M. C. B. standards have been conformed with in so far as couplers, wheel treads, etc., are concerned. The general dimensions of the half-units are as follows:

Length over all	23 ft. 6 in.
Height from top of rail to top of roof	13 ft.
Height from top of rail to top of pantograph bow when lowered	14 ft. 11 in.
Width of cab over all	9 ft. 8 in.
Total weight of locomotive half-unit, fully equipped	67½ tons
(This weight is practically evenly divided over three drivers.)	
Weight of complete locomotive unit	135 tons
Length of rigid wheel base	16 ft.
Diameter of driving wheels	62 in.
Normal speed of train, ascending 2 per cent grade (miles per hour)	10
Normal speed on level tracks (miles per hour)	25 to 30

LOCOMOTIVE AND TRAIN ASCENDING GRADE.

In service it has been found that the locomotives will very readily handle a 1,000-ton train at from 11 to 12, and possibly 13 to 14 miles per hour on a 2 per cent grade, thus demonstrating their ability to more than fulfill the specified performance.





INTERIORS OF PUMPING STATION.

PUMPING:

The second service to be provided for electrically consists of the pumping necessary to free the tunnel approaches from water due to rain storms or melting snow, and the removal of a small amount of condensation and seepage water collecting in the tunnel. For this purpose pumping plants have been installed at both tunnel portals, that at the Port Huron entrance consisting of two centrifugal pumps, each capable of delivering 4,000 gallons per minute, driven by direct connected, 100 h.p., 3-phase, 25-cycle, 3,300-volt, induction motors, and that at the Sarnia entrance consisting of two 5,500 gallon pumps driven by two 200 h.p. motors of the same type. In addition a 150-gallon pump driven by small induction motor is located in each pump house, these pumps serving to take care of the small amount of water that is constantly finding its way into the drainage wells. The motors in the pump houses are controlled by oil switches located on suitable panels. Provision is made on the panels for connecting the motor bus bars with either of two feeders leading from the power plant.

The centrifugal pumps used in this service can be primed by means of the water stored in the large discharge pipes. Valves controlling the flow of the water are all located so as to be conveniently accessible for the pump house operator. The equipment has been found to operate in an entirely satisfactory manner, and provides for the handling of water with a minimum amount of attendance and expense.

Two 150-gallon, motor-operated, centrifugal pumps are located at the foot of the Sarnia grade, and serve to remove from the tunnel the condensation and seepage water, delivering it to the well at the Sarnia portal. The seepage pumps are similar to the small pumps installed at the portal pump houses, with the exception of motors, which for this service are entirely enclosed, suitable for continuous operation in the tunnel, where they are liable to be subjected to more moisture than are the motors located in the pump houses.

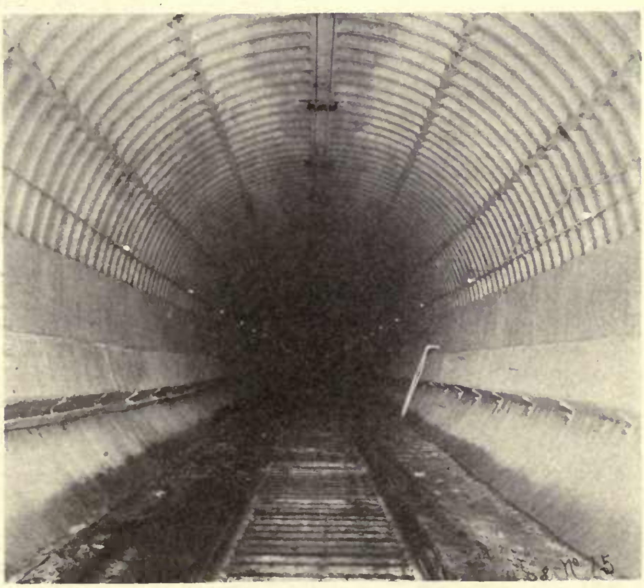
LIGHTING AND POWER:

Incandescent lamps in the roundhouses, the passenger stations, the Young Men's Christian Association buildings in both Port Huron and Sarnia, installed previous to the electrification of the tunnel, are now being furnished with current from the electric power plant by means of step-down transformers, reducing the voltage from 3,300 to 110 volts.

Motors operating at 3,300 volts have been installed in the roundhouses at Sarnia and Port Huron, the current supply being taken from the power plant.

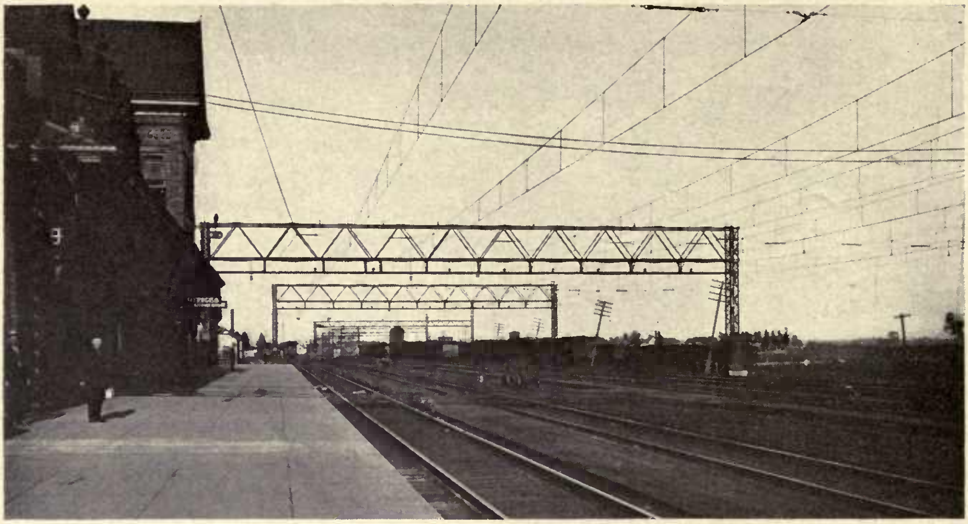
In all, 480 lights have been installed throughout the tunnel on either side at a height of 10 feet above the rail. The tunnel lamps are operated four in series from the 440-volt secondaries of the lighting transformers installed in the tunnel. Similar transformers furnish the current supply for the tunnel drainage pump motors.

In addition about 30 arc lights have been provided and installed in the yards at either terminal. These cars are used for general illumination around passenger stations, roundhouses, and coal chutes. The current for the arc

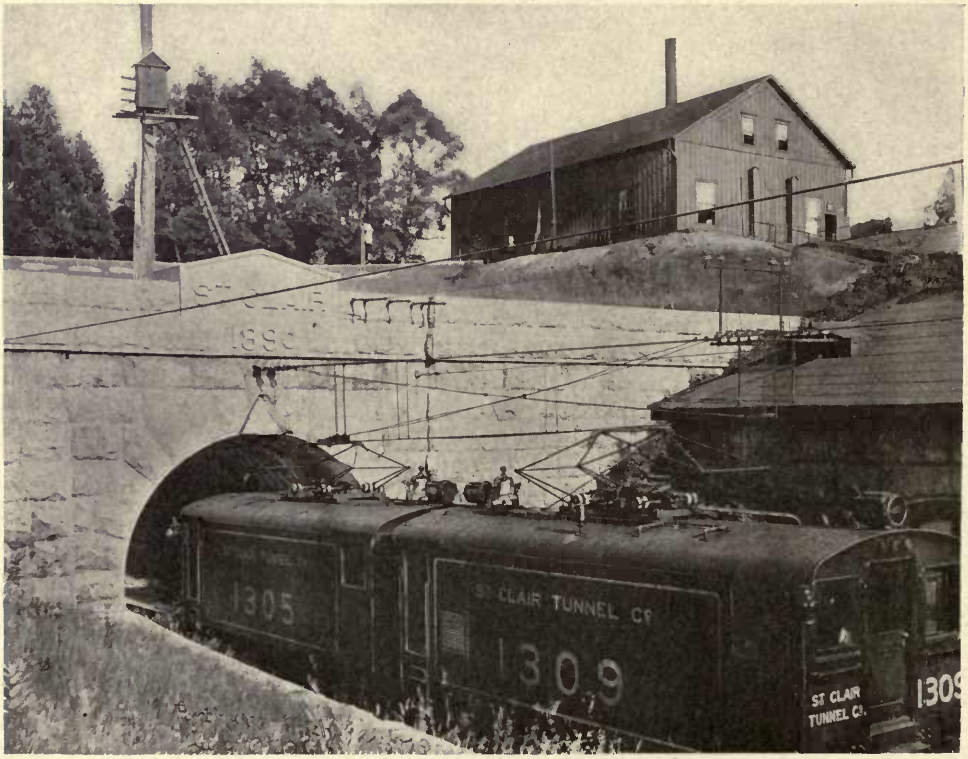


INTERIOR OF TUNNEL.

lights is furnished at the power plant by means of a mercury arc rectifier. The total amount of lighting is somewhat under 100 kw., which, together with the motor requirements of 100 kw., makes a total of slightly over 200 kw. for small power and lighting outside of the plant.



OVERHEAD WORK AT PORT HURON STATION.

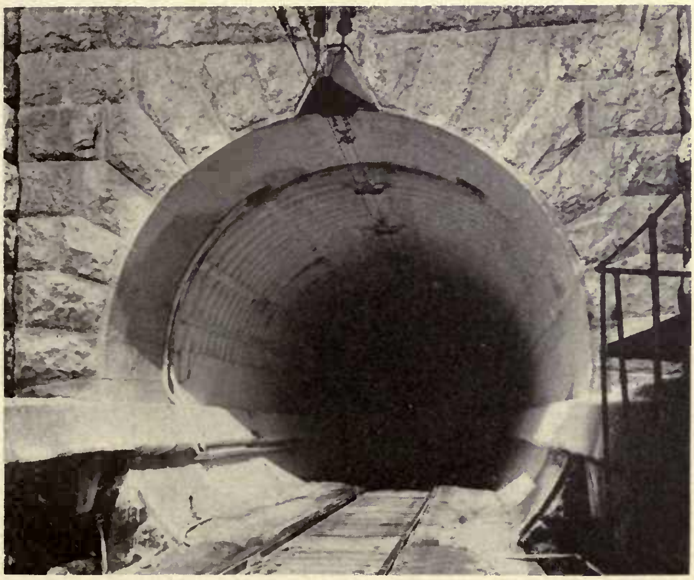


LOCOMOTIVE AT TUNNEL ENTRANCE.

ELECTRICAL DISTRIBUTION SYSTEM:

For distribution of the single phase current to the locomotive, substantial steel towers have been erected throughout the tunnel yards. The steel work used for supporting the working conductor consists of strong lattice columns supporting bridges of trussed construction. The average spacing of the overhead bridges is 250 feet. They are designed to extend over all tracks that are to be electrified, and in case of those located at passenger station extend, in addition, over the platforms, thus in no way interfering with the access of passengers to and from the trains. This necessitates a length of about 141 feet, in case of some of the bridges located on the Port Huron side, in which case the bridge spans seven electrified tracks, in addition to the station platform.

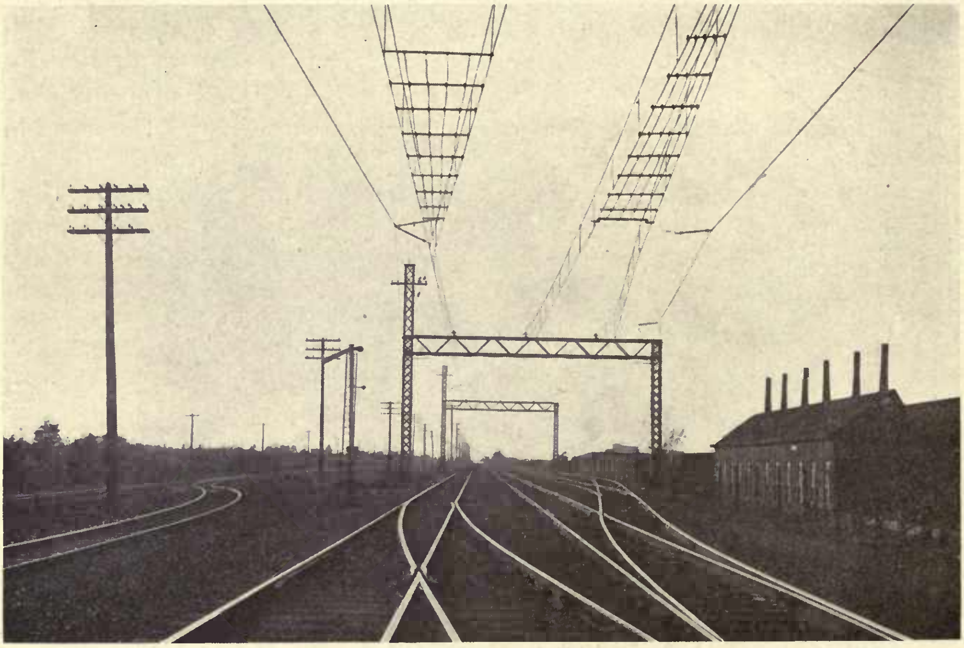
Single catenary construction is used throughout, a messenger cable of ⅝-inch extra heavy galvanized steel being suspended on the insulators located on the overhead bridges immediately over the center lines of the track to be equipped. The working conducter is attached to the messenger cable by means of fittings of varying lengths so arranged as to support it at a uniform height of 22 feet above the top of the rail. Number 4/0 hard-drawn grooved copper is used throughout the yards, and at all places, excepting on the tunnel approaches and throughout the tunnel, on which sections two 300,000 cm. conductors have been installed. The messenger cables forming the catenary construction terminate at the tunnel portals, where they are securely anchored to eye bolts imbedded in the heavy masonry portal. At this point the messenger wires supporting the working conductor



TROLLEY SUPPORTS AT TUNNEL ENTRANCE.

throughout the tunnel are anchored to special brackets located on the tunnel face. The working conductors in the tunnel are continuous with those on the tunnel approaches.

The method of supporting the trolley inside of the tunnel shell was conditioned by the requirement that complete overhead equipment should not encroach on the tunnel opening more than 9 inches. This has been accom-

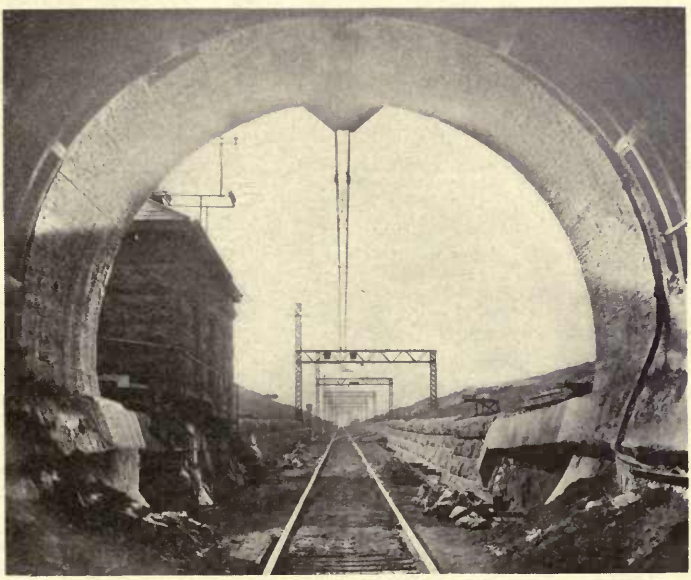


END OF ELECTRIC ZONE, PORT HURON YARDS.

plished by bolting to the tunnel shell special iron brackets, each of which supports two spool-shaped insulators. These insulators in turn support steel messenger cables, which are drawn taut throughout the length of the tunnel, and attached at the tunnel portal to special brackets. Special clamps are attached to these messenger cables at points between the insulator supports, and these in turn serve to support the two trolley wires. The insulating supports are attached to the tunnel shell at intervals of 12 feet, as also are the clamps connecting the messenger cable with the trolley. This method provides an attachment at once sufficiently rigid to maintain the proper clearance between the trolley and the tunnel shell, and at the same time sufficiently flexible to provide for the proper operation of the trolley bow on the overhead conductor. Section switches have been provided where necessary to permit of disconnecting the working conductor over any switch track from the main line extending throughout the tunnel.

The columns at one end of the transmission bridges have been lengthened, for the purpose of supporting the transmission wires which supply current for the power and lighting service at the roundhouses and stations, as well as for the arc light circuits. Overhead lines terminate in the pump houses, at either tunnel portal, where they are connected with the underground feeder system at the panel boards.

All feeder lines connecting the various parts of the equipment to be supplied from the power plant are carried in the tunnel conduits. For this purpose four conduit lines have been laid on either side of the tunnel throughout its length. Connection has been made with these conduit lines at a point about 1,700 feet from the Port Huron portal, with a vertical shaft extending from the top of the tunnel to the surface of the ground, terminating at a point about 75 feet from the power plant. The overhead feeders, terminating as above noted in the portal pump houses, are continued as underground feeders down through the tunnel and up the shaft, finally terminating in the switchboard at the power plant. For the pumping service, two independent feeders are laid from each portal pump house, one being installed on either side ot the tunnel and both terminating at the power plant switchboard. The heavy feeders for supplying the locomotive current to the trolley extend from the tunnel through the vertical shaft to the power house. This arrangement provides for all feeders leaving the power plant underground. The cables are paper insulated, lead encased and are installed in tile ducts.



PORT HURON GRADE FROM TUNNEL.

POWER PLANT:

(a) Building. The power plant is located on the Port Huron bank of the St. Clair River, about 100 feet distant from the center line of the tunnel. The building is 50 feet from the street property line, which provides ample

FRONT OF POWER HOUSE.

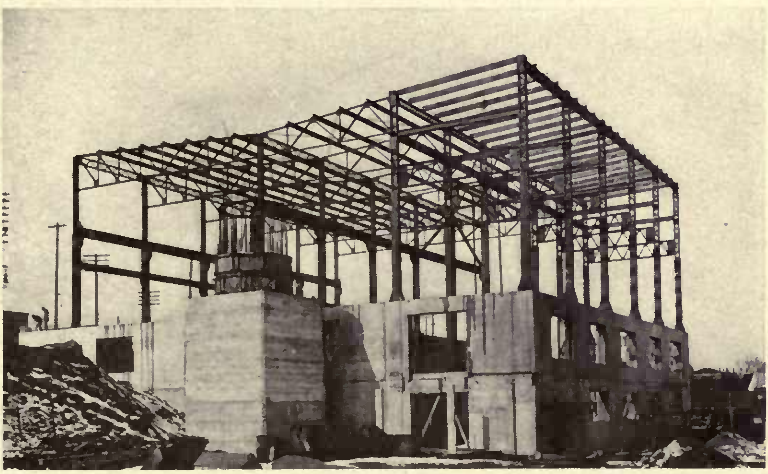
space for a lawn in front, while the back building line is about 50 feet distant from the retaining wall, which serves as a dock line along the river. Sufficient space is afforded between the building and the river front for side-track, a spur of the Grand Trunk Railway, which is used for bringing in coal and various supplies needed for the operation of the power plant, as well as the removal of ashes. The proximity of the river makes it possible for coal to be received and handled by boat in case this should be found desirable. The power plant building covers a ground area approximately 100 feet square. The building is divided longitudinally by a fire wall separating the boiler from the turbine rooms. In the front elevation, the height of the brick work above the water table is about 36 feet, the water table being about 2½ feet above the grade on the front side of the building. As the building is located on the side of a hill flanking the river, the ground line falls away rapidly alongside of the building until the grade line of the dock is reached, which is maintained for all entrances at the rear, this being 24 feet below the street level. The foundation up to the water table is constructed of mass concrete; the building superstructure is of steel and massive paving brick of dark brown color. The building trimmings are of cut stone and concrete. The general design of the building is along simple massive lines and presents upon completion a very attractive appearance.

The foundation footings for the buildings were carried down at all points into the clay, which is found underlying all of the surface soil in the vicinity. They were designed for bearing pressure of two tons per square foot. All of the column footings supporting the coal bunkers, as well as the footing underneath the stack, receive additional support in the way of piling, the location on the river bank making it advisable to take this additional precaution.

The self-supporting steel structure is carried on concrete foundation walls and footings. The steel work carries not only the reinforced cinder concrete roof, but in the turbine room the runway for the traveling crane, and in the boiler room the reinforced concrete coal bunkers. The brick building walls are also carried on the concrete foundations, and are built about the steel columns. The walls are finished at the top with a parapet capped with concrete coping. The wood work used in finishing the interior of the offices and turbine room is of mission oak.

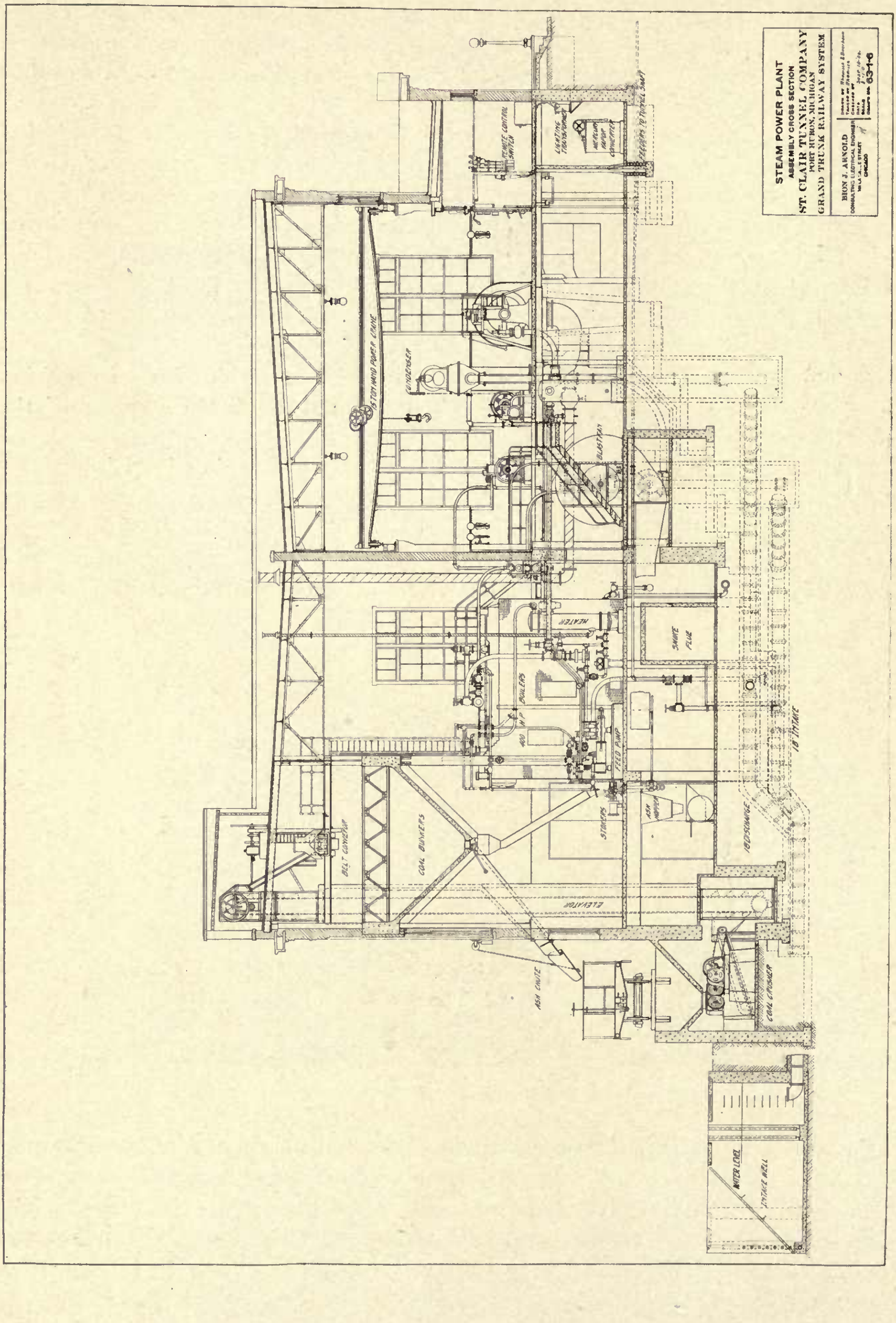
The roof is constructed of cinder concrete overlaid with composition roofing. Drainage downspouts are taken down through the interior of the building and discharge into the sewer system.

The interior of the engine and boiler rooms are lined with pressed brick of a light gray color. In the turbine room a wainscoting 8 feet in height of white enameled brick is carried around the three sides of the room. in which the brick wall surface is exposed, the front side of the turbine room being given up entirely to the switchboard, the glazed partitions separ-

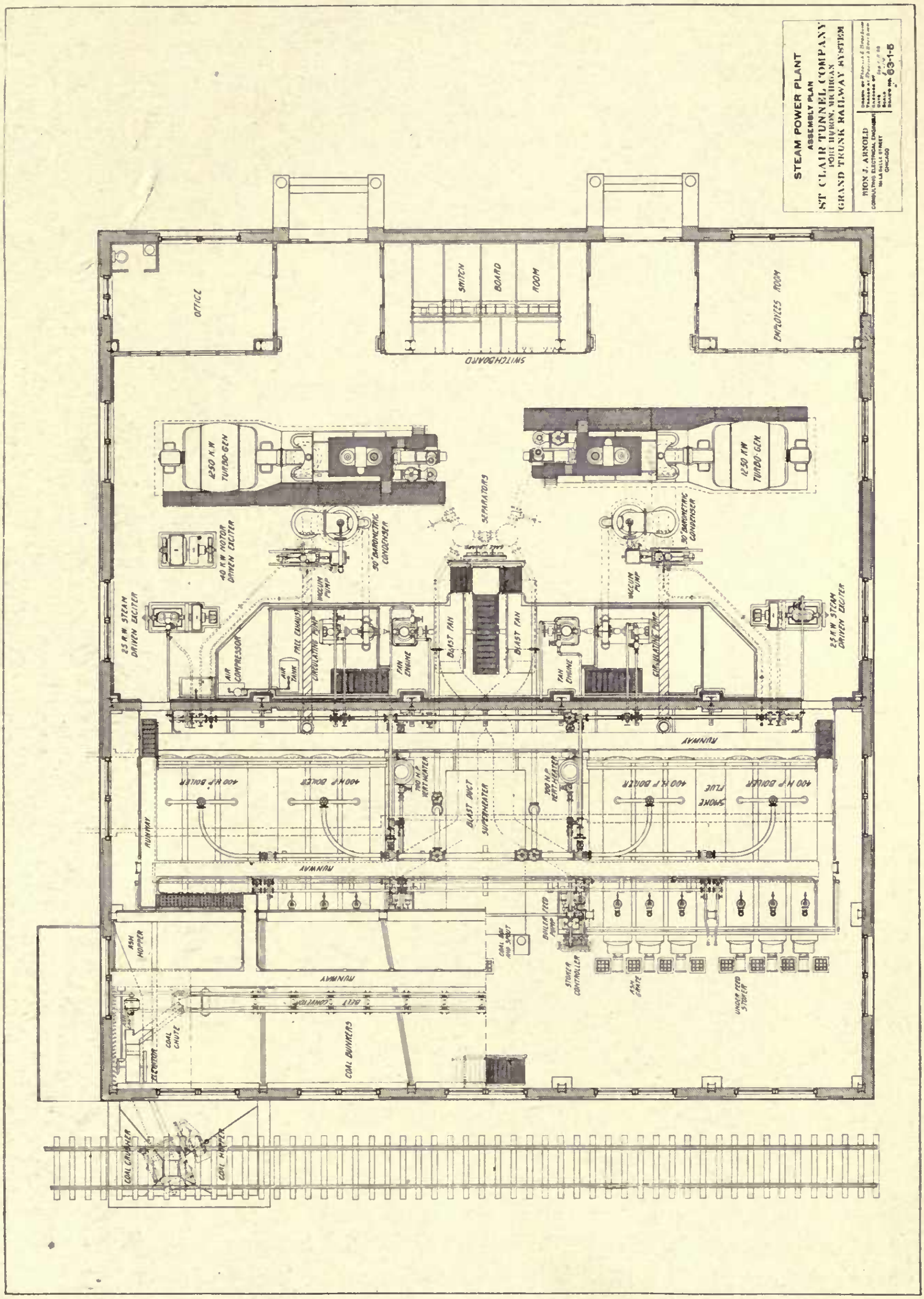


CONSTRUCTION VIEW OF POWER HOUSE.

ating the officers' and employes' room, the turbine room and the entrance hallways. All floors are concrete, the building being practically fireproof throughout. The light color of the brick, together with the light gray paint applied to the roof trusses and ceilings, tends to materially enhance the ample natural lighting which is provided for the building by means of a large window area.



SECTIONAL ELEVATION OF POWER HOUSE.



PLAN OF POWER HOUSE.

The general artificial illumination in the building is taken care of by means of Nernst lamps, eight of which are provided for the illumination of the turbine room, these being suspended from the lower chords of the root trusses, and two for the boiler room. In addition, nearly two hundred incandescent lamps are used for illumination in various parts of the plant. Wall brackets of design to harmonize with the interior finish are used in the turbine room. Chandeliers, wall brackets, and ceiling globes are provided for the lighting in the offices and hallways. Four incandescent lamp clusters are mounted on cast iron pedestals on either side of the two front entrances of the building. Hooded lamps are installed over all side entrances, as well as over the coal-receiving hopper at the rear of the building. All passageways behind and above the boilers, along the pipe lines, as well as those leading to and over the coal bunkers are well lighted, the lights being controlled by switches located at convenient points.

The water supply for house use in the power plant is furnished by a service pump and drawn either from the city water mains or from the St Clair River, as desired. Toilets and lavatories have been installed in connection with the engineer's office and in the turbine room on the basement floor, in the latter of which a shower bath with hot and cold water has been provided for the use of the employes. The necessary heating in the offices has been taken care of by radiators receiving their steam supply from auxiliary header of the power plant.

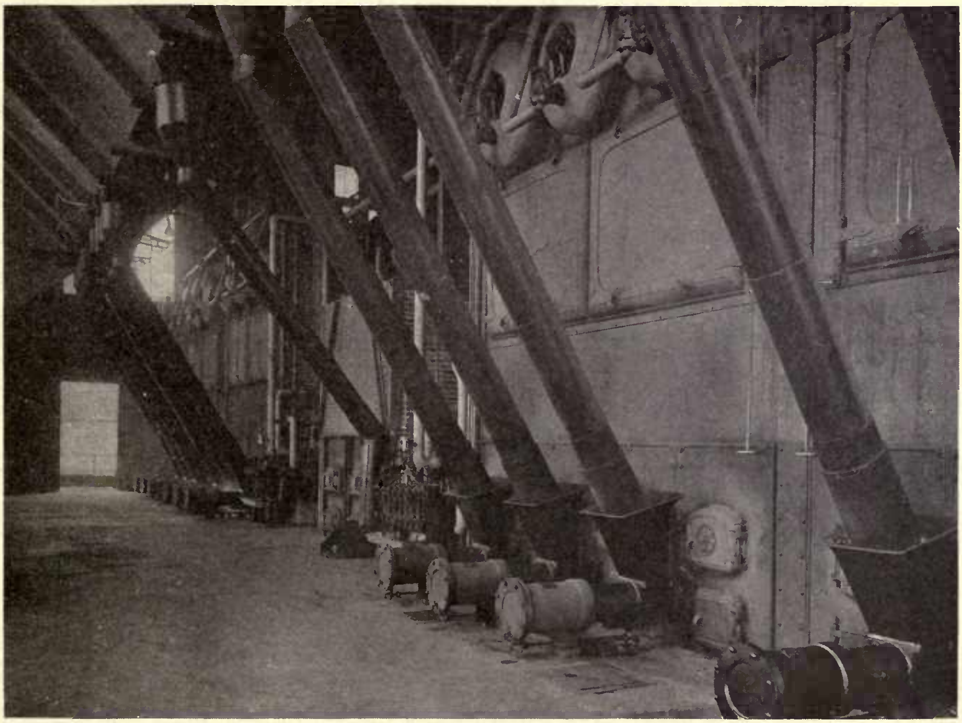
A sewer system has been installed in connection with the building, and connections have been made to fittings in the toilet rooms and to traps installed at various points in the basement floors, as well as to the downspouts, this latter to take the run-off from the roof.

(b) Coal and Ash Handling. Coal is delivered to the plant in hopper cars, which are run over a wooden trestle leading above the receiving hopper, into which it is dumped by gravity. The coal-receiving hopper feeds directly into the crusher, which has a capacity of about thirty tons per hour, and which acts at the same time as a feeder, delivering the coal at a uniform rate to the vertical bucket elevator extending to the top of the building. From the vertical elevator the coal is fed by chutes onto a conveyor belt, from which it is discharged by an automatic tripper arranged to deliver the coal at any point above the bunkers. Slow speed induction motors of the squirrel cage type drive the coal handling apparatus, a 20 h.p. motor being used in the crusher and a 10 h.p. motor installed in the pent house at the top of the building for the operation of the elevator and conveyor.

The coal bunkers are constructed of reinforced concrete resting on the steel building columns. The space occupied by them, located in front of and above the boilers, is separated entirely from the boiler room by metal lath partition, thus practically insuring the exclusion of coal dust from the boiler room. In a similar way the coal crusher pit and the coal elevating mechanism are enclosed as completely as possible.

Coal for firing purposes is drawn directly from the bunkers, through sheet metal chutes, into the stoker hoppers, which are located in front of the boilers.

The ashes are drawn from the grates of the boiler furnaces onto the boiler room floor, where clinkers are broken and delivered through a coarse grating into the ash hoppers which are suspended underneath the floor. From the hoppers they fall by gravity through ash grates into the push cars, and are dumped into an ash chute connecting with the coal elevator. The elevator, when handling ashes, discharges into a spout leading to a small ash bunker at the end of the building. From this bunker they can be delivered by gravity into cars alongside the power plant.



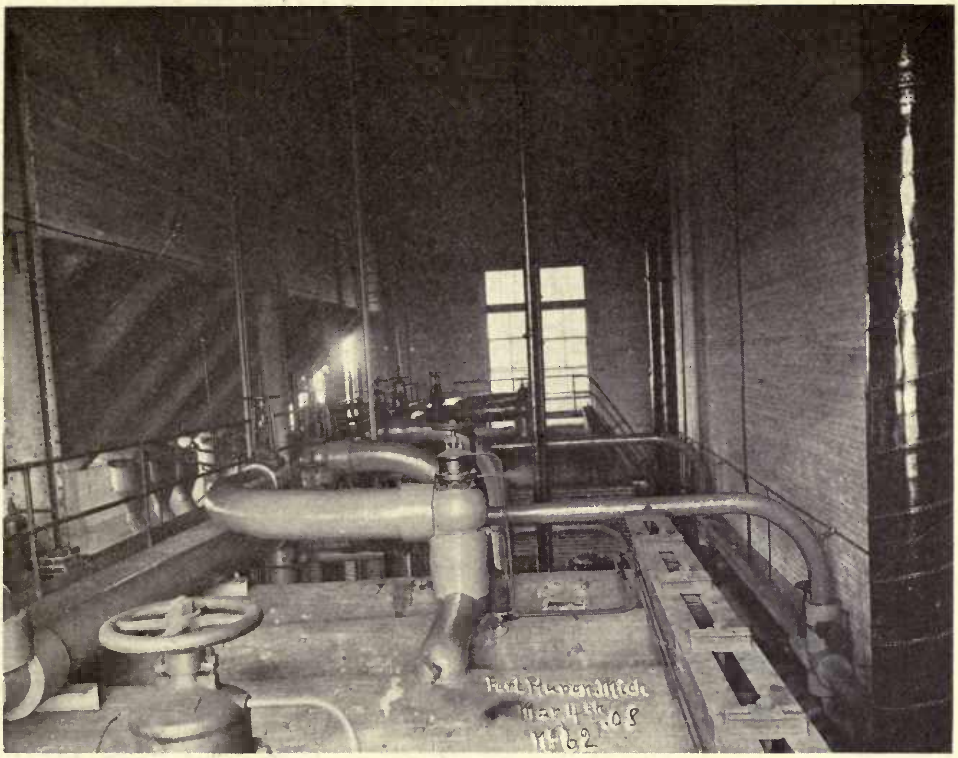
BOILER ROOM IN POWER HOUSE.

(c) Stokers. Jones Under Feed stokers are installed in the plant, six being used for each battery of two boilers, making a total equipment of twelve stokers. Forced draft is supplied for each battery by an American Blower Company steel plate fan 11 feet in diameter and 3 feet 5 inches wide, driven by 10x10x10 type B enclosed vertical engine directly connected to the fan shaft. These fans are located in the pit of the turbine room. By means of a special blast gate in the galvanized iron duct leading from the fans to the boilers, either battery of stokers may be supplied from either of the fans. Each battery of stokers is controlled by a Cole Automatic Regulator, which is driven from the shaft belted to the fan engines. Friction clutches on this shaft supply cross connection for driving either of the Cole Regulators from either engine. This driving mechanism, together with the galvanized iron ducts and gates, is suspended from the ceiling of the boiler room basement.

On account of the very great variation in the load on the power plant, special precautions were necessary for the control of the fires under the boilers, in order to keep the steam pressure fairly constant. This is accomplished by means of the Jones stoker equipment, which controls the fire automatically, both by regulating the air forced through the stokers and the rate of feeding of coal into the boiler furnaces. This regulation is accomplished by means of a Kitts regulating valve, which acts as a throttling valve on the fan engines. The potential piping leading from the regulator is connected to the main steam header between the superheater and the turbine. In case the pressure in the steam lines tends to drop, the Kitts regulating valve increases the supply of steam to the fan engine, thus at the same time increasing the amount of air supplied to the boilers, and the frequency of operation of the stokers. In case the boiler pressure tends to rise, the Kitts valve decreases the supply of steam to the fan engine, thus decreasing the amount of air and coal supplied to the furnaces. This apparatus is entirely automatic, and has been found to control the steam pressure very closely.

(d) **Boilers.** This equipment consists of four 400 h.p. Babcock & Wilcox sectional water tube boilers arranged in two batteries of two each, each boiler having three drums 42 inches in diameter and 23 feet 4 inches in length. This results in an unusually wide boiler, the tubes being arranged nine high and twenty-one wide, in order to secure quick-steaming. This requirement is a necessary complement to the automatic stoker control referred to above. In addition the three drums provide storage for a large quantity of heated water available for quick steaming on any decrease in pressure. The boilers are designed to carry 200 pounds steam pressure, each unit being equipped with two tandem connected 2½-in. Morris blow-off valves, the necessary pressure gauges, water columns, check valves, high and low water lines and other fittings.

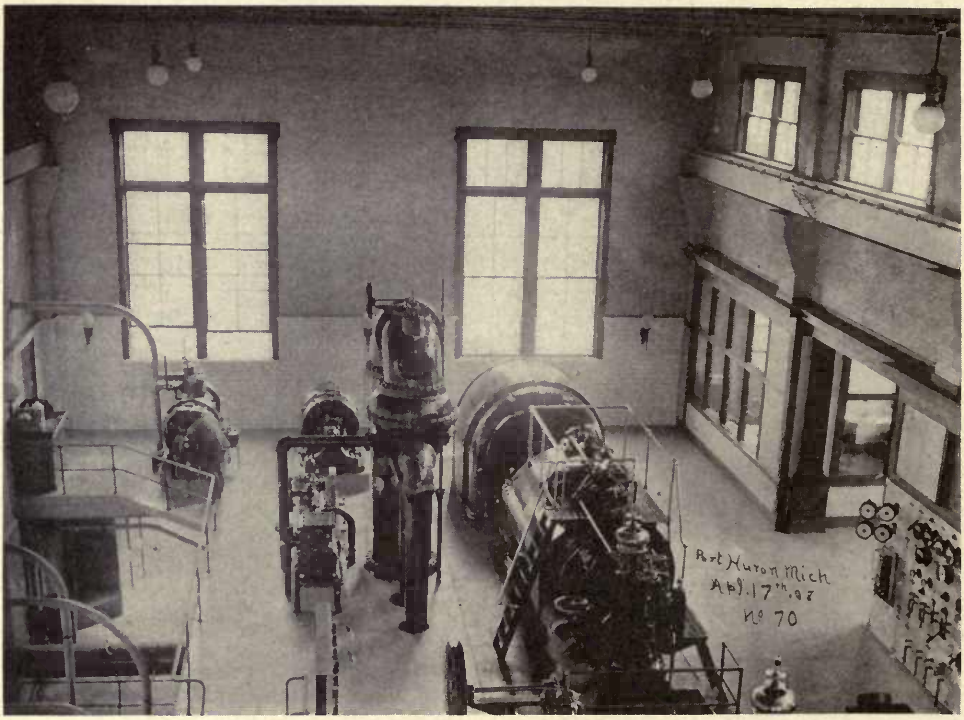
(e) Smoke Flue and Stack. The smoke flue, located in the boiler room basement floor, is built of reinforced concrete. The boiler flues open directly down into the smoke flue, which in turn leads in a straight line through the south building wall to the reinforced concrete stack. The height of stack from the top of the smoke flue is 150 feet, or 162 feet above the basement floor. It was built by the Weber Steel-Concrete Company. The inner shell is of standard construction, and the outer shell, which is the same height as the building, has a square exterior, being faced with brick above the grade line to conform with the building construction. Lightning protection has been applied to the stack in the form of standard equipment furnished by the Ajax Conductor & Manufacturing Company.



PIPING OVER BOILERS.

(f) Superheater. The separately fired Foster superheater is located between two batteries of boilers, and was furnished by the Power Specialty Company. The superheater has a capacity to add 200 degrees of superheat to 36,000 pounds of steam per hour. The superheater is hand-fired, but requires very little additional attention, as it is provided with automatic temperature regulator, which, by admitting air either above or below the fires, serves to control the superheat within narrow limits, approximately 30 degrees. The regulator consists of a thermal coupling installed in the superheater steam outlet, which in turn operates through a relay and solenoid on the by-pass valve of the hydraulic cylinder, the piston of which directly controls the dampers in the air ducts. The regulating device is so adjusted as to provide a superheat of about 100 degrees under actual working conditions, and has been found in operation to very closely control the temperature of the steam, notwithstanding the great variation of load to which the power plant is subjected.

(g) Piping. The steam is supplied by the boilers at 200 pounds pressure, and is delivered through the system of high pressure piping either to the superheaters and thence to the turbines, or through by-pass connections directly to the turbines, steam separators being installed in the piping system adjacent to the latter. The long sweep bends connecting the boiler nozzles with the main header are of 6-in. extra heavy pipe. The short header connecting the two batteries of boilers, in which are located the valves leading to the superheater and turbines, is 8 in. in diameter, while the lines



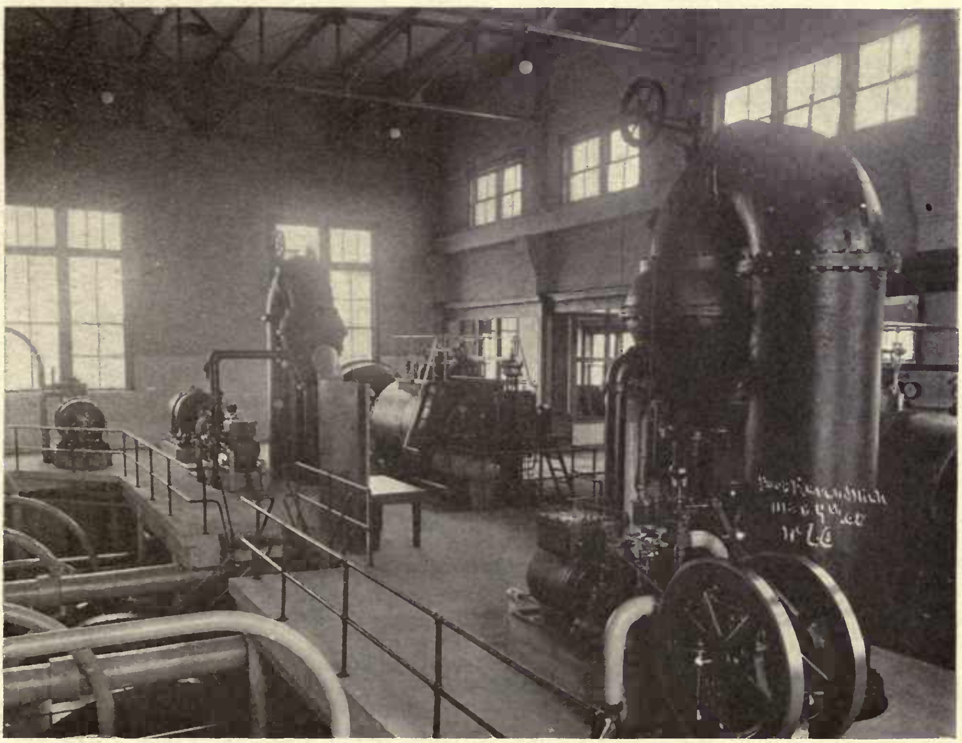
TURBINE ROOM (FROM CRANE).

from the header to the turbines are 7 in. The fittings throughout are of mild steel, and designed for heavy pressure with superheated steam. All high pressure piping is provided with welded flanges. The necessary drips have been supplied for the proper draining of the high pressure system. An auxiliary header 6 in. in diameter, operated at 125 pounds, is installed along the boiler room wall at the rear of the boilers. From this header the steam supply is taken to all of the steam auxiliaries in the plant.

The free exhaust piping from the back pressure relief valve is of 14-in. spiral riveted steel pipe, extending through the boiler room basement and thence up through the roof. The auxiliary exhaust is made of 8-in. pipe, supported in the boiler room along the fire wall, and receives the exhaust steam from the various auxiliaries in the plant. Steam is delivered by the header to either of the enclosed heaters installed in the boiler room just back of the superheater. A 12-in. Cochrane oil separator is installed in the exhaust steam line just before it enters the feed water heater. Goubert type B vertical water tube heaters, each of 700 h.p. capacity, are used. A 4-in.

spiral riveted pipe for free exhaust leads from each heater up through the roof.

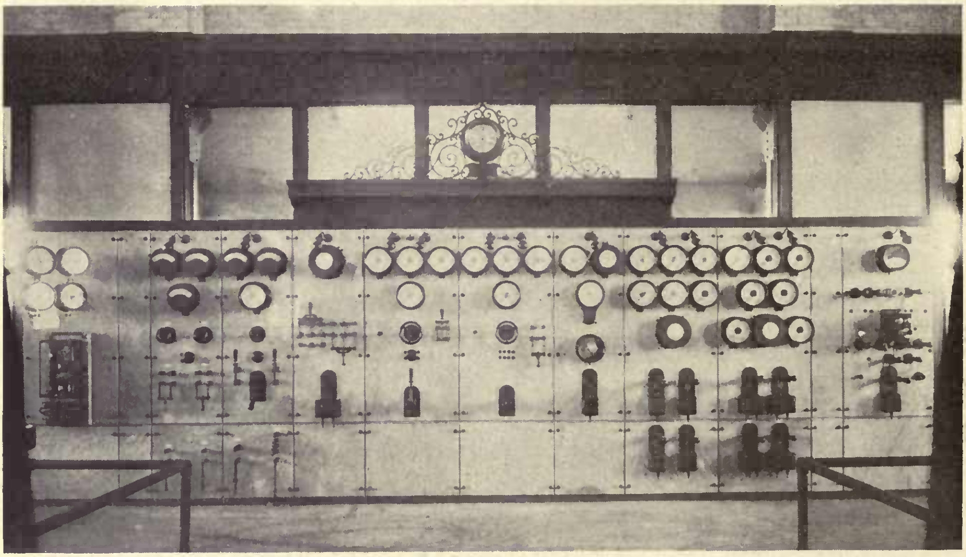
(h) Condenser and Boiler Feed Water Supply. The condensing water is obtained from the St. Clair River, a concrete intake provided with structural steel grid and woven wire screen being installed along the dock line. From the intake the water flows through an 18-in. tile to the cold wells located below the centrifugal circulating pumps in the pit of the turbine room basement. Water is delivered from each of these by the circulating pump through the condenser, and is discharged into the hot well below the condensers. From the hot wells the water flows through an 18-in. pipe into a sump under the boiler feed pumps. These pumps deliver the water through the feed water heater to the boilers. Excess water in the pumps is discharged through an 18-in. tile pipe emptying into the river. A 3-in. Worthington water meter is connected between each of the feed pumps and the heater. The city water supply is connected to each feed pump by a 3-in. tap. In



TURBINE ROOM.

addition, the suction of the feed pumps may be connected to the cold water intake, thus making three sources of supply for the boiler feed water.

(i) Pumps. Each battery of boilers is fed by a 12x6x10 duplex outside, end-packed Worthington boiler feed pump. In addition water is provided for various other purposes, such as cooling the lubricating oils in the turbines, supplying the glands of the turbines, for hose connections in and about tne power plant, all of this being supplied by a small Burnham service pump, drawing supply from one of the cold wells. The discharge pressure on the water system supplied by this pump is maintained by a pressure-regulating valve at about 75 pounds. A connection containing a check valve is made from the city mains to this piping. In so far as the city pressure is carried



SWITCHBOARD IN POWER HOUSE.

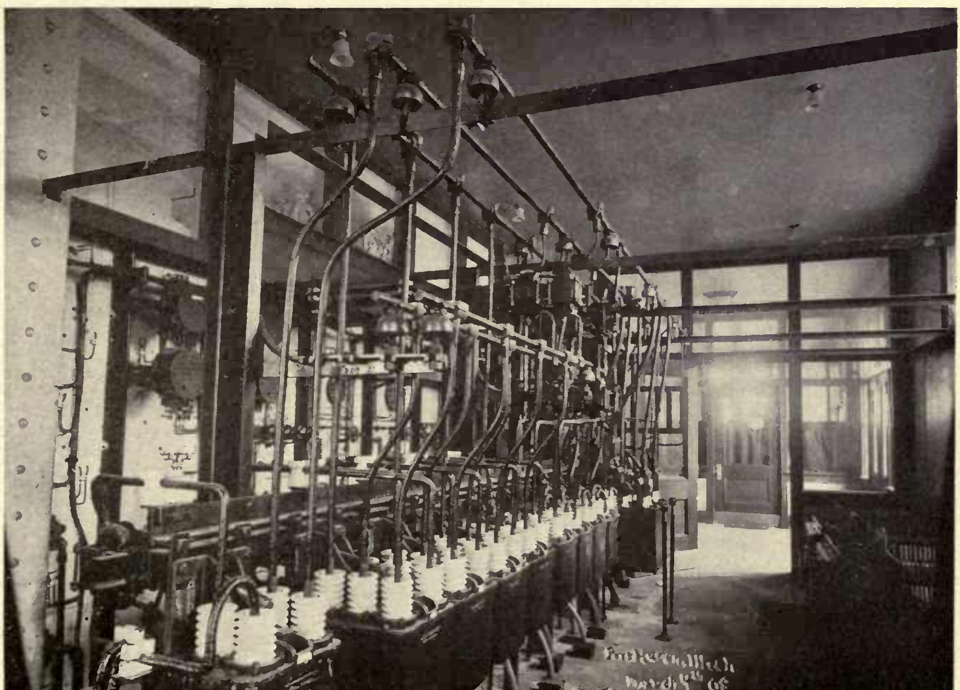
at about 45 pounds, the entire water supply will be furnished normally by the service pump. In case, however, the service pump should fail to operate, the necessary water supply will be forced in from the city mains through the check valve.

(j) Turbo-Generators. Two Westinghouse Parsons turbo-generators have been installed in the plant. The machines are designed to operate at a normal voltage of 3,300 volts, with a frequency of 25 cycles per second. They are 3-phase machines, but are further required by the specifications to furnish their full rated load of 1,250 kw. single phase current. The turbines are approximately 37 ft. over all, 6 ft. in width, and 8 ft. high, and designed to operate at 1,500 r. p. m. The generators are cooled by means of air drawn through the coils by vanes installed on the rotor. A speed limit device is arranged to cut off the supply of steam in case the speed of the turbine exceeds a predetermined value.

(k) Condensing Equipment. Barometric jet condensers with 30-in. inlet manufactured by the H. L. Worthington Company have been installed in connection with each of the steam turbines. A 36-in. exhaust pipe connects the exhaust outlet of the turbine with reducing fitting attached to the condenser head. A 14-in. automatic relief valve is installed in connection with the exhaust fitting, and connected to the free exhaust piping. The cooling water for each condenser is furnished by a 10-in. volute pump driven by 7x9 vertical engine. The rotative straight line vacuum pumps, 8x6x12 in dimension, are supplied in connection with each condensing equipment. The dry vacuum pumps are located on the turbine room floor alongside the condensers, while the circulating pumps are located in the open pit in the turbine room basement, where they are in plain view from the turbine room floor.

(l) **Exciters.** Two steam-driven exciters have been installed in the plant, each of 25 kw. capacity, this being sufficient to provide excitation for a single turbine. In addition a motor-driven exciter of 40 kw. capacity is installed, and is ordinarily used in the operation of the plant, the two steam-driven exciters being for additional security so far as continuity of service is concerned. The generators of the steam-driven exciters are of the Westinghouse Electric & Manufacturing Company make, and are driven by Westinghouse Machine Company vertical type engines. Both generator and motor of the motor-driven exciter are of Westinghouse manufacture, the motor being 3-phase, 3,300-volt, of the squirrel cage induction type.

(m) **Switchboard.** The switchboard, also of Westinghouse make, contains ten panels, and is made up as follows: One panel on which is mounted



BACK OF SWITCHBOARD.

the Tirrill regulator, the voltmeters, frequency meter, and synchroscope; two panels, one of which controls the two steam-driven exciters, the second of which controls the motor-driven exciter; one panel for the control of the current supply for power and light in the plant; two panels for the control of the two turbo-generators; one panel for the locomotive feeder; one for the pumping feeders; one for the power and light feeders; and one for the control of the arc light circuits.

All of the high-voltage oil switches are located on structural steel frame work in the switch room directly behind the switchboard, no high-tension current being brought to the switchboard itself. Direct current at 125 volts is supplied for excitation, this being controlled from the main switchboard. The power plant lighting current is supplied as alternating current, through step-down transformers installed in a high-tension compartment underneath the switchboard room, by means of which the 3,300-volt current is transformed to 110-volt for lighting distribution in the plant. By means of a special switch the lighting system can be transferred from the secondary of the transformer to the exciter bus bars.

The switchboard panels are provided with standard apparatus, such as ammeters, voltmeters, and indicating wattmeters. Recording wattmeters have been installed as well, and so located as to measure the output of the plant required for the various kinds of service, namely, the locomotive service, pumping service, and lighting service. The voltage control of the generators is provided for by the installation of a Tirrill regulator, which controls the voltage of the locomotive phase. The lighting load is carried on this phase as well, and is thus free from the large voltage variations that are liable to occur on the other phases.

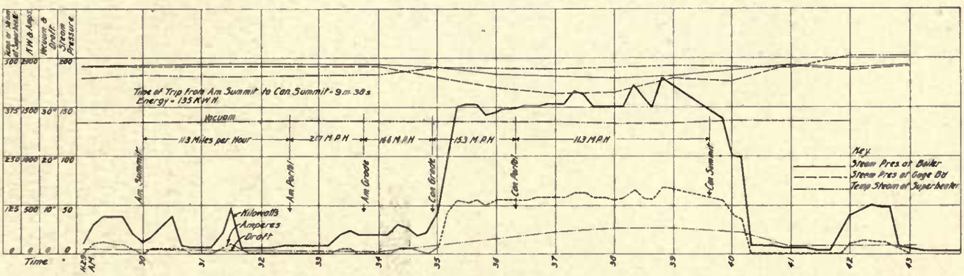
The station for the operating engineer is directly in front of the switchboard, from which point all the electrical indicating instruments, as well as the switches used in the operation of the plant are accessible. On the opposite side of the turbine room, facing the switchboard, is a gauge board, on which are installed the various gauges, both indicating and recording, giving full information with regard to the operation of the boiler plant. This arrangement brings to the immediate view of the operating engineer all information necessary in actual running of the plant.

(n) Traveling Crane. A hand-power traveling crane of 15 tons capacity, manufactured by the Northern Engineering Works, is installed on runways in the turbine room, by means of which all parts of the equipment in the room can be conveniently handled.

V—Construction and Operation of the Electrified System

The entire electrical equipment has been in preliminary operation during the larger part of the year 1908. The work of construction was done without any material interference with the traffic through the tunnel. The greatest difficulty was experienced in carrying out that part of the installation located in the tunnel proper. For this purpose the tunnel was given over to the contractor for construction purposes for two 2-hour periods each day during the time that actual construction was in progress in the tunnel. The construction of the overhead work in the yards was carried out without any serious interference with the ordinary traffic of the road, and the power plant construction, being entirely removed from any of the properties operated by the St. Clair Tunnel Company, was not subject to any interference on account of railroad operation.

The problem of transferring the operation of the St. Clair Tunnel Division of the Grand Trunk Railway System from steam to electricity gave rise to another problem which was successfully solved by the mutual coöperation of the representatives of the Tunnel Company and the contractor. No attempt was made to make a sudden transfer, but every precaution was taken, not only to thoroughly test out all electrical equipment before attempt-



GRAPHICAL LOG OF POWER PLANT OPERATION; CONDENSING. RUN NO. 3—MAY 28, 1908. (WEIGHT OF TRAIN WITH LOCOMOTIVE, 1,020.5 TONS.)

ing to use it in regular service, but also to allow ample time in which to thoroughly familiarize all those connected with the operation of the equipment with their work. Steam locomotive engineers were trained in the use of the electric locomotives. The force required for maintenance of the locomotives and for maintenance and operation of the power plant were secured and assigned their duties during the time that the first experimental and test runs were made with the equipment. When everything was in readiness, test runs were made with light locomotives through the tunnel, and later, moderate-size trains were taken through the tunnel as test loads, and finally a limited number of regular trains were handled by the electric locomotives. In this way, by gradually increasing the amount of work done by the electrical equipment, the entire operation was transferred from steam to electricity. The fact that no delays worthy of notice have occurred, either during the time of partial operation, or later, during the time of preliminary electric operation, is worthy of special note, indicating as it does not only the high character of the system so far as design and construction is concerned, but as well the conformity to the operating conditions that must necessarily be made in changing the operation of a division of a railway system from steam to electricity.

Some of the salient features in the operation of the plant may be seen by reference to a typical load curve. This curve is a graphical log of the operation of the plant during the time required for the passage of trains from one terminal to the other. It shows at a glance the power required by the locomotive, and the variation of boiler pressure, forced draft pressure, superheat, etc., during the cycle represented by train movements in the tunnel. The efficiency of all parts of the equipment is fully up to the contract requirements, and in fact in many cases the performance is found to exceed that guaranteed. From the results of preliminary operation it appears that the economies which will be effected by the electrification will be slightly in excess of the attainment estimated at the time the preliminary report on the proposition was submitted. This satisfactory showing, together with the entire elimination of obnoxious gases from the tunnel, is a source of congratulation to the Railway Company, together with those connected with the enterprise in an engineering or contracting capacity.

COMPLETED PLANT.

THE GRAND TRUNK RAILWAY SYSTEM.

Its Rail and Water Lines Together Will Total 15,134 Miles. In 1907 It Carried 20,305,275 Tons of Freight and 13,854,883 Passengers.

Many people fail to appreciate the commanding position that the Grand Trunk Railway System, which for more than 50 years has had its headquarters in Montreal, Canada, occupies among the great Railway Systems of the North American Continent. It is the Pioneer railway of Canada and one of the earliest built and operated on this side of the Atlantic.

From a financial standpoint, the Grand Trunk Railway System is the largest organization in Canada, and one of the greatest in the British Empire—the total capitalization of the Grand Trunk and its subsidiary lines being $353,268,487. Including the Grand Trunk Pacific Railway the total capital at June 30th, 1908, was the enormous sum of $447,898,932 for the entire Grand Trunk and Grand Trunk Pacific System of Railways.

The present total mileage of the Grand Trunk, including its subsidiary lines, is 5,300 miles, with a double track mileage of 1,035, which makes it not only the longest double track railway in Canada, but the longest continuous double track railway under one management in the world.

Great Rail and Water System.

Including the mileage of the Grand Trunk Pacific main line now under construction and contemplated—3,560 miles, of which 2,240 miles are under contract, also 5,000 miles of branch lines—the total length of the entire System of Railways will eventually amount to 13,895 miles.

In addition to the rail mileage the Grand Trunk operates steamer lines on the Great Lakes, between Midland, Depot Harbor, and Fort William, Milwaukee and Chicago. It also owns and operates large car ferry steamers on Lake Ontario, between Cobourg and Charlotte (60 miles), the total mileage of lake lines being 1,239. Adding the lake line mileage to the rail mileage above, gives a grand total of 15,134 miles of rail and water lines.

Grand Trunk's Enormous Business.

With regard to the amount of business handled: The Grand Trunk also stands in the forefront. During the year 1907, on the entire Grand Trunk System, the number of tons of freight handled amounted to 20,305,275, while the number of passengers handled was 13,854,883.. According to the official reports for 1907, the Grand Trunk takes rank among the ten largest Systems on the North American Continent, based on the business handled (freight tonnage and passengers), while on its lines in Canada only, it handled 2,000,000 tons of freight and 2,100,000 passengers more than the railway doing the next largest business; also, according to the Government reports, it handled 27 per cent of the total freight hauled, and 33 per cent of all the passengers carried by all the railways in Canada.

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L. G. Coleman	Asst. Superintendent	Belleville, O.
M. Donaldson	Supt. Ottawa Division	Ottawa, Ont.
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P. J. Lynch	Asst. Superintendent	Allandale, Ont.
U. E. Gillen	Supt. Middle Division	Toronto, Ont.
A. J. Nixon	Asst. Superintendent	London, Ont.
C. S. Cunningham	Supt. Southern Division	St. Thomas.
F. W. Egan	Supt. Western Division	Detroit Mich.
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R. L. Burnap	Asst. General Freight Agent	Chicago, Ill.
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Wm. Cuthbertson, General Assistant, 20 Water St., Liverpool, Eng.

T. S. Jones, General Agent, 44, 45 and 46 Leadenhall St., London, E. C., Eng.

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