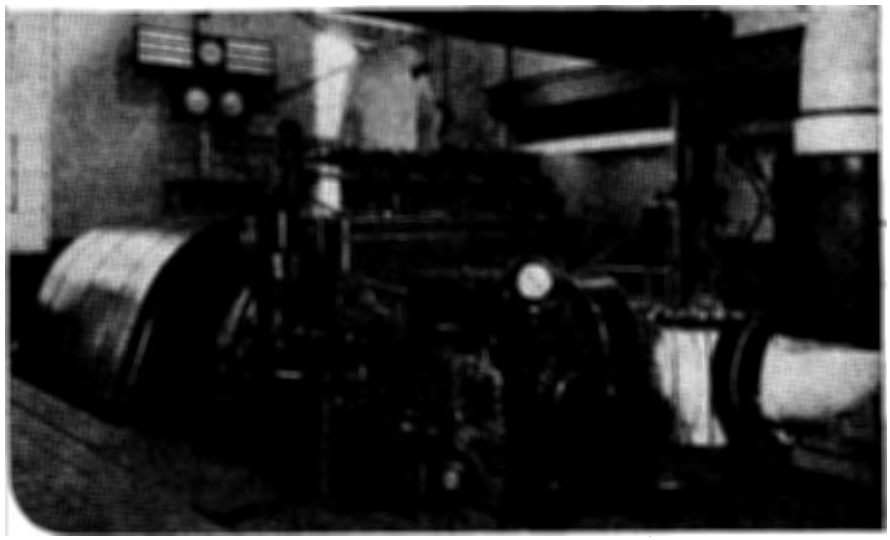


Fig. 1 — This 6,000-kw. turbine-generator operates with steam at 650-lb. and 750 deg. F. and exhausts into the low-pressure header at 210 lb. and 530 deg.

# "TOP" Cuts Coal Rate 42%

**By installing a 660-lb., 6,000-kw. "top" on a low-pressure plant, Rochester Gas & Electric Corp., reduced coal rate on a 21,000-kw. load from 1.9 to 1.1 lb. per kw.-hr. This is the first step in a progressive modernization program.**

ON THE power system of the Rochester Gas & Electric Corp., Rochester, N. Y., there are six steam-electric generating plants, with capacities ranging from 750 to 62,500 kw. Only the latter, known as No. 3, operates condensing. All the others exhaust into the company's extensive district-heating system, and therefore, heating- and process-steam requirements of this system determine their power output.

When in 1934 it became evident that more off-heating season power-generating capacity would soon be necessary, consideration was given to several possibilities. Of these, modernizing No. 3 plant with a high-pressure "top" proved to be the most economical. This plan would not only give maximum capacity for a given investment but also produce a kilowatt-hour at a lower cost than any other. For the present it saves all the investment in the old plant and makes its efficiency comparable with that of a modern station. The plan allows progressive modernization of the plant as new capacity is required without interfering with operation.

Plant No. 3 comprised 22 boilers, twelve having 8,700 sq.ft. and ten 6,000 sq.ft., of water-heating surface. Twenty are stoker- and two pulverized-coal-fired, all supplying steam at 200 lb. gage. Some of the boilers are more than 25 yr. old. Generating units include one 15,000-kw., four 10,000-kw. and one 7,500-kw. turbines.

Space was available at one end of the plant to build an extension to house two high-pressure units and use one of the present stacks. The first unit has been in operation for about four months. This unit comprises a boiler with a maximum continuous rating of 250,000 lb. of steam per hr. at 660 lb. and 750 deg. F. total temperature and a 6,000-kw. turbine-generator exhausting at 210 lb. and 530 deg. F. total temperature at full load.

The size of this unit was determined by the 15,000-kw. low-pressure turbine. Although the high-pressure turbine exhausts through a desuper-heater into the low-pressure steam main, it can serve as a "top" on the 15,000-kw. machine and the two operate as a 21,000-kw., 650-lb., 750-deg. condensing unit.

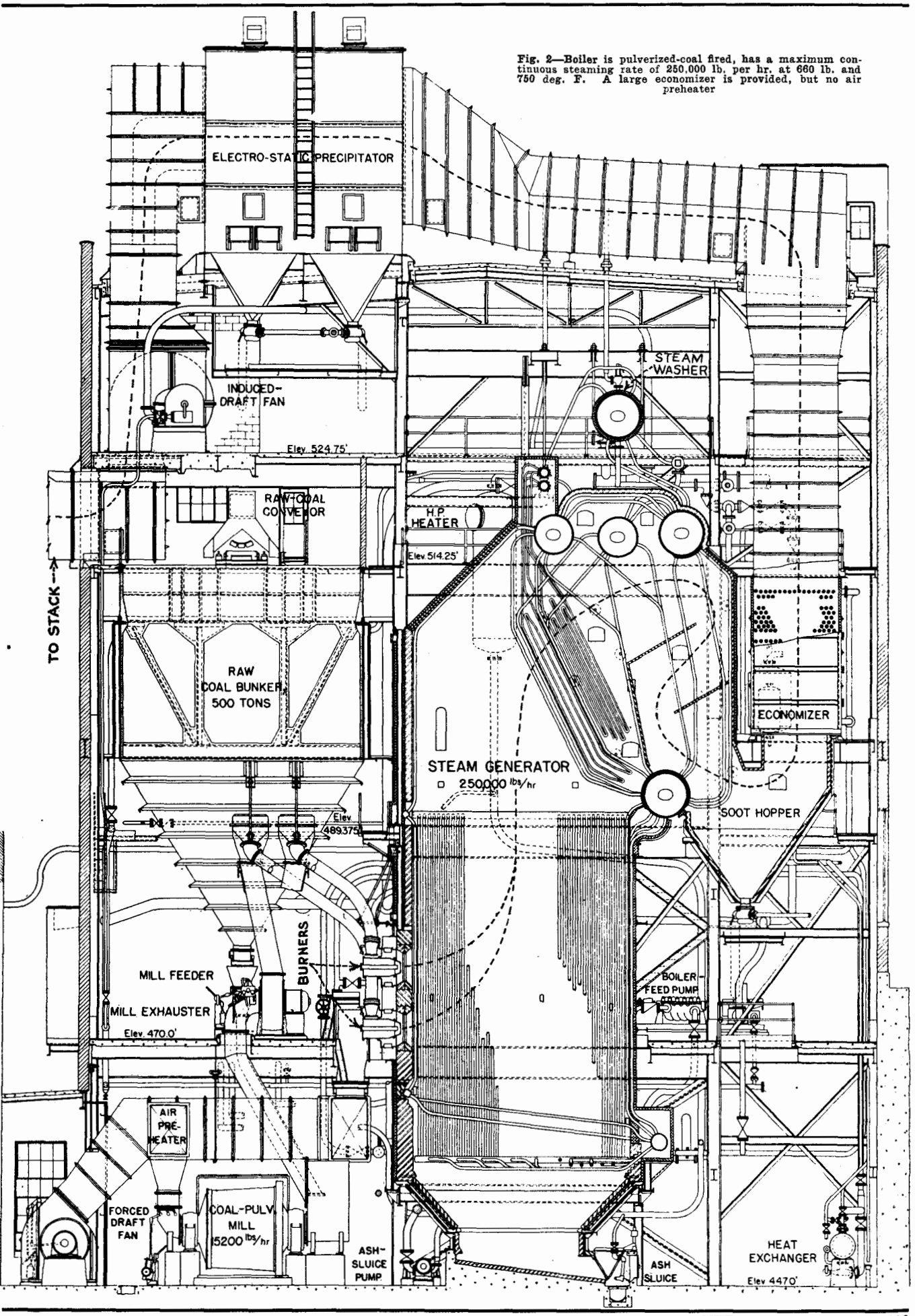
The second high-pressure unit will have a capacity of 7,500 kw., this being sufficient to act as a "top" for two 10,000-kw., low-pressure machines, the combination operating as a 27,500-kw. condensing unit. Future extensions will be made by replacing old boilers and turbines with high-pressure condensing units, as load increases require, until the whole plant is modernized.

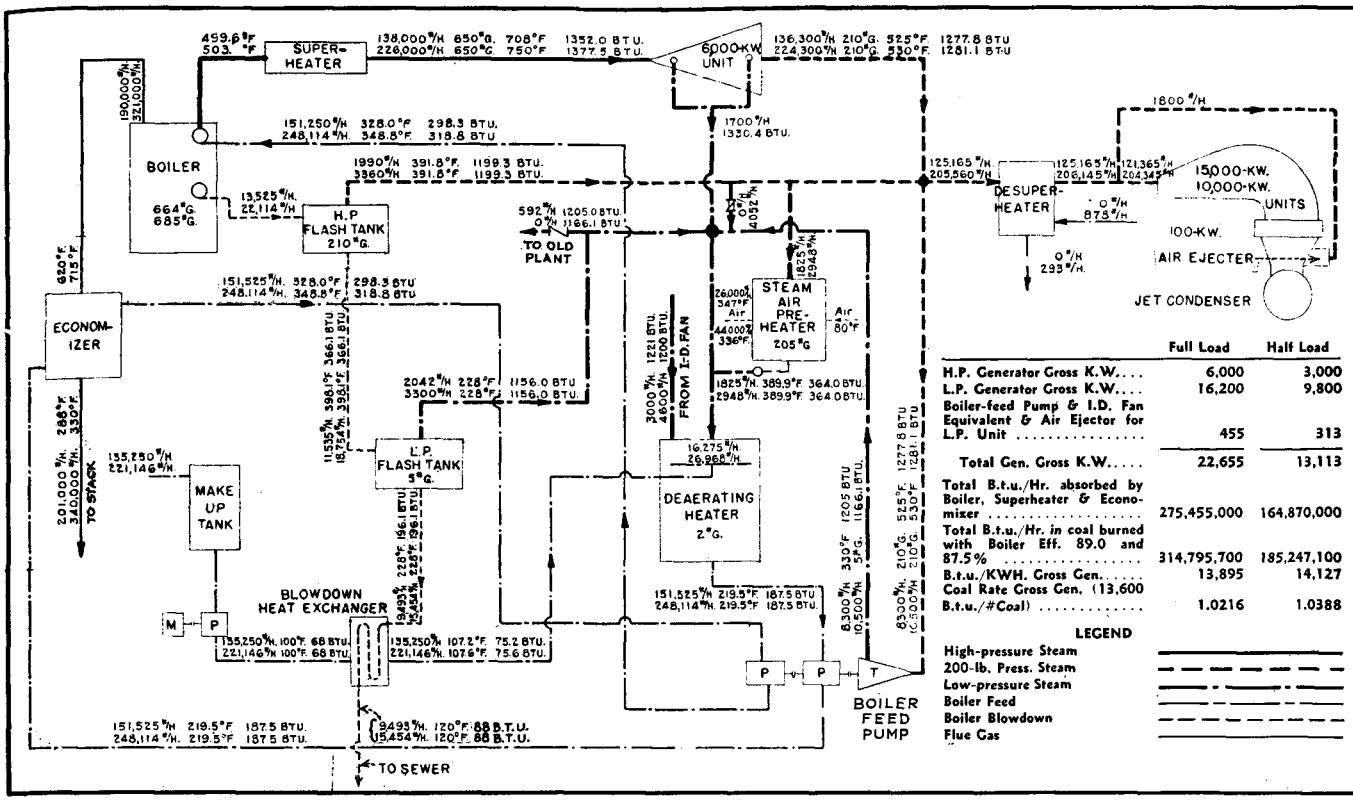
The new boiler, a cross-section of which is shown in Fig. 2, is of the 4-drum, bent-tube type, with a maximum continuous rating of 250,000 lb. of steam per hr. All drums are fusion-welded and X-rayed to insure proper fusion. A fifth drum for steam washing, 48 in. diameter and 23 ft. 7 in. long, connects with the upper rear steam drum by 34 3½-in. steam tubes, and in addition has six 3¼-in. feedwater tubes. The washer is designed to handle the maximum rating of the boiler when its water contains 3,000 parts of concentrates per million and deliver steam containing not more than 5 p.p.m.

The superheater comprises 24 two-loop semi-radiant elements, having 1,330 sq.ft. effective heating surface in lanes of the first boiler-tube bank. Installed behind this bank are 53 convection superheater elements with 3,120 sq.ft. of effective heating surface. Superheat in steam to the turbine is not controlled, but its exhaust is desuperheated to maintain 530 deg. automatically when entering the 200-lb. header.

A separate economizer is provided, but no air preheater, although both were considered. Either or both could have been used with about equal economy, consequently the more simple arrangement of one or the other

**Fig. 2—Boiler is pulverized-coal fired, has a maximum continuous steaming rate of 250,000 lb. per hr. at 660 lb. and 750 deg. F. A large economizer is provided, but no air preheater**






| | Full Load | Half Load |
|---|---|---|
| H.P. Generator Gross K.W. | 6,000 | 3,000 |
| L.P. Generator Gross K.W. | 16,200 | 9,800 |
| Boiler-feed Pump & I.D. Fan Equivalent & Air Ejector for L.P. Unit | 455 | 313 |
| Total Gen. Gross K.W. | 22,655 | 13,113 |
| Total B.t.u./Hr. absorbed by Boiler, Superheater & Econo-mizer | 275,455,000 | 164,870,000 |
| Total B.t.u./Hr. *in* coal burned with Boiler Eff. 89.0 and 87.5% | 314,795,700 | 185,247,100 |
| B.t.u./KWH. Gross Gen. | 13,895 | 14,127 |
| Coal Rate Gross Gen. (13,600 B.t.u./#Coal) | 1.0216 | 1.0388 |

LEGEND

High-pressure Steam
200-lb. Press. Steam
Low-pressure Steam
Boiler Feed
Boiler Blowdown
Flue Gas

**Fig. 3—Heat-balance diagram at one-half and full load for high-pressure "top" on 200-lb. plant**

## PRINCIPAL EQUIPMENT FOR NEW UNIT

### Rochester Gas & Electric Corp.

Boiler and water walls.....Combustion Engineering Co.
Boiler, heating surface, 15,300 sq.ft.; water walls, 3,990 sq.ft.; max. continuous steaming cap., 250,000 lb. per hr.; working pressure, 660 lb.g.; total steam temp., 750 deg. F.; furnace volume, 13,720 cu.ft.; max. B.t.u. liberated per cu.ft. per hr., 20,000.
Economizer, 20,808 sq.ft. .....Foster Wheeler Corp.
Superheater, 4,450 sq.ft. .....Superheater Co.
Steam washer, cap. 250,000 lb. per hr.
Combustion Engineering Co.
Boiler and furnace setting .....Combustion Engineering Co.
Furnace walls above water wall, DeWolf type of construction. Subcontractor for furnace walls.
Wm. Summerhays' Sons Corp.
Furnace refractories .....Harbison-Walker Co.
Boiler heat insulation .....Smith-Murray, Inc.
Boiler ducts and breechings .....Connery & Co.
Structural-steel contractor .....A. W. Hopeman & Sons Co.

**Combustion Equipment.**

Pulverized-coal burners, 4, arranged 2 high by 2 wide, cap. each, 7,600 lb. per hr.
Combustion Engineering Co.
Coal pulverizer, 2 ball mills, cap. each, 15,200 lb. per hr. .....Foster Wheeler Corp.
Pulverizers driven by 150-hp. 870-r.p.m. Westinghouse squirrel-cage motors through Bethlehem snub couplings and Falk gears.
Mill exhausters, 2 .....Foster Wheeler Corp.
Driven by 75-hp. Westinghouse squirrel-cage motors
Coal feeders, 2, vibrating type .....Jeffrey Mfg. Co.
Forced-draft fan, 69,000 c.f.m., 4.5 in. static pressure, adjustable-Vortex type .....Clarage Fan Co.
Driven by 75-hp. Westinghouse squirrel-cage motor through Bartlett-Hayward Co., Fast flexible coupling.
Induced-draft fan, double-width, double inlet..Clarage Fan Co. Driven by 200-hp. 3,645-r.p.m. Allis-Chalmers steam turbine, through Falk herringbone reduction gears and Bartlett Hayward Co., Fast flexible coupling. Speed adjusted by Bailey combustion control.
Steam air-heaters, 2; cap. each, 30,000 lb. air per hr. 80 to 347 deg. F., Aerofin type ....American Blower Corp.

**Coal and Ash Handling.**

Coal-handling equipment, apron feeder, belt and bucket conveyor, belt conveyor and tripper
Robins Conveying Belt Co.
Motor drives on coal-handling equipment
Westinghouse Elec. & Mfg. Co.
Motor control on coal-handling equipment
I-T-E Circuit Breaker Co.
Hammermill crusher .....Pennsylvania Crusher Co.
Crusher driven by 40-hp. Westinghouse motor through Bethlehem snub coupling.
Ash-handling equipment, Hydrojet on furnace bottom and Hydrovac on flyash system for economizer and electrical precipitator .....Allen-Sherman-Hoff Co.
Electrical soot precipitator, Cottrell type.....Research Corp.
Soot blowers, boiler 16, economizer 16
Diamond Power Specialty Co.

**Control and Valves.**

Water columns, 2.....Diamond Power Specialty Co.
Water-level indicator .....Diamond Power Specialty Co.
Floor level water column .....Diamond Power Specialty Co.
Water-level recorder .....Bailey Meter Co.
Feedwater regulator .....Bailey Meter Co.
Automatic combustion control .....Bailey Meter Co.
Safety valves .....Consolidated Ashcroft Hancock Co.
Blow-down valves .....Cochrane Corp.
Forged-steel needle valves.....Edwards Valve & Mfg. Co.
Non-return valves .....Edwards Valve & Mfg. Co.
Stop and check valves in feed line.....Lunkenheimer Co.
High-pressure valves .....Lunkenheimer Co.
Medium-pressure valves .....Reading Pratt & Cady Co.
Reducing valves.....Bailey Motor Co.
Electric valve operators, Limitorque
Philadelphia Gear Works
Piping .....W. K. Mitchell & Co., Inc.

**Feedwater System.**

Boiler feed pumps, 2, each comprising a primary and secondary pump in series. Primary pump, 642-ft. head, secondary pump 730-g.p.m., 1,485-head
Allis-Chalmers Mfg. Co.
Feed-pump drive, one 450-hp., 3,450-r.p.m. turbine
Allis Chalmers Mfg. Co.
Feed-pump drive, one 450-hp., 3,450-r.p.m. turbine
Moore Steam Turbine Corp.
Pump speed-regulating valves .....Bailey Meter Co.
Make-up water pumps, 2 .....Worthington Pump & Mach. Co.
Driven by 50-hp. Westinghouse motors.
Feedwater purification equipment .....Cochrane Corp.
Feedwater deaerating heater .....Cochrane Corp.
Continuous-blowdown equipment .....Cochrane Corp.

**Meters.**

Boiler-meter and control board .....Bailey Meter Co.
Turbine-meter and control board .....Bailey Meter Co.
Boiler meter .....Bailey Meter Co.
Steam-flow meter .....Bailey Meter Co.
Feedwater level recorder .....Bailey Meter Co.
Feedwater flow meter .....Bailey Meter Co.
Pressure gages, indicating .....Bailey Meter Co.
Pressure gages, recording .....Bailey Meter Co.
Thermometer, .....Taylor Instruments Companies
Temperature recorders .....Taylor Instruments Companies
Draft gages .....Bailey Meter Co.
$CO_2$ recorder .....Hays Corporation
Smoke-density recorder .....Bailey Meter Co.

**Turbine Room.**

Turbine-generator, one non-condensing 6,000-kw., 0.80-p.f., 3-phase, 60-cy., 11,500-v., 3,600-r.p.m., with direct-connected exciter.....General Electric Co.
Steam conditions 650 lb. 750 deg. F. at throttle, exhaust 210 lb. 535 deg. F. at full load.
Desuperheater on turbine exhaust .....Blaw Knox Co.
Desuperheater regulator .....Bailey Meter Co.
Generator air cooler .....General Electric Co.
Air-cooler water pump ....Worthington Pump & Mach. Corp.
Rotary strainer on house-service water.....Andale Co.
Oil cooler .....General Electric Co.
Oil purifier .....Sharples Specialty Co.
Station transformers ..... Allis Chalmers Mfg. Co.
Station lighting transformers .....General Electric Co.
Motor-generator, 5 kw., 125 volts .....Electric Products Co.
Generator oil circuit breakers .....General Electric Co.
Generator switchboard .....General Electric Co.
House switchboard .....I-T-E Circuit Breaker Co.
High-voltage cable ..General Electric Co. and Safety Cable Co.
Station auxiliary and lighting conductors
Kerite Insulated Wire Co. and Rockbestos Products Corp.
Electric elevator .....Graves Elevator Co.
Travelling crane, 15-ton ..Shaw-Box Crane & Hoist Co., Inc.

was preferable. If a large air heater had been selected, it would have given air temperatures of approximately 550 deg. F., considered undesirable from an operating standpoint. An air heater alone would require heating feedwater with steam that could be used for power generation. An economizer was therefore selected of sufficient size to raise the feedwater temperature from about 212 to 350 deg. F. during normal operation and reduce the gas temperature to about 330 deg. F.

A furnace of 13,720 cu.ft. volume is provided. At maximum boiler rating, heat liberation of 20,000 B.t.u. per cu.ft. per hr. obtains. Water walls on all four sides of the furnace extend up to an elevation in line with the mud-drum bottom. Above the water walls, on the sides and front, the furnace walls are a DeWolf type of suspended refractory construction supported on structural members. Riser tubes from the water-wall header are between the vertical steel members of the DeWolf construction. From the top of the burners down, the front wall is 18 in. thick, of first-class firebrick. All walls are insulated with 3 in. of Rockwool and incased in No. 12 gage steel.

At the bottom of the furnace a slag screen is provided through which ash drops to a refractory-lined hopper. Water from the generator air coolers flows over the surface of this hopper to keep it cool and to disintegrate ash, which is carried away by a Hydrojet sluicing system.

Combustion equipment includes a squirrel-cage motor driven, Vortex-controlled, forced-draft fan, two steam primary-air preheaters; two ball-mill coal pulverizers; two vibrating-type coal feeders, two mill exhausters, four burners, and a steam-turbine driven, induced-draft fan all regulated by an automatic combustion-control system to maintain the correct air-flow steam-flow relation. Only the primary air going to the mills for drying the coal is preheated.

Coal is fed into one end of the mills from the raw-coal bunker by the feeders. Air from the forced-draft duct is taken through the heaters and its temperature raised and thermostatically controlled to give an outlet temperature on the mills of 150 deg. F., which requires preheating to about 350 deg. F. Drawn from the mills by the exhausters, the coal-and-air mixture at 150 deg. is delivered to the burners, where it mixes with the secondary air from the forced-draft fan. Gas flow from the furnace through the boiler, economizer, electrical precipitator, induced-draft fan and to the stack is indicated.

Pulverized-coal equipment is essentially two duplicate unit systems, each with two burners. In the top of the duct from the mill exhauster, a splitter divides the coal-and-air stream, each half going to a burner. No provision has been made for operating less than two burners, as operating conditions will not require very low ratings. Fly ash in the flue gas is removed by an electrostatic precipitator, comprising two units of eleven ducts each, with electrodes of the rod-curtain type. Dust is collected on the rods, and periodically they are struck mechanically to deposit the dust into hoppers below the precipitator.

In the old plant, the turbines exhaust to jet condensers, consequently 100% make-up water has to be provided. These condensers were installed a good many years ago and appeared best suited to water conditions at that time. When new condensing units are installed, they will have surface condensers.

River water used for boiler feed is turbid and hard. To condition this water for boiler use it is first heated to about 100 deg. F and given a preliminary treatment in the make-up tank. Then it is treated by a hot lime-soda process to throw down the solids, deaerated and filtered through magnetite ore. In this process the water is heated to about 220 deg. F. A continuous-blowdown system maintains boiler concentrates below a safe value.

Two boiler-feed pumps, each comprising a primary and a secondary pump in series, are turbine driven. Feed water is taken from the deaerating heater by the primary pump and discharged through the economizer at about 250 lb. and then returns to the secondary pump which sends it into the high-pressure boiler, as indicated on the heat-balance diagram, Fig. 3. This diagram gives operating conditions at full and half load, full load being based on a total load on the high- and low-pressure units of 22,200 gross kilowatts.

## Steam Turbine

The steam turbine is a 7-stage impulse-type rated at 6,000 kw. with 650-lb., 750-deg. steam at the throttle and exhausting against 210 lb. back-pressure. Under these conditions the exhaust will have a total temperature of 530 deg. F. The turbine has seven governor valves, six of which when open will admit sufficient steam for 6,000 kw. Seven valves in service permit generating 7,000 kw. The generator is designed for 11,500 volts, 3 phase, 60 cycles and is cooled by air recirculated through coolers. Raw river water pumped through these coolers is used, as previously mentioned, to wet the surfaces of the ash hopper below the boiler furnace.

The new unit has been in service since the first of the year, and for the last ten weeks has been practically in continuous operation under full load 24 hr. per day. Opportunity has been had to obtain a fairly good check on efficiency of combined operation of the high- and low-pressure machines. Based on a 21,000-kw. load on the old plant, the best coal rate was 1.9 lb. of 13,600-B.t.u. coal. With the same load, but 6,000 kw. carried by the high-pressure unit, the coal rate is 1.1 lb., a reduction of 42%. The new unit is equipped with a very complete automatic combustion-control and metering system, which will be the subject of another article.

Design of the high-pressure section of the plant was worked out by the E. M. Gilbert Engineering Corp. in cooperation with the engineering and operating departments of the Rochester Gas & Electric Corp. Sheppard T. Powell served as consulting chemist on feedwater.

Fig. 4—Controls for the high-pressure boiler and turbine are centralized on these two meter and control boards