Combined High-Pressure Power and Heating Plant

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A PULVERIZED-COAL boiler plant furnishes steam at 380 lb. per sq.in. to a turbine exhausting into heating mains at pressures from 5 to 15 lb. per sq.in. gage, with supplementary live-steam service for heavy demands.

After a careful investigation of the possibilities for central-station heating in the business district of Rochester, N. Y., the Rochester Gas & Electric Corporation decided last fall to build a new steam-generating plant and distribution system intended ultimately to cover the business district of the city.

A study of costs led to the choice of 380 lb. per sq.in. pressure, the steam to be passed through a non-condensing turbine and reheated to from 20 to 40 deg. superheat before delivery to the low-pressure system.

The distribution system consists of high-pressure and low-pressure lines with a return line for the condensation from the heating customers. The low-pressure system is designed to take care of approximately 80 per cent of the maximum demand when the outside temperature drops to zero. The other 20 per cent will be supplied through the high-pressure system by means of reducing valves at the far ends of the systems. This method reduces the investment in the low-pressure system and gives a relatively inexpensive method of taking care of peak loads of short duration.

The high-pressure and low-pressure steam pipes and return lines are inclosed in a concrete duct. Both steam lines are insulated with a laminated type of all-asbestos insulation, the return line being left bare. In addition to these three pipe systems, a single low-pressure line has been built through a district requiring low-pressure steam only.

A tract of land was purchased near the center of distribution, large enough to accommodate a final plant double the size of the plant now being built. This tract runs from one street to another, and the second half of the plant will be practically a duplicate of the first, permitting receipt of coal at either end of the plant.

The present plant is approximately 62 ft. wide by 113 ft. long, and provision has been made for installing two boilers at present, a third unit in the future, considerable substation equipment, and space for two turbines. The turbines will be located in the basement, one of these machines (a 3,000-kw. unit) to be installed at present and the second unit in the future. The building stands approximately 80 ft. high.

The boilers are a recent design of high-pressure units, each boiler containing 9,580 sq.ft. of boiler-heating surface, with sufficient integral economizer surface to bring the total to 11,220 sq.ft. Each boiler is made up of eight unit sections in width, reduced to six units wide on the rear section of the boiler proper, and six economizer units. Each boiler is designed to deliver a maximum of 120,000 lb. of steam per hour at 380 lb. per sq.in. pressure. Superheaters are installed, designed to give about 125 deg. superheat.

Economizers having 4,707 sq.ft. of surface, are installed above the boilers. They are of the baffled type, and the gases pass from the economizer to an induced-draft fan with double motor drive. A 15-hp. motor drives the fan up to about 20 per cent of boiler rating. Above this rating a 75-hp. motor will drive the fan up to 400 per cent of boiler rating. Slip-ring variable-speed motors are used, driving the fan through spur gears. The smaller motor is in gear at all times, and a magnetic clutch is provided between the large motor and the gear so that it is disconnected except at the high rating. When the smaller motor is driven above synchronous speed, it will be automatically disconnected from the line by a reverse power relay.

The economizer is somewhat novel in that it is designed to carry a maximum of only 15 or 20 lb. per sq.in. pressure. The discharge headers of the economizer are connected to a drum in which is a float controlling the water admitted to the economizer and designed to maintain a constant level in the drum. This drum is vented to the low-pressure steam distribution system so that any steam generated in the economizer will be taken off in this way.

The boiler-feed pumps are between the economizer and the boiler, taking their water from the economizer drum under about 30-ft. head. Feed-water regulators control the admission of water to the boilers.

Powdered-Coal Equipment

The necessary unit mill pulverizing capacity is provided to drive these boilers to 400 per cent of capacity. Each boiler is provided with one 2,000-lb. mill and two 7,000-lb. mills. The small mill has the exhaust fan built in as an integral part of the mill, but in the case of the 7,000-lb. mills the exhauster is separate from and mounted just above the mill, together with the feeders for the large mills. The mills are provided with constant-speed alternating-current motors and the exhausters with slip-ring variable-speed motors. The firing will be vertical, one burner being provided for the 2,000-lb. mill and two burners for each of the 7,000-lb. mills. The burner for the small mill is on the center line of the boiler with the burners for the large mills located symmetrically about the center line, to give a uniform flame distribution in the furnace with any of the mills in operation.

The furnaces have a total volume of approximately

10,000 cu.ft., or about 0.9 cu.ft. per 10 sq.ft. of boiler-heating surface. A design developed by the author is used in the construction of these furnaces, these being made up of special brick, the side walls and the arch construction proper being built out of the same brick.

As indicated in Fig. 1, the front and back walls are vertical. The lower two to three feet are built of ordinary firebrick, and above this point the walls are entirely of the special brick. As indicated in Fig. 1A, the lower 16 ft. of the side walls are corbeled in toward the furnace, the remainder of the side walls being vertical. The front portion of these walls is 30½ ft. high, and on the sides back of the arch, 41½ ft. The design of the brick used is such as to provide for contraction and expansion, and repairs may be made at any point without disturbing the remainder of the wall. Six-inch I-beams carry the weight of the walls, in vertical sections 32 in. high, each section carried on an angle clip riveted to the I-beam. Any one of these 32-in. vertical sections can be removed without disturbing the one above or below it. Special asbestos millboard will be clamped to the outer flanges of the 6-in. I-beams, to provide a space between the brick and the millboard, through which air will be circulated and preheated before going to furnace or pulverizing mills.

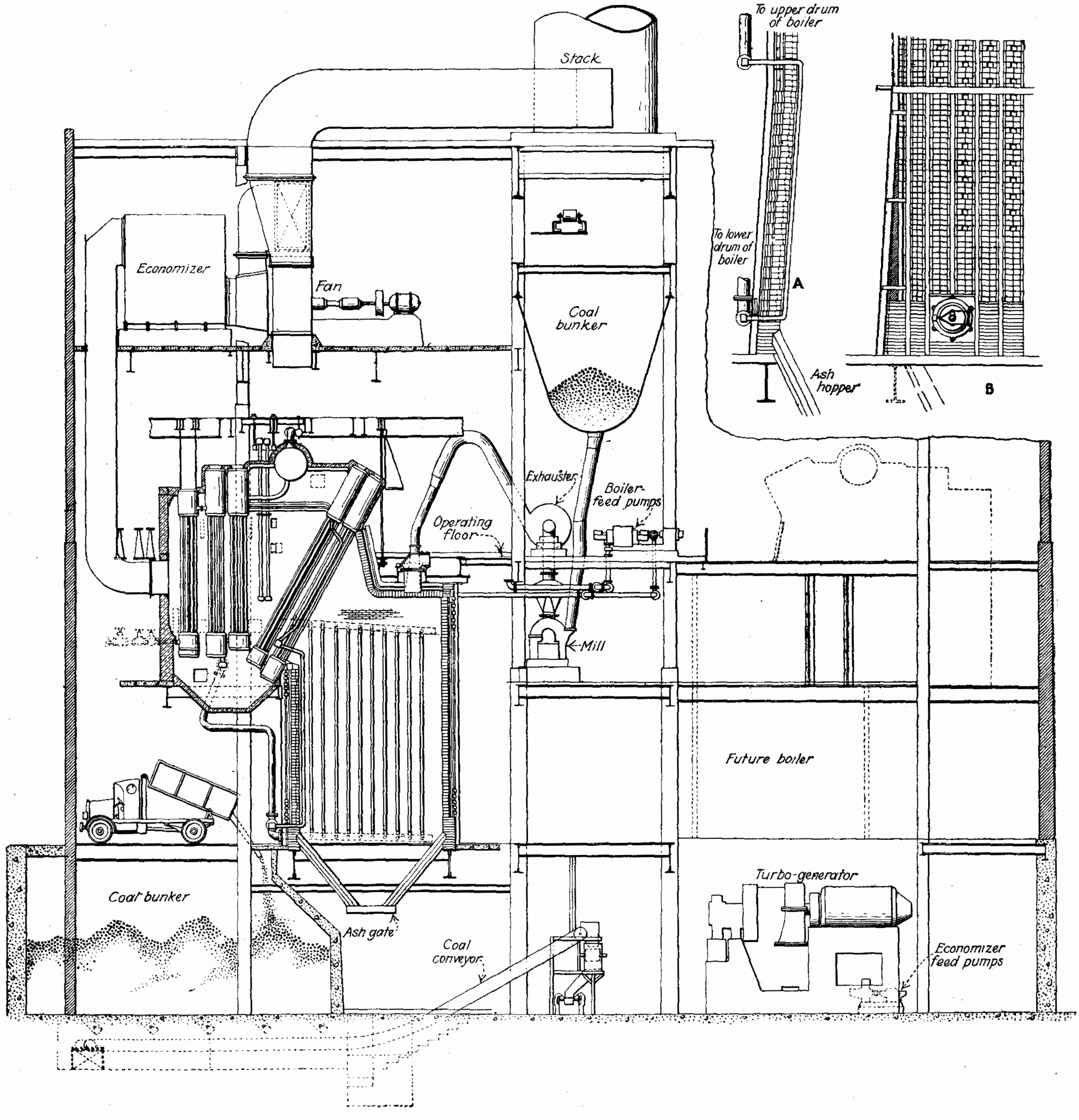

Fig. 1—Cross-section of plant showing compactness of layout, coal delivery and section through furnace

A—Furnace side walls are corbeled in and protected by water tubes. *B*—Secondary air enters furnace through openings in front walls.

A novel feature incorporated in the design of the arch proper is shown in Fig. 1. The horizontal portion of this arch is rigidly supported by 4-in. I-beams, and the vertically inclined portion is flexibly suspended by rods so that this slab can swing in or out or rotate around the suspension, to take care of the expansion or contraction of the arch itself or of the boiler. No packing is required between this arch and the boiler drums, as the motion referred to keeps the vertical arch always in contact with the boiler drums or the horizontal portion of the arch.

As indicated in Fig. 1B, secondary air openings are provided in the upper half of the front wall between each pair of 6-in. I-beams, the space between these I-beams being blocked off at mid-height. The secondary air for combustion is taken in at the bottom of the side walls, passes up through the space between the 6-in. I-beams to an air duct not shown on the drawing, which conveys the air to a duct along the front wall.

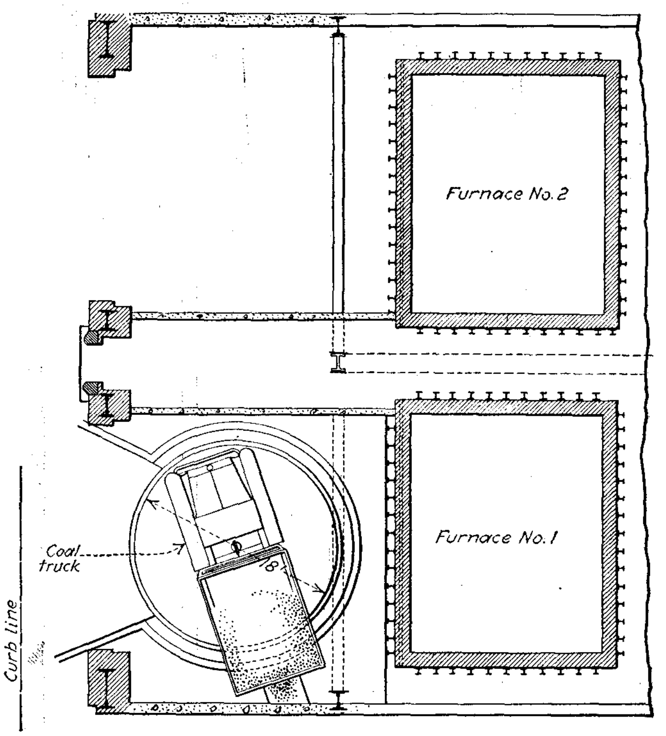

Fig. 2—The truck turntable facilitates receipt of coal

Damper control is provided in this duct across the front of the furnace so that the air entering the space between the 6-in. I-beam and the front wall can be controlled.

In addition to the duct taking air to the front, a duct is provided connecting the high portion of the side wall with a duct that supplies preheated secondary air to these burners, likewise under damper control.

Secondary air openings are also provided in six of the spaces between the 6-in. I-beams in the lower portion of the front wall. The air for these will be taken in at the bottom of the front wall, dampers being provided in each vertical duct between the I-beams. The remaining eight vertical ducts between the I-beams in the lower portion of the front wall are connected to a common air duct from which preheated air is delivered to the pulverizing mills. It is believed that supplying the mills with this preheated air will make it possible to handle very wet coal without material difficulty.

Water screen tubes are provided on the side walls and rear wall of the furnace. The side-wall tubes are spaced on 18½-in. centers and are connected to headers at the bottom and top of the furnace. In the case of the rear wall tubes it was felt that the ordinary tile baffles between boiler units might cause excessive building up of ash, and therefore these tile baffles were replaced by an additional 3¼-in. tube, coming out of the upper B unit of the boiler and brought down midway between the outermost tubes of the A units. This tube from the top of the boiler runs into a connection box just above the bridge wall, and from this connection box a second tube runs to the lower portion of the rear wall, where it is brought out to a header.

The gases from the induced-draft fans pass through the roof to a flue which delivers them to a stack carried by the steelwork of the building immediately above the center of the bunker. The stack is 170 ft. high by 9 ft. in diameter, of reinforced concrete.

Coal will all be trucked into this plant. To facilitate handling the trucks, turntables are provided, one of which is shown in Figs. 1 and 2. A truck will be driven on the turntable, turned to the correct position for dumping, and after dumping, turned so that it can be driven head on out of the building. These turntables are directly above the basement coal bunkers.

As indicated in Fig. 1, coal is delivered by chutes to an apron conveyor which delivers it over a magnetic separator to a bucket conveyor by which it is lifted to the coal bunkers at the top of the building. The conveyors are motor driven with interlocks so that the apron conveyor cannot be started unless the bucket conveyor is in operation; and also so that a stoppage of the magnetic separator or the bucket conveyor will stop the apron conveyor. From the bunkers, coal flows by gravity through chutes to feeders which deliver it to the pulverizing mills.

A large tank in the basement receives the condensation returns from the heating system and receives the makeup water. Centrifugal pumps deliver this water to the economizers, and boiler-feed pumps take the water from the economizers and deliver it to the boilers. Two economizer feed pumps and two boiler feed pumps are installed initially. One of each is driven by a motor, the other by a turbine.

Operating Features

The plant is laid out for minimum operating labor, one man and a helper per shift. All the operating equipment is located on a single operating floor in the space between the main columns carrying the overhead bunkers. On this floor will be located the variable-speed motor-driven exhausters for the large pulverizing mills, the coal feeders for all the mills, the boiler-feed pumps, the control for the induced-draft fans, and the necessary switchboard and instrument panels for the operation of each individual boiler and its equipment. Control panels for the two boilers now being installed, and the future third boiler are grouped so that one operator can easily handle all the equipment. The control panels will include the usual pressure instruments, draft gages, meters, CO_2 recorders, etc.

A 3,000-kw. non-condensing turbine will be installed initially. This turbine takes steam at 375 lb. pressure and exhausts at such pressure between 5 lb. and 15 lb. gage as may be required to deliver the required steam through the low-pressure distribution system to heating customers. A special back-pressure control is provided, which can be set to maintain any desired back pressure and will automatically increase or decrease the amount of steam taken by the turbine as the back pressure may decrease or increase.

The generator is a 4,150-volt alternating-current machine delivering current directly to a 4,150-volt distribution system and, as previously indicated, the load carried by this generator is controlled by the demand for steam so as to maintain a given back pressure.

This turbine is designed to operate automatically without constant supervision. Automatic devices are installed so that in case the lubricating oil reaches too high a temperature or the oil pump fails to deliver oil, or the generator overheats, or the machine is thrown out of balance and vibrates, the unit will be automatically shut down and disconnected from the bus. In this event, reducing valves are provided to supply steam to the low-pressure distribution system.

The exhaust from the turbine, before passing to the low-pressure steam distribution system, passes through a coil reheater designed to give the exhaust steam from 20 to 40 deg. superheat. High-pressure live steam is used for supplying this heat.

By delivering superheated steam to the low-pressure distribution system, the condensation losses will be materially less than would be the case if saturated steam were used.

Motor and Substation Equipment

Special precautions have been taken in the selection of the motors used throughout the plant to provide sturdy equipment, capable of withstanding severe service. No-voltage release coils have been omitted on all essential motors so that after a momentary interruption these motors will start again automatically. In the case of slip-ring motors, the slip rings and brushes are inclosed in dustproof cases.

A portion of the space within the building is devoted to substation equipment, including distribution transformers, switchboards, etc. Five galleries are provided on the west side of the bay in which the turbine is installed. The distribution transformers are in fireproof compartments in the basement and are connected to the 220-volt secondary distribution bus. All the motors in the plant, as well as the outgoing secondary distribution lines, are connected to this bus, which can be sectionalized. By thus combining the station auxiliary load with the distribution system load, it is possible to use larger transformers than either load alone would warrant, and to reduce spare transformer capacity without reduction of reliability. Two 1,500-kw. three-phase units are being installed initially. While this plan has resulted in higher cost for the motor equipment, it effects considerable saving in the investment required to handle the secondary distribution system load supplied by this station, and gives a better load factor on the transformers.

The general features of design and construction have been under the general supervision of the writer, W. S. Burch, engineer in charge of the engineering department, Howard Harding, mechanical engineer, and I. E. Powell, superintendent of steam and hydrogeneration. D. L. Alloway is superintendent of the plant.

PRINCIPAL MECHANICAL EQUIPMENT FOR THE LAWN STREET HEATING

BOILERS

Make	The Bigelow Company
Type	Vertical Water Tube
Number installed	Two
Boiler pressure, gage, lb.	375
Steam temperature, deg. F.	540
Water-heating surface, sq.ft.	11,219
Drum	Dia. 48 in., plate thickness 1 3/32 in.
Tubes, diameter, in.	3¼

SUPERHEATERS

Make	Power Specialty Co.

ECONOMIZERS

Make	The Green Fuel Economizer Co.
Heating surface, sq.ft.	4,707
Ratio economizer area to boiler-heating surface	1 to 2.362

SOOT BLOWERS

14 for boilers	Diamond Power Specialty Co.

REHEATER

Make	The Superheater Co.

FURNACES

Type boiler setting	Brick steel construction DeWolf arch construction
Suspended arches	DeWolf arch construction
Arch brick	Harbison-Walker Refractories Co.
Furnace casing, transite	Johns-Manville Co.
Furnace volume, cu.ft.	10,000=1 cu.ft. per 1.12 sq.ft. of water-heating surface

BURNING EQUIPMENT

Pulverized-fuel system	Combustion Engineering Corp.
Number of mills	3 for boiler
Mills unit type	2,000 lb. per hour (1 mill) 7,000 lb. per hour (2 mills)
Burners	Combustion Engineering Corp.
Burners per boiler	Five

DRAFT EQUIPMENT

Exhauster, mill	Combustion Engineering Corp.
Induced-draft fans	The Green Fuel Economizer Co.
Drive motor	Westinghouse Elec. & Mfg. Co.

STACK

Type	Concrete, brick-lined
Make	Rust Engineering Co.
Height above ground level, ft.	250
Height above operating floor, ft.	217
Diameter of stack, ft.	9
Smoke flues, steel	Connery & Co.

COAL-HANDLING EQUIPMENT

Turntable	The Easton Car & Const. Co.
Apron conveyor	The Erskine-Healy, Inc. Jeffreys Mfg. Co.
Bucket conveyor	Jeffreys Mfg. Co.
Coal bunkers	Allen-Sherman-Hoff Co.

FEED PUMPS

High pressure	
1—6 stage pump (300 gal. per min.)	Pennsylvania Pump Co.
1—5 stage pump (500 gal. per min.)	Pennsylvania Pump Co.
Turbine	Terry Turbine Co.
Motor	Westinghouse Elec. & Mfg. Co.
Medium pressure	
2 pumps	The Goulds Mfg. Co.
Turbine	Terry Steam Turbine Co.
Motor	Westinghouse Elec. & Mfg. Co.

VALVES AND PIPING

High pressure	
Steel gate valves	Chapman Valve Mfg. Co.
Steel globe valves	Edward Valve & Mfg. Co.
Check valves	Chapman Valve Mfg. Co.
Boiler stop valves	Elliott Co.
Reducing valves	Ruggles Klingemann Co.
Atmospheric relief valve	Cochrane Corporation
Safety valves	Consolidated Valve
Blow-off valves	Yarway
Blow-off valves	Everlasting Rack & Pinion
Steam traps	Cochrane Corp.
Piping	W. M. Kellogg Co.
Steam header	Pittsburgh Valve Foundry & Const. Co.
Low Pressure	
Globe valves	Edward Valve & Mfg. Co.
Gate valves	Pittsburgh Valve Fdry. & Const. Co.
Piping	Pittsburgh Valve Fdry. & Const. Co.
Piping pulverized fuel	Pittsburgh Valve Fdry. & Const. Co.
Float valves	Klipfel Mfg. Co.
Blowoff piping	Pittsburgh Valve Fdry. & Const. Co.

TURBO-GENERATOR

Turbo-generator unit	General Electric Co.
Capacity, kw	3,000
Voltage	4,150
Pressure at throttle, lb.	350 per sq.in. gage
Pressure at exhaust, lb.	5 to 20 per sq.in. gage
Air cooler	General Electric Co.
Atmospheric exhaust piping	American Spiral Pipe Works

MISCELLANEOUS

Crane—15 tons capacity	The Whiting Co.
Feed-water regulators (Copes)	Northern Equipment Co.
Metering equipment	The Bailey Meter Co.
Machinery foundations	Cork Foundation Co.
Return-water storage tank	Hammond Iron Works
Air compressor	Ingersoll-Rand Co.
Economizer tanks	Coatesville Boiler Works
Magnetic clutches	Cutler-Hammer Mfg. Co.