

vapor or of warm air was tried but did not seem to offer any pronounced advantages. The dry residue should be titrated; the results by weight constant to 110° C. are a little high. In some cases fiftieth-normal acid and alkali instead of tenth-normal may be used to advantage in the final titration.

Following the method as given, a final result has been obtained in four hours after weighing the sample to be examined. About four or five hours longer would have been required if the alkaloidal solution had been brought to a dry residue before titrating.

Sodium bicarbonate has been used instead of ammonia water, but the results were about two per cent. high, probably due to some of the alkali going through to the titration.

One objection to the method is the cost of phenylethyl alcohol: the present market price is \$2.00 per ounce or \$25.00 per pound, but since an ounce is sufficient for four or five estimations, this figure is not entirely prohibitory.

Any sample, such as powders, hypodermic tablets, compressed tablets, etc., from which a satisfactory solution can be prepared, is suitable for this method. Obviously the identity of the alkaloid is not considered, nor is a separation of morphine from other alkaloids taken into account, but as a control test for checking the manufacture of tablets, etc., the method is believed to be satisfactory.

#### ABSTRACT.

An aqueous solution containing morphine is made alkaline and shaken with a mixture of phenyl-ethyl alcohol and benzene; the solution of the alkaloidal in phenylethyl alcohol is then partially evaporated and titrated. The method is designed for quantities of sample representing less than 0.175 gram anhydrous alkaloid and can be completed in about 4 hours.

LABORATORY OF PITMAN-MYERS COMPANY,  
INDIANAPOLIS, IND., May 18, 1911.

## PLANTS AND MACHINERY

### TRANSFORMING STATIONS OF NIAGARA ELECTROCHEMICAL AND ELECTROMETALLURGICAL INDUSTRIES.<sup>1</sup>

By A. J. JONES.

Grouped around Niagara Falls are seven hydro-electric generating stations, four of which are on the Canadian side. From these seven stations energy is being used at the rate of 128,000 h. p. for electrochemical purposes, 56,000 h. p. for railway service, 36,000 h. p. for lighting, and 55,000 h. p. for various industrial services, the total being 275,000 h. p., or about 5.5 per cent. of the available power of the cataract. Of this total amount 146,000 h. p. is employed locally in industries that have been attracted to Niagara Falls by reason of the generating stations located there, electrochemical processes forming 87 per cent. of this amount and 46 per cent. of the total amount utilized.

The brief description here given of some of the installations for transforming and distributing this power in electrochemical plants, together with a discussion of the more salient features, it is hoped, may prove of interest. In any event, the rapid progress of the electrical art makes desirable a frequent comparison of notes regarding methods of design and operation.

#### INTERNATIONAL ACHESON GRAPHITE COMPANY.

The new 11,000-volt transformer station of the International Graphite Company, with a capacity of 2,800 kw., made up of one 1,600 kw. and three 400 kw. units, is thoroughly modern in all the details of its design.

This station is supplied with power by The Niagara Falls Power Company. Two 3/0 (85 sq. mm.), 3-conductor, lead-sheath cables, with provision for a third cable, each capable of transmitting approximately 3,200 h. p., connect this station with the step-

up transformer plant of the power company. A second station operated by the International Acheson Graphite Company receives its energy from the same power company but in the form of 2,200 volt, 2-phase power. This station is fed by two 2-phase underground feeder systems, each system being made up of four 1,000,000 cir. mil. (506 sq. mm.) lead-sheathed cables with a capacity of 2,000 h. p. per phase.

The switch room of the 11,000-volt station is situated on the west side of the International Acheson Graphite's new furnace room in a two story brick building with a floor space of approximately 21 feet by 41 feet (6.3 × 12.3 meters). On the lower floor are located the switching apparatus, bus bars, meter transformers, etc. On the second floor are located the switchboards and low-voltage control apparatus (Fig. 1).

The incoming power cables enter through a subway which extends the full length of the building. On each side of the subway are erected the masonry cells enclosing the oil circuit-breakers for both the incoming and outgoing circuits. Directly over the subway above the oil circuit breaker cells is located the bus-bar structure made of seasoned maple. Disconnecting switches mounted on porcelain insulators fastened to marble slabs are bolted to each side of the bus-bar structure. Suspended from the ceiling in line with the disconnecting switches are two platforms containing meter transformers.

Each incoming power cable terminates in a brass pot head; thence passes through current transformers to the oil switch; thence to disconnecting switches to the bus-bars.

The oil switches are of General Electric make, form K12, 15,000 volt, of 300 ampere capacity, operated from the switchboards above by link connection.

There are four switchboard panels of blue Vermont marble 7 feet 6 inches (2.25 meters) high. One panel 30 inches (0.75 meter) wide controls the three incoming

<sup>1</sup> Presented at the General Meeting of the American Electrochemical Society, Toronto, September, 1911.

cables. On this panel are mounted two watt-hour meters which measure the total power delivered to the bus-bars, a bracket-type voltmeter and time-limit relay of the bellows type. The other three panels are 20 inches (0.5 meter) wide and control the 1,600 kw. unit and two 400 kw. units, the third 400 kw. unit being located in a separate building with its switching apparatus in the same room with the transformer. On each of the unit panels are mounted an ammeter, indicating wattmeter, special voltmeter for indicating the position of the secondary switch, a secondary voltmeter, watt-hour meters and control switches for operation of the regulator switch.

The regulator transformers are located a short

age variation of 40 to 160 volts with full output at any voltage. Two of the 400 kw. units have a voltage range of 80 to 160 volts. The third 400 kw. unit has a secondary voltage variation of 30 to 60 volts. The regulation is accomplished by means of a dial switch which is rotated by an induction motor controlled from the switchboards in the switch room. The rotating switch of the 1,600 kw. unit consists of two dials of 22 points each mounted on a 2-inch (5 cm.) marble slab in a dust-proof case. The 400 kw. units have single dials of the same number of points as the 1,600 kw. unit (Fig. 2). As all the regulating is done on the primary side of the transformers, the volts per step are quite high. In order to have this

switch meet the heavy duty required of it, manufacturers have arranged two electrically operated switches or contactors, in series with each half of the rotating switch. These operating circuits are so connected to a small contact device on the main switch as to open auxiliary contactor and interrupt the contact and again close the circuit after it has made contact with any of the various stationary contacts. With this arrangement all arcing is removed to the auxiliary contacts which are made with heavy and easily replaceable parts.

The arrangement of the 2,200 volt station is similar to the 11,000 volt station just described. The incoming feeders enter through a manhole in the lower floor of the switch house which is situated on the west side of the graphite furnace room. The incoming power passes through General Electric K<sub>4</sub> oil circuit-breakers, thence through knife switches to bus-bars mounted on an iron framework back of the switch-board. On the main floor of the switch house, in addition to the receiving panels, there are located two 150 kw. and two kw. oil-insulated, self-cooled, General Electric transformers with 230-volt secondaries which supply power to the motor circuits; two 17½ kw. oil-insulated, self-cooling transformers with 11-volt secondaries used for lighting, two water switches for control of the main units, one 180 kw. induction regulator and one 5 kw. motor generator set used for arc lighting and experimental work.

On the second floor of the switch house are located three switchboard panels controlling the motor and light transformers and main regulating transformer, also three low-tension panels connected to the low tension side of the motor and light transformers. The high tension panels are constructed of blue Vermont marble 24 inches (0.6 meter) wide mounted with oil circuit-breakers, ammeters, voltmeters, and watt-hour meters. The low-tension panels are equipped with knife-switches, cartridge-fuses, and 3-pole, 600-volt, carbon-break circuit-breakers.

There are two regulating transformers used for furnace operation, each with a capacity of 1,600 kw.,

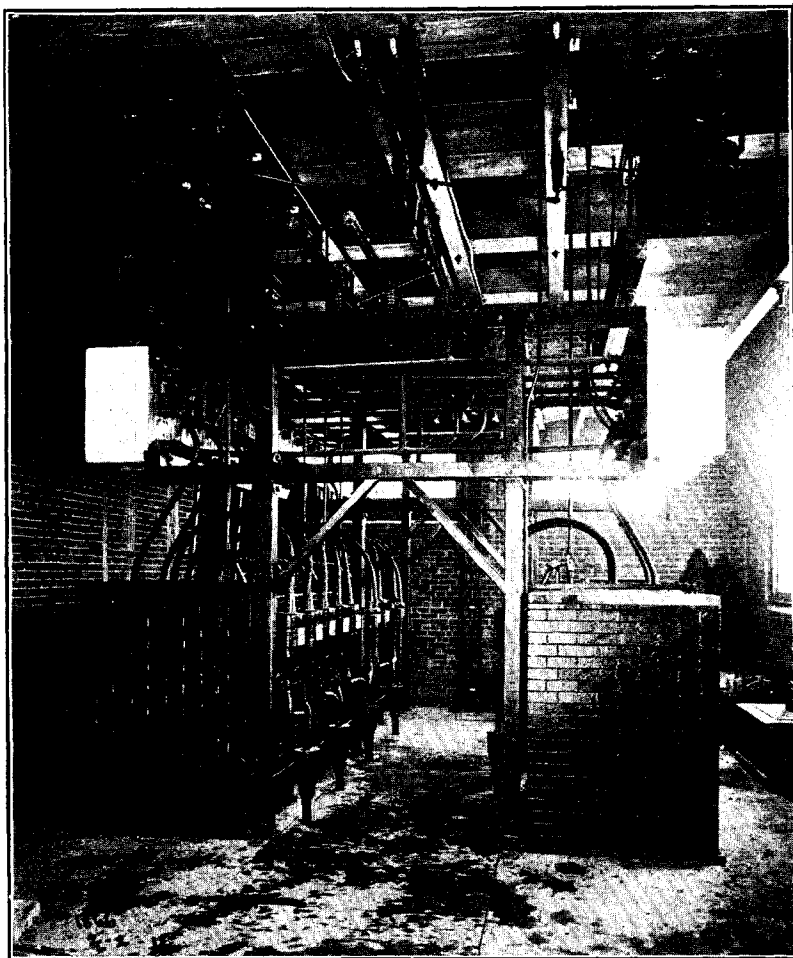


Fig. 1.

distance from the switch house in separate bays and are fed by a duplex lead-sheathed cable. The oil circuit-breakers that control the transformers are of the same type as the circuit breakers on the incoming cables except that they are 2-pole instead of 3-pole. The selector switches are single pole, double throw, so arranged that the units may be connected to any one of the three phases.

The regulators represent the latest development of the General Electric Company and are known as the transformer type of regulator. They are oil-insulated, water-cooled with primaries wound for 11,000 volts. The 1,600 kw. unit is capable of a volt-

one manufactured by the Westinghouse Electric & Manufacturing Company and the other by the General Electric Company. They are oil-insulated water-cooled. The Westinghouse unit is capable of a voltage regulation of 80 to 190 volts and is made up of a 180 kw. induction regulator in series with the primary of the main auto-transformer. Taps of the main transformer are connected to a series of oil switches which are opened and closed by drum and cam arrangement operated by a small induction motor controlled from the switch room. The main transformer gives a step by step regulation, the regulator being used to vary the voltage gradually between each step on the main transformer.

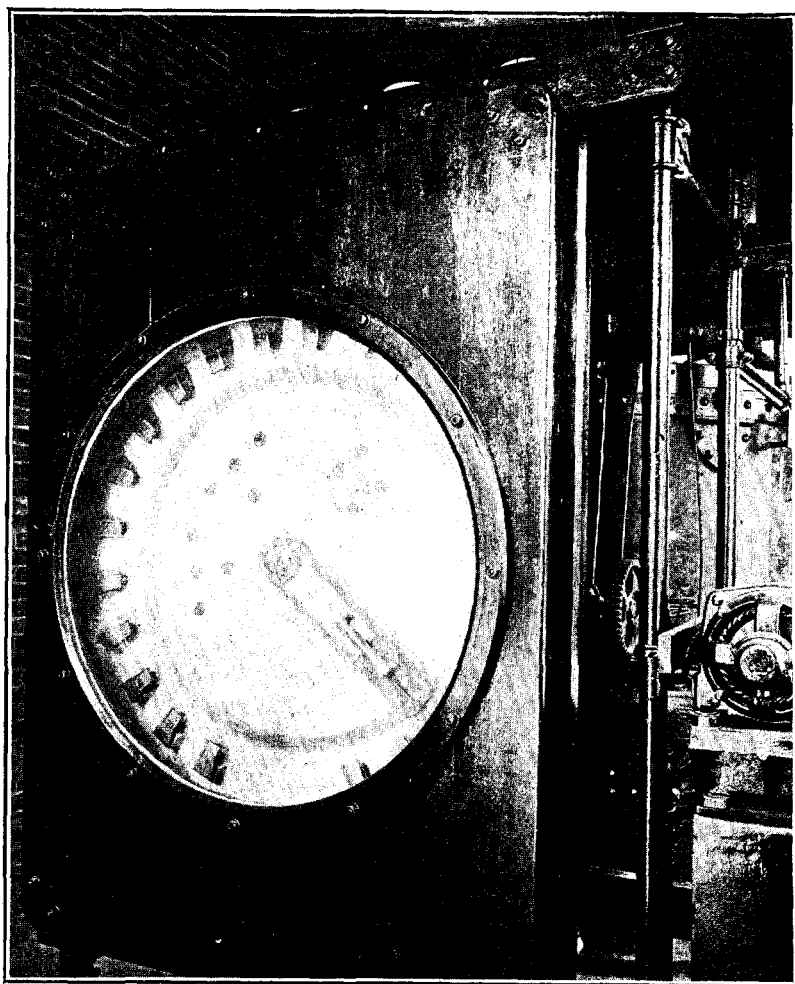


Fig. 2.

The General Electric unit (Fig. 3) is similar to the 11,000 volt units just described except that it has an additional drum-switch and is capable of giving a straight line voltage variation of 40 to 200 volts, part of this being accomplished by a motor-operated knife-switch in the secondary (Fig. 4). The accompanying diagram (Fig. 5) shows the connections of the dial switch and drum-switch (Fig. 6). The two regulating units are housed in a small brick building in the center of the furnace room. The low-tension bus-bars are constructed of aluminum and extend the full length of the furnace room.

#### THE ALUMINUM COMPANY OF AMERICA.

Electrical energy is supplied the Aluminum Company of America at its No. 1 Niagara Works by the Niagara Falls Power Company, delivery being made at three stations known as 1A, 6A and 10A. These stations are designated by the number of the buildings in which they are located and are of two classes, one containing rotary converters, the other regulating transformers.

The rotary converter station is of interest as being the first station to receive power from The Niagara Falls Power Company. Power was first delivered to this station in August, 1895, since which time it has been in continuous operation with very few interruptions. The equipment consists of 600 kw.

General Electric rotary converters, 2-phase, 25-cycle, running at 187.5 r. p. m., some of which are located on the west side of the station and others on the east side, the middle section of the station being occupied by banks of air-blast, step-down transformers. The transformers are single-phase with 2,200 volt primary, and are supplied with air by two blowers driven by direct-current shunt motors located on the floor of the station. A subway is carried under the transformer which conducts the air from the blowers to the transformers.

Alongside of each bank of transformers and in line with the rotary shaft is a switchboard panel which controls the primary and secondary circuit of each bank. This panel is equipped with four 2,000-volt knife-switches, without barriers, mounted at the top of the panel and four low-voltage knife-switches mounted at the bottom.

The direct current side of the rotary is controlled by a panel provided with knife-switches, field-switch and field-rheostat handle. All of the rotaries are connected on the direct current side to a bus-bar, supported on an iron framework on the west side of the station, the leads from the two rotaries on the east side being carried under the floor in a subway.

In the north end of the station are the receiving panels, two in number, one of which is equipped with single-throw, single-pole knife-switches, the other with two automatic double-pole, 1,500 ampere, type B, Westinghouse oil circuit-breakers. These panels

are made of asbestine stone and are mounted side by side on an angle framework. The incoming power cables enter through a subway and manhole under the receiving panel. They are single conductor, lead-sheathed, with a cross section of 1,000,000 cir. mils. (506 sq. mm.) each.

Transformer station 6A is located in a two-story brick building tacked on to the south wall of the carbon furnace plant. In this building are located the switchboards and control switches for six regulating transformers located in transformer houses in the furnace room. On the ground floor is an asbestine

stone panel to which are connected six 1,250,000 cir. mil. (632 sq. mm.) single conductor, paper and lead cables constituting a 2-phase and a single-phase feeder system. From the disconnecting panel the cables pass up to a marble panel on the second floor, mounted with two double-pole, remote-control, automatic, type B, Westinghouse oil circuit-breakers and necessary meters. A two-phase bus-bar system in the rear of the switchboard receives the current after it passes through the oil circuit-breakers.

In addition to the receiving panel there are five unit panels and one direct-current control panel. The unit panels are equipped with meters and oil switches, the disconnecting switches being mounted on a framework in the rear of the panels with the master switches controlling the units located in front.

The regulating transformers are located in dust-proof brick houses at distances varying from 50 to 200 feet (17 to 67 meters) from the switch house. They are known as the unit switch type of potential regulator, the electrically operated switches being of the open type, mounted on marble panels. The control voltage is 110-volt direct-current and is supplied by a small motor-generator set in the switch house.

Across the street from the carbon plant is located building No. 10, containing transformer station 10A. A small brick structure located in the center of the building houses the switchboards and transformers. The transformers are located in the basement and consist of two 1,000 kw. oil-insulated, water-cooled, General Electric transformers. One transformer is used for experimental purposes and has a range of 30 to 77 volts. The other transformer is used in conjunction with an induction regulator and is capable of giving a voltage variation of 45 to 60 volts.

The switchboard panels are located on the main floor, and consist of an incoming feeder panel and

four unit panels, one for each transformer and regulator and one for motor transformers. The receiving panel is located along the east wall of the building and is equipped with knife-switches and General Electric oil circuit-breakers. The other panels are

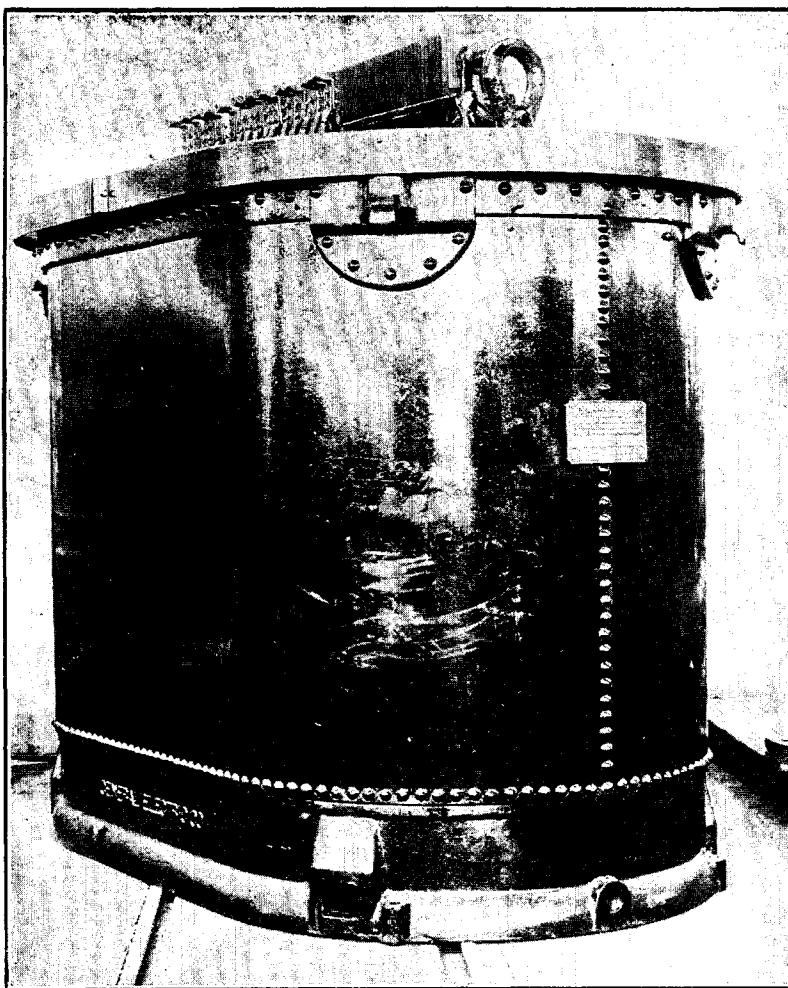


Fig. 3.

equipped with General Electric oil circuit-breakers, ammeters, and wattmeters.

A 2-phase, underground feeder system tapped to the same feeder that supplies station 6A enters the basement and connects to the receiving panel.

#### THE CARBORUNDUM COMPANY.

The main transformer station of the Carborundum Company is located in a rectangular brick building situated in the west end of the furnace room. In this building are located switchboards, water switches, two small motor-generator sets and two regulating transformers. Power is supplied to this station by ten single-conductor, lead-sheathed, underground cables, each having a cross section of 1,250,000 cir. mils. (632 sq. mm.) which connect to the No. 2 generating station of The Niagara Falls Power Company.

In the east end of the station facing each other are located the two regulating trans-

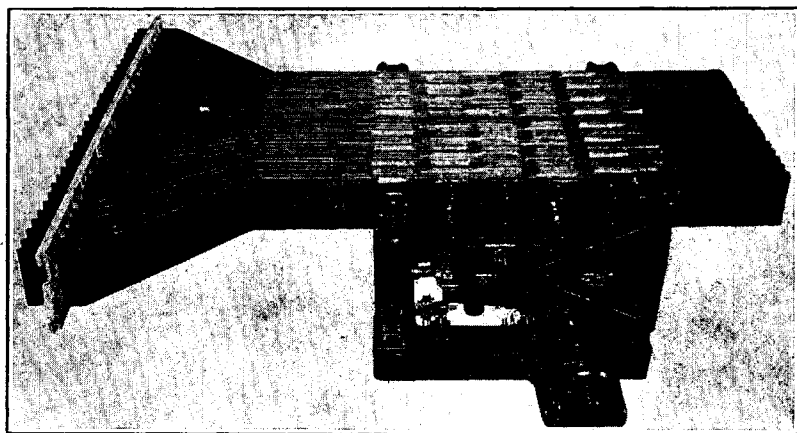


Fig. 4.

formers with their control panels. Along the south wall about four feet apart are four switchboard panels which control transformers located in bays in

lock to prevent their being opened too rapidly. The

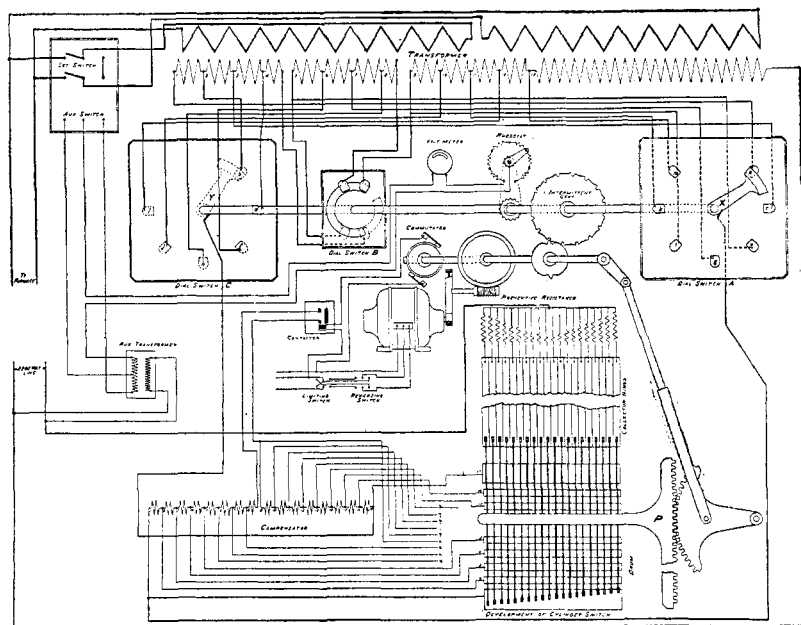


Fig. 5.

the furnace room and in the northwest corner of the station is a 2-phase motor panel.

The switchboard panels are standard single-phase panels, 24 inches wide, constructed of slate, made by the Westinghouse Electric & Manufacturing Company. Each panel is equipped with an automatic, 2-pole, type B circuit-breaker, knife-switches and meter. Above each panel on the wall are water switches consisting of an iron tank lined with a section of sewer tile 24 inches in diameter.

The regulating transformers are four in number and bear the name of the Westinghouse Electric and Manufacturing Company. They are of the oil-insulated, water-cooled type, each with a capacity of 1,600 kw., 80 to 300 volt secondary. Two of these regulators, as mentioned before, are located in the transformer station, the other two being located in transformer houses in the furnace room.

The regulators are what is known as a unit-switch type of potential regulator, being of special design for handling heavy currents. The regulator consists of a number of electrically operated switches controlled from a master switch located in front of the control panel. The transformer windings are divided into sections and two floating coils are provided which are connected to various taps on the main auto-transformer. These floating coils have intermediate steps and the successive operation of the switches connect the floating coils in proper sequence to the main auto-transformer and transfers the line connection

from one point of the floating coil to the next. The master switches are arranged with an automatic lock to prevent their being opened too rapidly. The magnet switches themselves are so interlocked that the proper sequence of operation is insured. The main contacts are oil-immersed and entirely enclosed, making them dust-proof.

Low-voltage control cables in underground ducts connect the master switch to the regulator, the control current being supplied from the two small motor-generator sets located in the transformer house.

In addition to the regulating transformers the Carborundum Company operates two 1,500 kw. oil-insulated, water-cooled transformers with 2,200 volt primary and 100 volt secondary, manufactured by the Westinghouse Company. These units are connected to panels in the transformer room. There is no receiving panel in the station, each single-phase circuit connecting directly to a single-phase transformer panel.

Motor power is obtained from a bank of transformers located in a shed near the furnace room, consisting of four 150 kw. General Electric oil-insulated, water-cooled transformers with 440-volt secondaries.

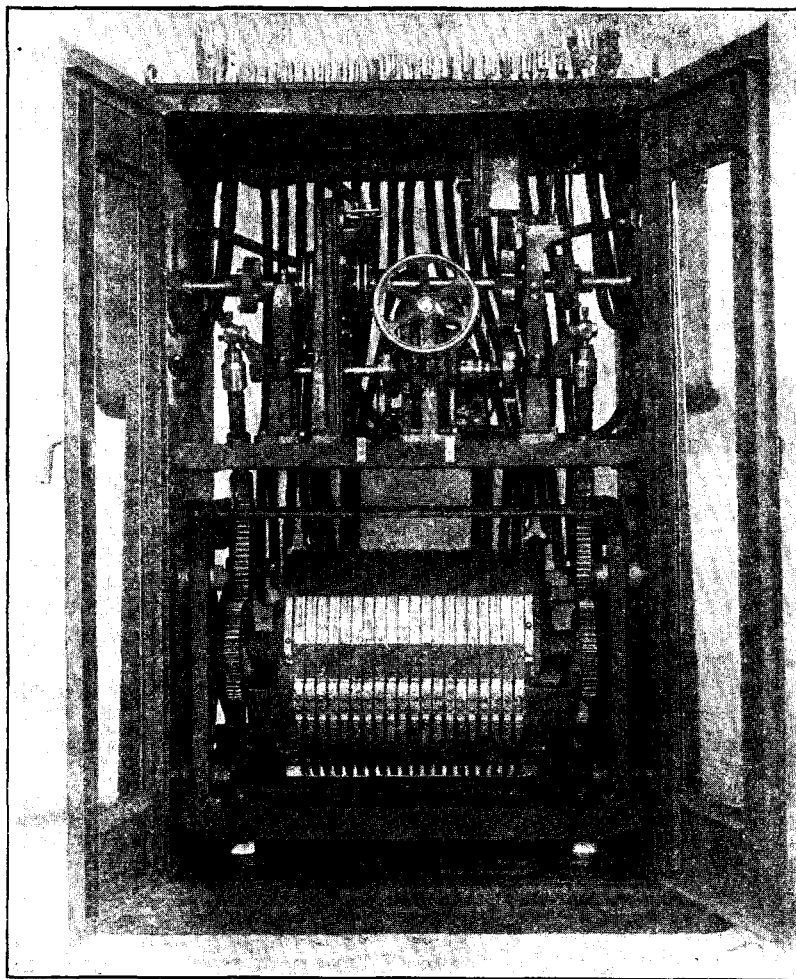


Fig. 6.

The No. 1 plant of the Carborundum Company is supplied from a small step-down transformer station in the basement of the mould building, consisting of two 150 kw. and six 50 kw. transformers, oil-insulated and self-cooled, made by the General Electric Company and one 75 kw., oil-insulated, self-cooled, Wagner transformer. The 75 kw. transformer is used for lighting, and has a ratio of 2,200 to 110,220 volts. The other transformers supply power to motors and have 440-volt secondaries. A 2-phase standard Westinghouse panel controls the incoming power, which is supplied from No. 1 generating station of The Niagara Falls Power Company by two duplex No. 2/o paper and lead cables.

#### NIAGARA LEAD COMPANY.

The transformer station of the Niagara Lead Company, situated in the south end of the main building, is supplied with power by The Niagara Falls Power Company by a 2-phase, 2,200 volt underground feeder system, consisting of two 3/o duplex paper and lead cables.

The incoming cables connect to a receiving panel mounted with four disconnecting switches and two 2-pole, automatic Westinghouse type B circuit-breakers. From the receiving panel the power is carried to the motors and transformers by conductors mounted on the walls on porcelain insulators.

Direct current power is obtained from two Westinghouse motor-generator sets, each consisting of a

motor belted to an overhead line shaft, which supplies the main shop with mechanical power. This motor is protected by a panel mounted with General Electric expulsion-type fuses.

On the west wall of the station are mounted two

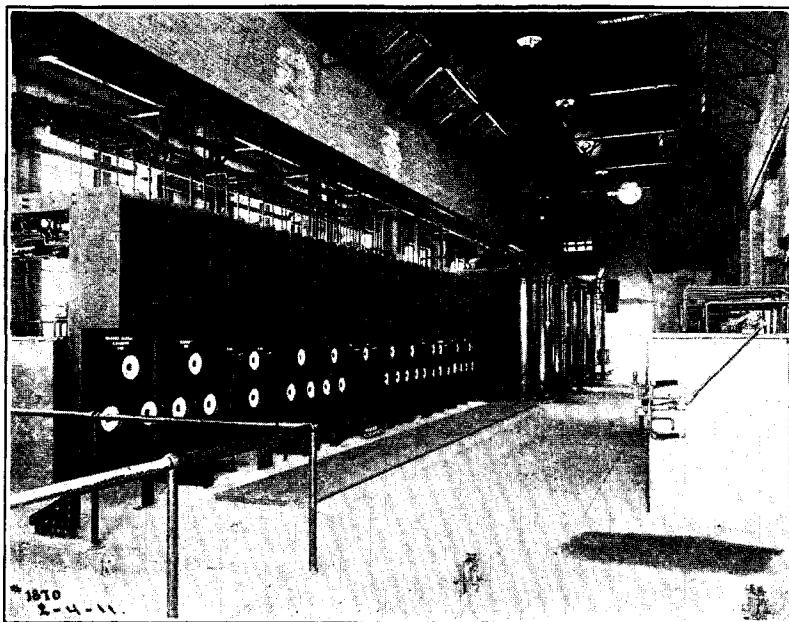


Fig. 7.

kw., oil-insulated, self-cooled, and four 5 kw., air-cooled, Westinghouse transformers, with 110-volt secondaries used for lighting. These transformers are also protected by General Electric expulsion fuses.

Each motor-generator set is provided with a motor and generator panel. The panel controlling the motor is located on the east side of the station between the wall and induction motor; ammeters, an oil-switch, auto-starter, and 4-pole, air-break circuit-breakers are mounted on the panel.

The direct current panels are located on the opposite side of the room near the west wall. Each panel is equipped with meters, field-rheostat handle, knife-switches and circuit-breakers. The direct-current power is carried to the cell-room by underground cables.

#### CASTNER ELECTROLYTIC ALKALI COMPANY.

Power in the form of 2-phase, 2,200-volt, 25-cycle current is delivered to the Castner Electrolytic Alkali Company at three stations located in their Niagara Falls plants.

Transformer Station No. 1 has a capacity of 1,375 kw. made up of eleven 125 kw. Westinghouse rotary converters, 500 r. p. m., 2-phase, 25-cycle, with Wagner step-down, air-blast transformers, each with a capacity

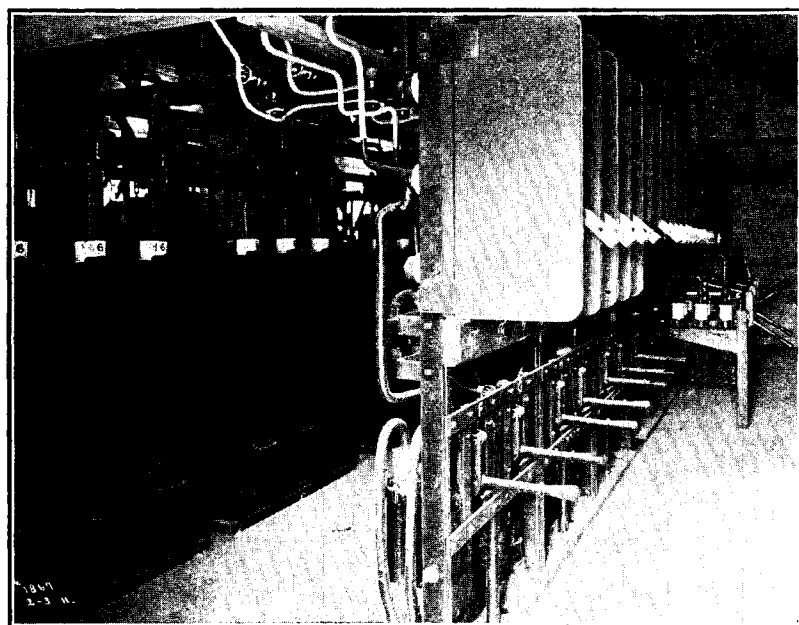


Fig. 8.

300 h. p., 2-phase, 2,200 volt, 487 r. p. m., induction motor, direct-current to a 187.5 kw., 125-volt, compound-wound, direct-current generator. In addition to the motor generator sets the station contains a 60 h. p., 2-phase, 2,200-volt Westinghouse induction

of 100 kw. These transformers have a secondary regulation of 30 volts, accomplished by means of a dial switch regulator in the primary circuit. The transformers are single-phase and are connected two in a bank to each rotary. The station is rectangular



in shape with the rotary converters occupying the south side and the transformers the north side. The switchboard arrangements consist of single panels mounted opposite each unit between the transformers and rotary converters. The panels are made of white



Fig. 9.

marble equipped with plug-type switches and fuse-blocks. A dial-switch with glass cover is mounted on the lower part of the panel.

In the east end of the station is located a receiving panel to which is connected eight single-conductor, lead-sheathed cables. The receiving panel is equipped with knife-switches and carbon-break circuit-breakers. There are no low-tension switchboards in the station, the direct current power being carried directly from the rotary converters to the cell room. In addition to the rotary converters the station contains four 25 kw., oil-insulated, self-cooled, Westinghouse transformers with 220-volt secondaries, which supply power to motors.

Transformer Station No. 2 has a capacity of 4,000 kw., consisting of eight 500-kw. Stanley synchronous-motor, direct-current generator sets, the motors being 2-phase, 2,200 volts and rated at 580 kw. The sets are arranged four in a row on each side of the transformer room. On opposite sides of the room, between the wall and motor-generator sets, are two eight-panel marble switchboards made by the Stanley Manufacturing Company. Each switchboard consists of four alternating-current panels and four direct-current panels, mounted side by side. The alternating-current panels are equipped with oil circuit-breakers, Stanley hot-wire ammeters and field ammeters. The direct-current panel is equipped with Weston ammeter, voltmeter, knife-switches, and circuit-breakers. Supported on brackets in the rear of

the switchboard are both alternating and direct-current bus-bars. Located in the northwest corner of the station is the main-line panel, equipped with eight knife-switches and carbon-break circuit-breakers. The incoming cables, eight in number, have a cross section of 1,000,000 cir. mils. (506 sq. mm.) each and are capable of transmitting approximately 8,000 h. p.

Motor power for the No. 2 station is obtained from six 50-kw. Wagner transformers with 2,200-volt primary and 220-volt secondary. A 75-kw., oil-insulated, self-cooled, Wagner transformer supplies power for lighting. These transformers are controlled from a panel equipped with oil circuit-breakers.

No. 3 station of the Castner Company is equipped with an 800-kw. General Electric, oil-insulated, water-cooled transformer with 2,200-volt primary and 144-volt secondary. Connected in the secondary circuit is a potential regulator capable of varying the voltage from 85 to 225 volts. The regulator is oil-insulated, water-cooled, and of same make as the transformer. A single-phase slate switchboard is mounted in the station in front of the transformer. The switchboard is equipped with knife-switches, oil circuit-breakers, indicating meters and watt-hour meters. The primary circuit is opened and closed through a water-switch, mounted on the wall above the transformer.

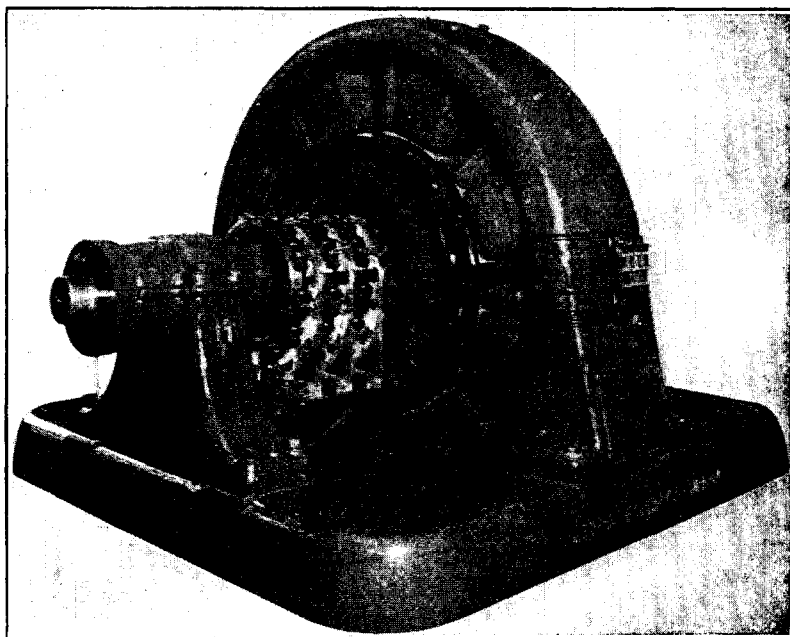


Fig. 10.

THE NORTON COMPANY.

The electrical equipment of the Norton Company at its Niagara Falls, N. Y., works is typical of the equipment of several plants in the Niagara district. Power is received at a switch house from which it is

distributed to step-down transformers located in bays along the side of the furnace room.

In the switch house are located a marble receiving panel mounted with disconnecting switches, two double-pole, General Electric, K<sub>3</sub>, oil circuit-breakers, a motor and light panel equipped with knife-switches and General Electric expulsion fuses, and a transformer panel. Adjacent to the switch house is a transformer bay containing a 1,500-kw., oil-insulated, water-cooled, Wagner transformer with 2,200-4,400-volt primary and 110-220-volt secondary, with a water-switch mounted on the wall above the transformer. The panel for this transformer is located in the switch house.

Attached to the furnace room on the same side as the switch house are two bays containing 750-kw. units, together with control panels and water-switches. One of these transformers bears a Westinghouse name plate, the other a General Electric. Both units have a ratio of 2,200 to 110 volts, and are of the oil-insulated, water-cooled type. The bays are connected to the switch house by a pair of single-conductor, lead-sheathed cables with taps at each bay.

In the north end of the main building are located the lighting and motor transformers, consisting of two 30-kw. and two 10-kw., oil-insulated, self-cooled, Westinghouse transformers with 110- and 440-volt secondaries.

Power is supplied to the Norton Company from No. 2 generating station of The Niagara Falls Power Company by a two-phase, 2,200-volt feeder system, consisting of two 500,000 cir. mil. (253 sq. mm.) and two 1,000,000 cir. mil. (506 sq. mm.) lead-sheathed

#### UNION CARBIDE COMPANY.

The plant of the Union Carbide Company at Niagara Falls, N. Y., is of interest both on account of its size and on account of the great amount of power transformed by it for electrochemical purposes.

Power is distributed to the Union Carbide Company

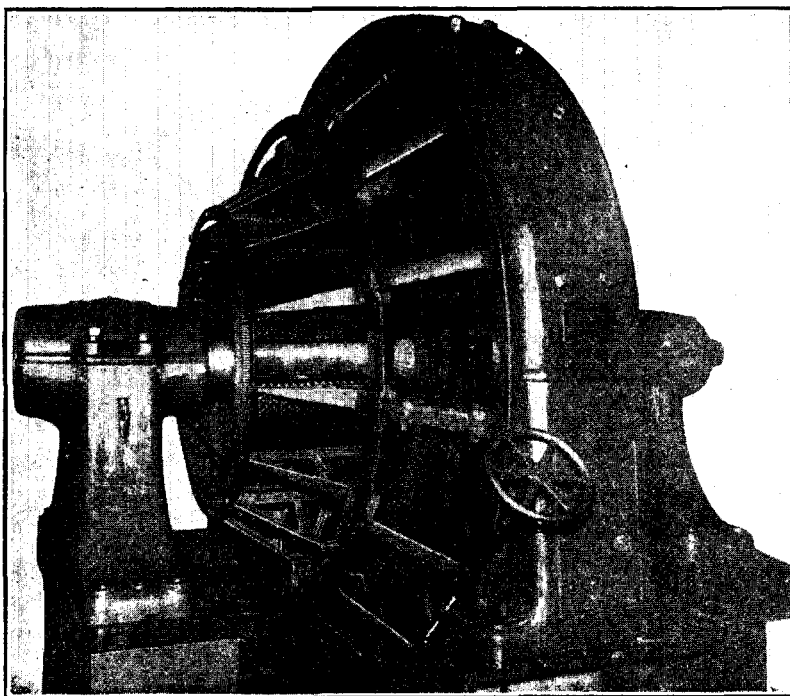


Fig. 11.

by The Niagara Falls Power Company and by the Cliff Electrical Distributing Company, from sub-stations located near the Carbide Works.

The Union Street sub-station of The Niagara Falls Power Company is located on the west side of the Carbide Company's No. 1 plant at a distance of about 60 feet. This station is used as a switching station and as a step-down station, being equipped with switch-board panels, oil circuit-breakers, and step-down transformers (Fig. 7).

The sub-station of the Cliff Electrical Distributing Company is located midway between the No. 1 and No. 2 plants and contains switching apparatus only.

In the plants of the Carbide Company, widely separated from the sub-stations, are the large low-voltage step-down transformers which supply power to the furnaces. Some of the transformers have 2,200-volt primaries and others 11,000-volt primaries. They are all of the oil-insulated, water-cooled type, the cooling water being procured from city mains.

Practically all of the 11,000-volt units have a double source of supply for their power. Bricked in the wall of the transformer bay is a marble slab mounted with a double-throw knife-switch, the middle point of which is connected to the transformer, the jaws of one side

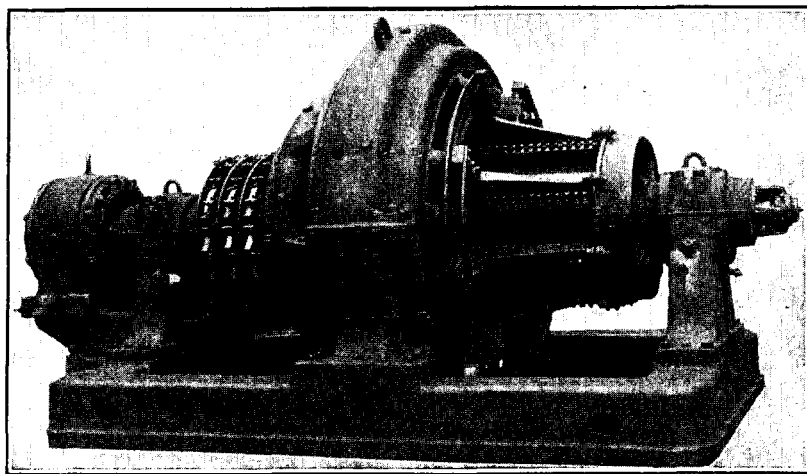


Fig. 12.

cables. The secondary current of the three furnace units is carried to the furnace room by copper bus-bars interlaced up to the furnaces. Each furnace is equipped with an indicating ammeter mounted on the wall opposite the furnace.



being connected to The Niagara Falls Power Company's circuits and those on the other side to the Cliff Electric Distributing Company's circuits.

The Union Street sub-station of The Niagara Falls Power Company has a capacity of 52,000 h. p., made up of four 1,870-kw. step-down General Electric transformers, two 11,000-volt switchboards, and one 2,000-volt switchboard, and supplies power to all of the plants in the immediate vicinity, including that of Union Carbide Company. Power is delivered to the station by eleven 3/0, 3-conductor, paper and lead cables, and a 3-phase, 500,000 cir. mil. (253 sq. mm.) aluminum overhead transmission line, both of which feed into a double bus-bar system through panels mounted with double-throw selector switches.

The switching apparatus which controls the carbide units is of two kinds: 2,000-volt and 11,000-volt apparatus. The 11,000-volt units are fed from panels equipped with ammeters, switch-handles, and double-

automatic, oil, circuit-breakers. From the knife-switches the circuits pass through the oil-switches to knife-switches and thence to bus-bars mounted on a maple framework.

The outgoing cables are connected to the bus-bars through knife-switches and non-automatic oil circuit-breakers.

#### NIAGARA ALKALI COMPANY.

The new transformer station (Fig. 9) of the Niagara Alkali Company will have, when completed, a capacity of approximately 1,500 kw., made up of two 705-kw., rotary converters, 6-phase, 375 r. p. m., direct-current voltage, 205 to 235 volts—one manufactured by the General Electric Company (Figs. 10 and 11) and the other by the Westinghouse Electric and Manufacturing Company (Fig. 12). The General Electric unit is known as a regulating-pole rotary converter, the direct-current voltage being varied by changing the excitation of the auxiliary poles. The Westinghouse unit regulates the direct-current voltage by a synchronous regulator mounted on the same shaft as the rotary converter, and connected between the armature-windings and collector-rings. Both these rotary converters have high synchronizing power and will not drop out of step when the alternating current voltage is dropped to 40 per cent. of normal.

Power is received over a 3/0, 3-conductor, 11,000-volt, paper and lead-covered cable from the Union Street sub-station of The Niagara Falls Power Company, and stepped down in 3-phase, 870-kw., oil-insulated, water-cooled transformers to a voltage suitable for the rotary converters.

The high-tension switching apparatus consists of four 3-phase, automatic, K4, 15,000-volt General Electric oil circuit-breakers, mounted in cells, constructed of pressed brick ranged along the west wall of the transformer station. One switch controls the main-line, the other three are unit switches for control of the two rotary converters and a bank of

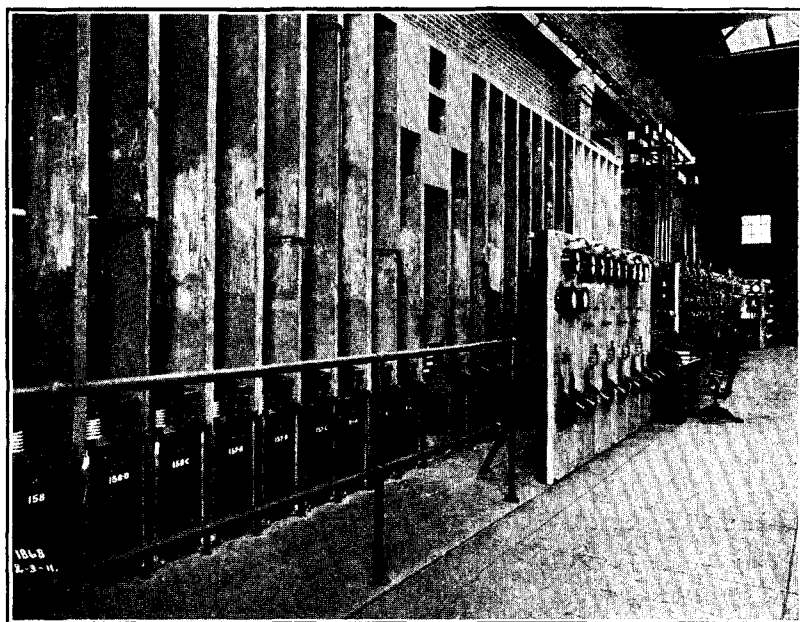


Fig. 13.

throw, single-pole knife-switches mounted on electrode insulators. The brick cells containing 2-pole, General Electric, K4, oil-switches are mounted back of the panels along the wall. Each unit is connected to the station by a duplex paper and lead cable laid in underground ducts.

The 2,000-volt units are fed from a switchboard on the east side of the station. Each unit is connected to a single-phase panel mounted with ammeters, oil circuit-breakers and selector-switches.

The sub-station of the Cliff Electrical Distributing Company consists of a one-story brick building with basement. Power enters the station at a pressure of 12,000 volts over five 3-conductor, paper and lead cables through ducts at the South end of basement (Fig. 8).

Each cable terminates in a pot-head, thence passes up to the main floor to knife-switches mounted in compartments in the rear of type C, Westinghouse-

motor and light transformers. Above the oil switch cells is an iron-pipe structure carrying the bus-bars, meter-transformers and disconnecting-switches. The bus-bars consist of heavy insulated rubber and cambric cables, mounted on petticoat insulators. Switch-handles for operating the oil-switches are mounted on the side walls of the brick cells. A main-line disconnecting panel is fastened to the wall directly above a man-hole in the northwest corner of the station. Between the rotary converters and transformers are two starting panels mounted with 3-pole, double-throw knife-switches. On the east side of the room is a low-tension switchboard consisting of slate panels 24 inches wide. Two panels control the direct-current side of the rotary converters, and are equipped with knife-switches, circuit-breakers, indicating-voltmeter and ammeters. The other panels contain the high-tension indicating-meters and watt-hour-meters.

In addition to the rotary converters the station

will contain two 25-kw. and two 50-kw., oil-insulated, self-cooled, General Electric transformers with a ratio of 11,000 to 460 volts, for motor power, and a lighting transformer of 15-kw. capacity, oil-insulated, self-cooled, made by the General Electric Company, with a secondary voltage of 115 to 230 volts. All the low-tension wiring is carried underground in fiber conduit. An overhead crane of 10 tons' capacity serves the station. A pit is excavated in the north-west corner of the station, so that transformers can be readily dismantled and repaired.

#### HOOKEE ELECTROCHEMICAL COMPANY.

The power station of the Hooker Electrochemical Company, recently reconstructed and enlarged, presents a good example of concrete construction as applied to switchboard work (Fig. 13). The station is located in a brick building with a basement floor. Power enters the building in the form of 3-phase, 11,000-volt, 25-cycle current, over two 3-conductor, 3/0 lead-sheath, paper-insulated cables which separate into six single-conductor cables in the basement and thence pass up through the floor to disconnecting switches mounted in concrete cells on the main floor. On the south wall of the building is located the concrete structure which contains the oil-switches and bus-bars. The cells containing the Westinghouse type E oil-switches are built on the floor. Above them are the disconnecting-switch and bus-bar compartments, the latter running lengthwise of the room. The bus-bars consist of bear wire, 4/0 in cross section, mounted on petticoat insulators. The oil switches are remote-control, hand-operated, 300-ampere capacity. The high-tension switchboard panels, six in number, are of blue Vermont marble and are equipped with power-factor meters, ammeters, and switch-handles. All the meter-transformers are mounted in concrete cells, the low-tension circuits of these transformers being carried to the switchboards in iron conduits.

The 11,000-volt current is stepped down by 300 and 400 kw. oil-insulated, water-cooled, single-phase Westinghouse transformers, located in a bay on the north side of the station. The 300-kw. transformers have a ratio of 11,000 volts to 198 volts and are connected in *delta*, supplying power to rotary converters. Some of the 300-kw. transformers are arranged for 3-phase to 2-phase transformation and have a secondary voltage of 2,200 volts. The 400-kw. transformers have a secondary voltage of 220 volts, and are used for lighting and motor power.

Direct-current power is obtained from Westinghouse booster-type rotary converters (Fig. 14), 6-phase, 375 r. p. m., direct-current voltage 230 to 320; and from Burke Electric motor-generator sets consisting of 720 h. p. synchronous motors, 2-phase, 2,200-volt, 375 r. p. m., direct connected to 500-kw., 250-volt direct-current generators, and 360 h. p., 2-phase, 2,200-volt synchronous motors, direct connected to

250-kw., 125-volt, 500 r. p. m., direct-current generators. The synchronous motors are excited by two Burke Electric exciter sets consisting of a 90 h. p. induction-motor, 2-phase, 2,200-volt, direct connected to a 60-kw., 125-volt, 720 r. p. m., direct-current generator. All the machines in the station are arranged so that they can be operated in multiple on the direct-current side, a direct-current bus-bar being carried along the rear of the low-tension switchboard. Each machine is controlled by a low-tension panel which is equipped with circuit-breakers, knife-switches and ammeters. The Burke Electric machines are controlled on the 2,200-volt side by panels equipped with oil-switches.

The low-tension circuits of the motor and light-transformers are carried to six panels mounted with four-pole knife-switches and cartridge fuses. A 2,200-volt receiving panel through which power was formerly supplied to the Burke machines is still in service, being used as a spare. The rotary converters are

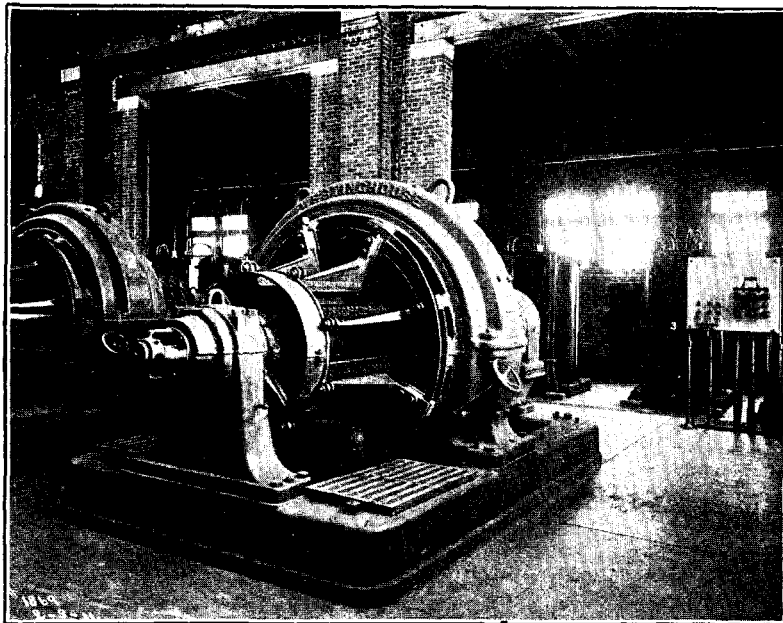


Fig. 14.

synchronized by small induction-motors mounted on the end of the shaft. A low-tension starting panel, mounted with two 3-pole knife-switches, is connected in the circuit between the transformers and alternating-current side of the converters. All of the 11,000-volt apparatus was furnished and installed by the Westinghouse Electric and Manufacturing Company.

#### NIAGARA ELECTRO-CHEMICAL COMPANY.

The transformer station of the Niagara Electro-Chemical Company is of interest in that it contains several different types of apparatus, each of which performs the same service, but in a slightly different manner.

The function of the station is to change the 2-phase, 2,200-volt, 25-cycle current received from The Niagara Falls Power Company into direct-current power. To perform this transformation the station is equipped with three different types of apparatus, namely, rotary converters with regulating transformers, in-

duction motor-generator sets, and synchronous motor-generator sets.

The transformer station is a large roomy brick building situated on the east side of the cell room. The general scheme carried out in the station is that of locating the transformer units on the center line

panel on both the low-tension and high-tension side. The induction-motor-generator sets are of standard design made by the Westinghouse Company. Each set is connected to two marble panels mounted with the usual instruments and switches.

The synchronous-motor-generator sets are made up of three units, two direct-current generators connected to opposite ends of a synchronous-motor. Each machine is connected to a separate panel mounted with meters and circuit-breakers. The switch-board is of blue Vermont marble, designed and installed by the Westinghouse Electric and Manufacturing Company.

THE UNITED STATES LIGHT AND HEATING COMPANY.

Located in the north end of the City of Niagara Falls is The United States Light and Heating Company, which has just completed a new transformer station designed by Dodge, Day & Zimmerman, of Philadelphia. When completed the station will contain four 750-kw. rotary converters, with necessary step-down transformers; two sets have already been installed (Fig. 15).

At the present time power is received from the Cliff Electrical Distributing Company by an overhead transmission line which will soon be replaced by

an underground cable system. Power enters the station in the form of 3-phase, 25-cycle current, at a pressure of 12,000 volts, and passes through General Electric disconnecting-switches mounted on insulators on a pipe framework adjoining the south

of the building with the switchboards along the walls, the receiving panels being located along the east wall and the unit panels along the west wall.

Power is delivered to the station by two 2-phase, underground feeder systems, one of which connects to a receiving panel in the south end of the station and the other to a panel in the north end of the station. A third feeder enters the building and connects to both panels. This feeder is considered a spare feeder and is used only in times of trouble on one of the other feeders. The panel in the south end receives its power from No. 1 generating station over four cables with a cross section of 1,000,000 cir. mils. (506 sq. mm.) each. The north end panel is supplied from No. 2 generating station, the cables having a cross section of 1,250,000 cir. mil. (633 sq. mm.)

Both of the receiving panels are of marble, and are equipped with eight knife-switches, single-throw, single-pole, and two double-pole Westinghouse type B, automatic circuit-breakers. From the receiving panels the power is carried to the unit panels through underground ducts in the floor of the station. The rotary converters in the south end of the station are equipped with starting motors and polyphase Stillwell regulators in the primary of the transformer circuits. The static transformers are of the oil-insulated, self-cooled type, both rotary converters and transformers being made by the Westinghouse Company. Each rotary is connected to a marble

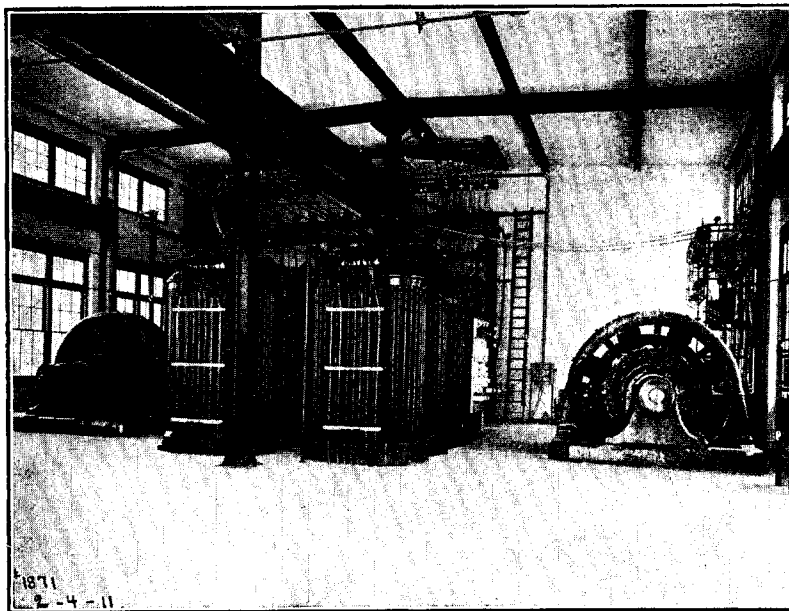


Fig. 15.

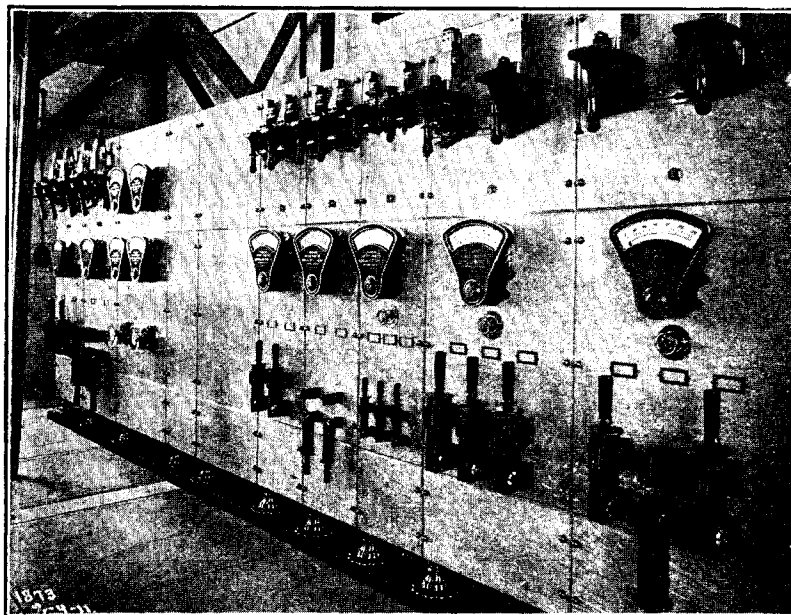


Fig. 16.

wall of the station. On each side of this iron structure are mounted meter-transformers and fuses. From the disconnecting switches circuits are carried overhead to choke-coils located on a pipe framework

mounted on top of a 3-pole, cell-type, K-12, General Electric, 15,000-volt, oil circuit-breaker. From this support the circuits pass through the oil-switch to a bus-bar system mounted directly over the static

primaries, Y-connected, and 199-volt secondaries, step-down the current for use in the rotary converters. The secondary leads of the transformers are carried to the starting panels, thence to the rotary converters through underground trenches on single-conductor, lead-covered cables.

The 750-kw., 6-phase, split-pole, 375 r. p. m., General Electric rotary converters with a direct-current voltage of 225 to 275 volts occupy space on each side of the station. The main and auxiliary field rheostats are mounted on angle iron framework near the rotary converters. Direct-current power from the rotary converters is carried to a switchboard in the east end of the station through underground ducts by single-conductor lead-covered cables.

The direct-current switchboard (Fig. 16) consists of ten blue Vermont marble panels  $2\frac{1}{2}$  inches (6.2 cm.) thick, made by the Fort Wayne Electric Works. On the left-hand end, facing the switchboard, are two 30-inch (75 cm.) panels which control the direct-current side of the two rotary converters, each panel being equipped with two carbon-break circuit-breakers, two single-pole, single-throw, 5,000-ampere knife-switches, and a 6,000-ampere Thompson astatic am-

transformers supported on insulators on an iron framework.

In front of the K-12, oil circuit-breaker stands a blue Vermont marble panel equipped with Thompson horizontal-type ammeter, watt-meter, power-factor meter, time-limit relay, and switch-handle. General Electric meter-transformers are mounted on the framework above the oil-switch cells.

In the rear and at right angles to the main oil-switch structure facing in opposite directions, are two additional brick structures containing automatic, remote, control, 3-pole, 15,000-volt, K4, General Electric oil-switches, which control the primary circuits of the static transformers. Above each cell is a pipe framework on which is mounted meter-transformers.

From the main-line oil-switch the current divides and passes through each of the two oil-switches described above to the primaries of the two banks of transformers. Located in front of the switch-cells are three marble panels, one of which controls the oil-switch, another being a starting panel for a rotary converter, while the third has mounted upon it the neutral circuit-breakers. On the oil-switch panel are mounted Thompson voltmeter, ammeter, power-factor-indicator, time-limit relay and switch handle. On the starting panel are mounted a 2,500-ampere, 3-pole, double-throw knife-switch, and a 1200-ampere, 3-pole, double-throw, knife-switch. On the rear of this panel is mounted a 3-pole, carbon-break circuit-breaker in the middle point of the secondary winding of the transformers.

Two banks of transformers, each bank consisting of three 275-kw., single-phase, oil-insulated, self-cooled, General Electric transformers, with 6,930-volt

meter. Next to the rotary panel is a 36-inch (90 cm.) panel equipped with three 300-volt Thompson astatic voltmeters, one 10,000-ampere ammeter and two Sangamo watt-hour meters. Two vacant panels come next, one 18 inches (45 cm.) wide and the other

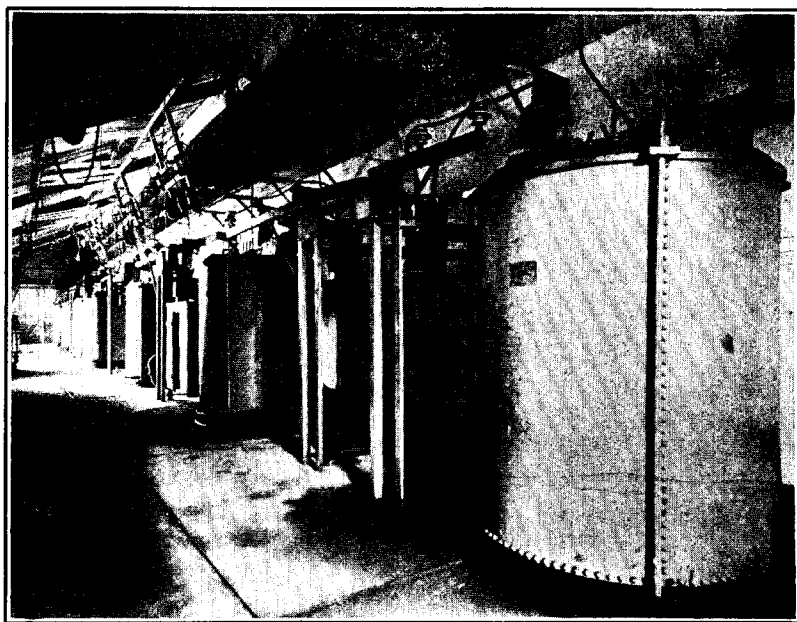


Fig. 17.

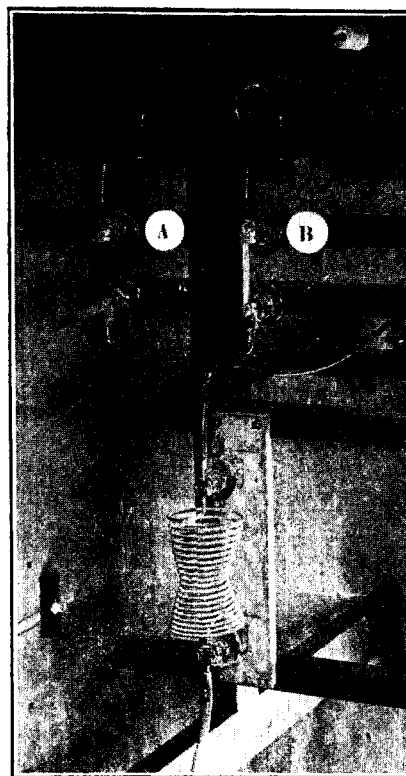


Fig. 18.

30 inches (75 cm.) wide, which have been reserved for booster controlling switch and instruments. A motor panel occupies the space beside the vacant 30-inch (75 cm.) panel. This panel is 18 inches (45 cm.) wide, and is mounted with two knife-switches, 1,500-ampere ammeters and two carbon-break circuit-

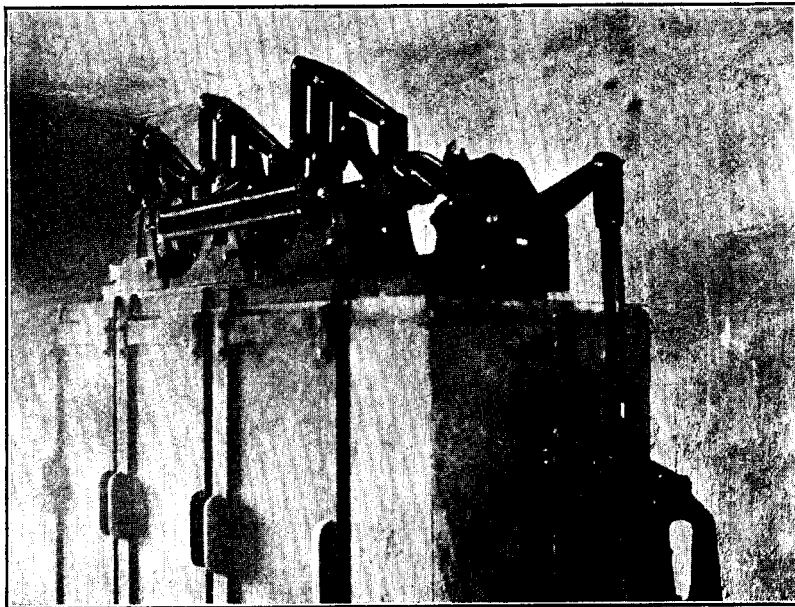


Fig. 19.

breakers. An 18-inch (45 cm.) fire-pump panel joins the motor panel, equipped with an 800-ampere ammeter, two single-pole, single-throw knife-switches and two carbon-break circuit-breakers. The eighth panel is an 18-inch (45 cm.) lighting panel, equipped with a 600-ampere ammeter, 2-pole circuit-breaker and a 3-pole, single-throw, 400-ampere knife-switch. The ninth and tenth panels are what is known as battery panels. These are each equipped with one 3,000-ampere ammeter, one 2-pole circuit-breaker and three 3,000-ampere, single-pole, single-throw knife-switches.

In the rear of the switchboard are located the copper bus-bars, three in number, constructed of 10 by  $\frac{1}{4}$  inch ( $25 \times 0.62$  cm.) copper bars. Three bus-bars are required, as the plant is operated on a three-wire system. From this switchboard the power is carried to the shops by insulated copper cables supported on an overhead pole line. The station is served by two overhead cranes of sufficient capacity to handle any unit in the station.

#### ELECTRO METALS COMPANY.

At Welland, Ontario, the Electric Metals Company has installed a modern transformer station which steps-down the high voltage current received from Niagara Falls to a low voltage suitable for furnace operation.

Power is received from Niagara Falls over two pole lines, each carrying two 3-conductor transmission lines which are dead-ended at a switch platform located

in the street outside of the Electro Metals Company's plant. From this structure the current is conducted into the plant over a single-pole line carrying two 3-conductor circuits which enter a brick switch room through porcelain tubes fastened in the wall and connect to knife-switches mounted directly inside on the wall. From the knife-switches the circuits are carried to bus-bars, thence through choke-coils to a 3-pole, type H, 13,000-volt Canadian General Electric Company oil circuit-breaker, mounted in a concrete cell on the main floor.

Mounted on the east wall is a meter panel containing three Westinghouse type F ammeters, watt-hour meters, and a Westinghouse graphic wattmeter. On the floor to the left of the meter board is a concrete structure containing the meter potential transformers and fuses. Westinghouse electrolytic lightning arresters protect the incoming lines.

From the bottom of the oil-switch the circuits pass along the west wall of the switch-house to the main transformer room, where they connect to bus-bars supported on three concrete shelves built in the wall above the transformers. On a shelf on the west wall of the switch-house are three 25-kw. Packard oil-insulated, self-cooled

transformers with a ratio of 12,000 to 220 volts, which supply power to the motor circuits. These transformers are protected by a General Electric 3-pole, K-4, oil circuit-breaker (Fig. 17).

In the main transformer room are located seven 750-kw. units with 12,000-volt primaries and 40-volt

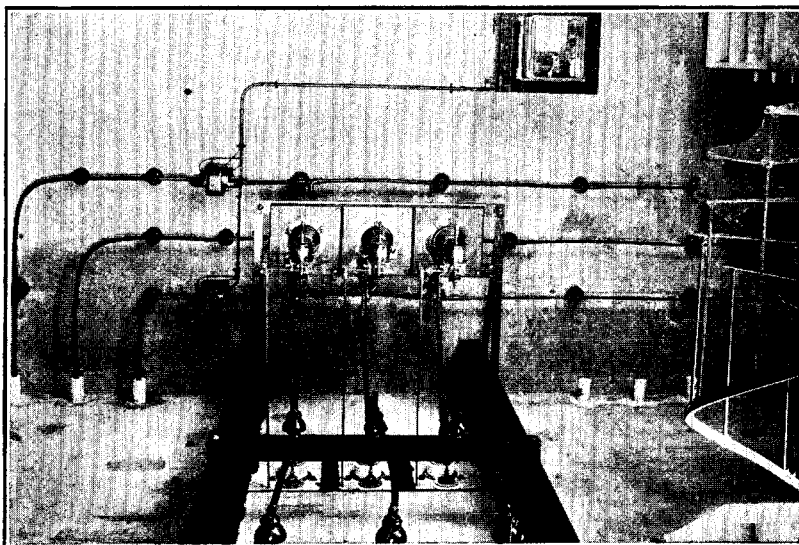


Fig. 20.

secondaries, oil-insulated, water-cooled, manufactured by the Packard Company. They are arranged in a line along the wall which separates the transformer room from the furnace room. Each transformer is controlled by a 2-pole, K-4, automatic remote-control, oil circuit-breaker in one leg of the circuit, the other



leg being connected to the bus-bar through a knife-switch. The circuit-breaker is mounted on a wooden framework alongside the transformer, and is controlled from the furnace room by iron connecting-rods. Knife-switches are mounted above the transformers, arranged to connect the transformers to any one of the three bus-bars, thereby keeping the load balanced. Copper bus-bars connect the transformers to the furnaces, the load on the furnace being regulated by a Thury regulator, manufactured in Geneva, Switzerland. A 500-kw. Packard water-cooled transformer is used for experimental purposes.

#### NORTON COMPANY.

The Norton Company has recently completed a new plant at Chippawa, Ontario, for the manufacture of crystolon. In this plant a modern transformer station has been installed whose function is to transform the high-voltage power generated by the Ontario Power Company at Niagara Falls to a lower voltage suitable for furnace work and induction-motor operation.

The transformer station proper is divided into two sections, namely, a room for the transformers and a room for the main-line switches, lightning-arresters, etc. The 3-phase transmission lines carried on the same pole line terminate in the switch-house and connect to knife-switches, cross-connected on the lower side so as to parallel the lines whenever both sets of switches are closed. From the knife-switches the current is conducted through choke-coils (Fig. 18) to a 3-pole, 300-ampere, form H4, 13,000-volt Canadian General Electric Company oil circuit-breaker (Fig. 19) mounted on a concrete cell on a gallery on opposite side of switch-house. This gallery is reached from the main floor by a spiral stairway.

On the ground floor and to the right of the knife-switches are located four cells of aluminum lightning-arresters with horn-type spark-gaps, designed and manufactured by the Canadian General Electric Company.

The oil circuit-breaker mentioned above is unique in that the time limit relays for tripping the switches are made to carry the full high-voltage current of the line instead of being energized from current transformers (Fig. 20).

The relays are mounted on porcelain insulators directly below the gallery floor, with a tripping-rod passing up through the floor to a toggle-joint on top of the switch. On the floor beneath the gallery in concrete cells are located meter-potential transformers and fuses.

From the oil-switch the circuits pass through a wall to bus-bars in the main transformer room. These bus-bars are constructed of insulated wire supported on brackets and insulators fastened to the wall adjoining the furnace room (Fig. 21).

The main unit consists of a 750-kw. transformer with induction regulator in secondary circuit. The

transformer<sup>23</sup> has a ratio of 12,000 volts to 145 volts, the regulator having a range of 75 volts up or down, which give a voltage variation on the bus-bars, of 75 to 215 volts. Both transformers are of the oil-insulated, water-cooled type, the transformer being built by the Canadian General Electric Company and the regulator by the General Electric Company.

The transformer is protected by a 2-pole, 300-ampere automatic, K4, Canadian General Electric, oil circuit-breaker mounted on an iron framework near the transformer. There are no walls or barriers between the switch-points, which are placed about two feet apart. Knife-switches connect the main unit to the bus-bars, and are arranged so that the transformer can be connected to either bus-bar. The 12,000-volt circuit is opened and closed through a water-switch, whose main elements consist of two

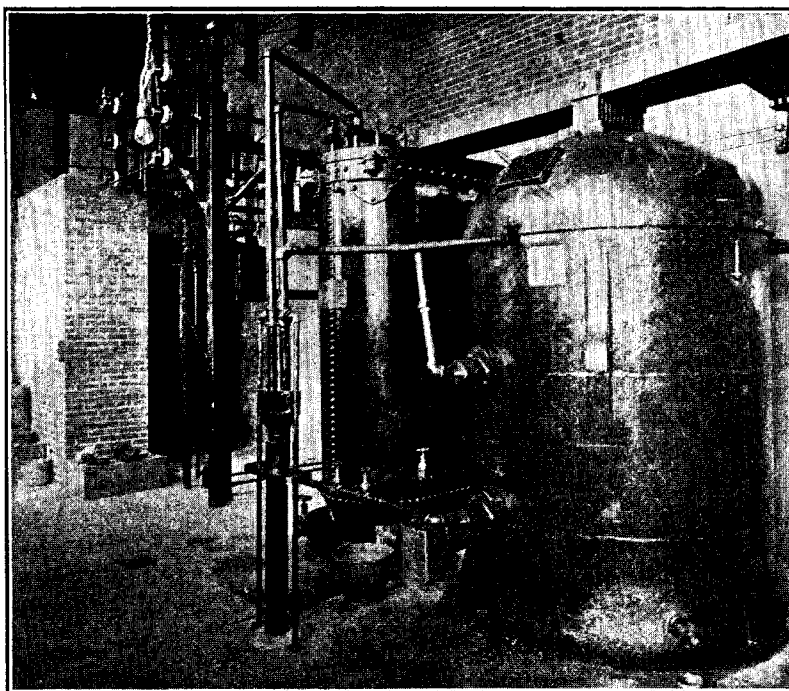


Fig. 21.

wooden barrels supported on porcelain petticoat insulators.

The motor load is provided for by three 40-kw., oil-insulated, self-cooled, Packard transformers, with 12,000-volt primaries and 440-volt secondaries connected in *delta*. A 3-pole, 300-ampere, automatic, K4, oil circuit-breaker mounted on pipe framework controls these transformers. A small transformer bearing the name of the Packard Company, with a capacity of 15 kw., 110- to 120-volt secondary, supplies power for lighting the plant. This transformer is protected by out-door, Canadian General Electric expulsion fuses. On a small panel in the furnace room are located the indicating meters of the main unit. The switch handles that operate the oil circuit-breakers are mounted on a small marble panel in front of the iron framework carrying the oil pots. The transformer room and main building are of concrete



construction. The apparatus was installed by the Norton Company.

### SMALL ELECTRIC FURNACE WITH HEATING ELEMENT OF DUCTILE TUNGSTEN OR DUCTILE MOLYBDENUM.<sup>1</sup>

By R. WINNE AND C. DANTSZEN.

Received September 23, 1911.

There are many uses for a simple furnace which can be run higher than the melting-point of iron, and in which substances can be heated without taking up either carbon or oxygen.

There have been a few special furnaces, electrically heated, which are capable of fulfilling these conditions. Of these, we may mention the following:

1. The iridium-tube furnace. This is very fragile and extremely expensive.

2. A carbon-tube furnace with a porcelain tube inside. This makes an excellent tube-furnace, but calls for special transformers.

3. The platinum foil or wire-wound body of fire-clay or other refractory. This has been to the average man the most easily accessible and most generally used form of small furnace for fulfilling the conditions. But it has its limitations. Most serious of these are the fact that the platinum is easily contaminated, and that, except for small sizes, the winding is very expensive. Besides, this much of the work for which these furnaces are used necessitates running the platinum perilously close to its melting-point.

4. The Arsem vacuum furnace,<sup>2</sup> in which a graphite heater is used to generate the heat and in which the oxidation is prevented by the vacuum. This introduces carbon when very high temperatures are used.

We will show in the following how two simple types of furnaces have been made with a winding of ductile tungsten or molybdenum. It is now possible to produce these substances in the form of wire or ribbon, and their high melting-points and relatively low cost adapt them admirably to the purpose.

#### CRUCIBLE FURNACE.

This consists of a helix of ductile tungsten or molybdenum, supported by an alundum tube and protected from oxidation by a hydrogen atmosphere. The container, for the charge to be heated, is a small crucible which is placed inside of the alundum cylinder.

The diagram, Fig. 1, shows the furnace in vertical section. *W* is the heating wire, of ductile tungsten or molybdenum. It is wound on *G*, an alundum cylinder which is molded plain inside and with a helical groove on its outer surface. *A* is a Battersea crucible. *B* is an inverted Battersea of which the bottom has been cut off. *C* is the crucible bottom, used as a cover. The bottom of *A*, as well as the space between *A* and *B*, is filled with powdered silica. Hydrogen is constantly supplied to the furnace through the pipe *D*, and burns as it escapes from the top of *B*. This gives a protecting atmosphere for both the tungsten or molybdenum winding and the object to be heated.

<sup>1</sup> Presented at the General Meeting of the American Electrochemical Society, Toronto, September, 1911.

<sup>2</sup> These Transactions, 9, 153-172 (1906); *J. Am. Chem. Soc.*, 28, 921-935.

Current is supplied to the winding through two large copper connectors, *E, E*.

An object to be merely heated, as for annealing, may be inserted directly into the alundum cylinder.

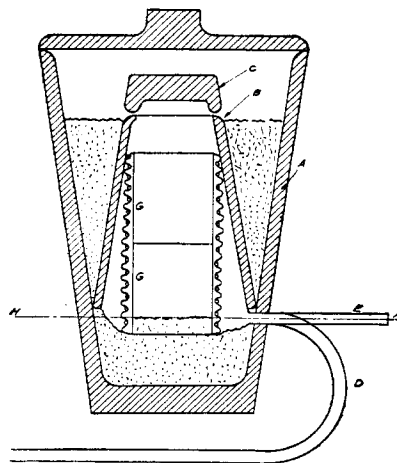


Fig. 1.

Material to be melted is placed in a small crucible, and this is let down into the alundum cylinder. An especially nice crucible to hold the charge is made of pure alumina.

A few dimensions and details of construction may be of interest.

In the apparatus shown in Fig. 1, the Battersea crucibles *A* and *B* are sizes *O* and *J* respectively. The alundum body *G* consists of two cylinders placed end to end. Each is 7.6 cm. high and 5.1 cm. inside diameter, while the distance from one convolution of the helix to the next is 0.95 cm. These alundum cylinders may be obtained from The Norton Company, of Worcester, Mass. The winding consists of 260 cm. square molybdenum wire, 1.27 mm. on a side. This wire is first wound on a mandrel 3.8 cm. in diameter, and wire and mandrel are then heated up to about 800° C. Upon then releasing the coil, it expands to the diameter of the alundum body, on which it can then be screwed. The copper connectors, *E, E*, are 0.8 cm. in diameter, and the ends of the coil are simply clamped in with set-screws. The copper connectors and the hydrogen inlet tube are held in place in the crucible wall by a mixture of powdered silica and water glass, which at the same time prevents loss of hydrogen.

This furnace can be safely run up to 1700° C. At this temperature it calls for 25 volts and 45 amperes.

We have melted pure iron and made many iron and other alloys in this furnace.

#### TUBE FURNACE.

This consists of a porcelain or alundum tube, wound with tungsten or molybdenum foil. Around the tube is a tight metal casing filled with powdered silica, and, to prevent oxidation of the winding, a hydrogen atmosphere is maintained in the casing.

Such a furnace is shown in the diagram, Fig. 2, in vertical length section. *A* is an alundum tube, 2.3 cm. inside diameter and 46 cm. long. The casing