POWER PLANT ENGINEERING

GENERATION - TRANSMISSION - DISTRIBUTION - UTILIZATION

Contents

Contents of back issues of Power Plant Engineering will be found in Industrial Arts Index on file in Public Libraries.

APRIL
1936
Vol. XL., No. 4

Published on the first of each month, copyright 1936 by the
Technical Publishing Co., 53 W. Jackson Blvd., Chicago.
New York Office, 171 Madison Ave.
EDITORIAL STAFF: ARTHUR L. RICE, Editor. R. E. TURNER, Managing Editor.
A. W. KRAMER, RICHARD H. MORRIS, Associate Editors.
Subscription price. U. S. A. $2.00 a year; other countries, $3.50 a year. Single copy current issue, 25c; other countries, 35c. January issue, U. S. A., 50c; other countries, 60c. Back issues, single copy, U. S. A., 40c; other countries, 50c. January issue, U. S. A., 75c; other countries, 85c.
Member, Associated Business Papers, Audit Bureau of Circulations.
Circulation of this issue, 20,200

New

Fig. 1. General appearance of operating room. The 250,000 lb. steam generating unit is at the left; the 6000 kw. turbine at the right and the control board in the central background. Note method of anchoring steam line

New 6000 kw. High Pressure Extension to Station No. 3 of the Rochester Gas & Electric Corp. Incorporates Complete Automatic and Centralized Control System

A SIGNIFICANT TREND IN PRESENT day power station practice, though a logical consequence of the recent advances in high pressure technique, is the increasing adoption of the so-called "top" plant idea; i.e., the superposition of a high pressure boiler and turbine on an existing lower pressure plant or system. This makes possible the realization of the high thermal efficiency of the high pressure steam cycle without the necessity of scrapping less efficient but otherwise good existing equipment.

There are many plants in existence today in which the generating equipment is in excellent operating condition and still good for years of service but which, in view of the greater efficiency of modern high pressure equipment, is obsolete from a thermal standpoint. By the addition of high pressure boilers and turbines, however, so arranged as to exhaust into the existing steam system, stations of this type can be improved so as to give thermal efficiencies which compare favorably with the best high pressure practice of today.

Several such "top" units have been built in recent years and at the present time a number of others are in course of development. The most recent actual development of this kind is that made by the Rochester Gas & Electric Corporation in their 1935 extension to Station No. 3 in Rochester.

This extension involved the construction of a new building containing a complete new high pressure steam electric generating plant consisting of a 6000 kw. turbo-generator and a 250,000 lb. per hr. pulverized coal-fired boiler operating at 650 lb. steam pressure. The plant was built during 1935 and it went into operation immediately after the first of this year.

Although not a large plant in terms of electric generating capacity, it is an extremely interesting plant from an engineering standpoint, not only because of its relationship to the old low pressure plant but because of the high excellence of its design. This station is one of the most completely automatic and centrally controlled steam plants that has yet been built. Practically the entire control of the station is centralized in a single position but the operation itself is, for the greater part, automatic, the attendants' duties being chiefly those of a supervisory nature.

Station No. 3, of which this new plant is an extension, is one of a number of generating stations, steam and hydro, which the Rochester Gas & Electric Corporation operates in the vicinity of Rochester, this particular plant being located in Rochester itself. The station dates back some 35 years and has a total generating capacity of around 65,000 kv-a. The new high pressure plant, however, was designed to operate specifically in conjunction with only two units in the old plant, units Nos. 7 and 4. These units operate on steam at 200 lb. gage and a temperature of 530 deg. at the throttle. Combined, these units have a capacity of around 17,000 kw. and a steam consumption of around 220,000 lb. per hr. These units were of course supplied with steam from the old boiler plant operating at about 200 lb. pressure.

The design of the new high pressure plant was based upon the steam requirements of these old units. What was necessary was a high pressure turbine which would deliver at the exhaust, some 220,000 lb. of steam at 200 lb. pressure and at a temperature of around 530 deg.

The turbine selected meets these requirements very closely. It is a 6000 kw. unit, designed for a steam pressure of 650 lb. gage, 750 deg. F. total temperature and the exhaust conditions at full load are about 210 lb., 530 deg. F. with a total steam flow of some 230,000 lb. per hr.

This unit is supplied by a steam generating unit

"TOP" Plant *for* Rochester

fired by pulverized coal and designed for a maximum of 250,000 lb. of steam per hr. at 660 lb. per sq. in. gage.

Essentially then the new high pressure station consists of one boiler and one high back pressure turbo-generator, generating 6000 kw. of electrical energy and supplying some 230,000 lb. of steam at 200 lb. pressure to units 7 and 4 in the old plant. Before passing to the old plant the exhaust from the high pressure turbine passes through a desuperheater so as to avoid excessive temperature of the steam going to the low pressure turbines when the high pressure turbine is operated at low loads. According to the guaranteed performance, the turbine when operating at 6000 kw. has an exhaust temperature of 534 deg. but at 1500 kw., the exhaust temperature is 590 deg., hence the necessity for means of desuperheating. The desuperheater is also required to reduce the temperature of the steam which is by-passed through a 6 in. reducing valve when the high pressure turbine is shut down. In the latter case the steam temperature has to be reduced from about 710 deg. to 525 deg.

Although the present building contains only one boiler and turbine, space has been provided for an additional future turbine and the building is designed so that it can be extended to incorporate another boiler.

General Arrangement

The general arrangement of the equipment is best understood from the plans and elevations shown herewith. As will be apparent, the arrangement is simple, logical and there is ample space around all equipment for safe and convenient operation and maintenance. To a considerable extent, the form of the building was dictated by the design of the boiler which, as can be seen, is a tall affair. As a consequence the building is correspondingly vertical in its general aspect.

The plant is built as a single unit, there being no separate boiler and turbine rooms. Both boiler and turbine are located in the same room and the main operating board is located so that a full view is had of both boiler and turbine. The operating room is roomy, neat and attractive in its general appearance. The walls are of cinder block, painted white, the operating floor of red tile. The boiler casing is finished in aluminum paint. That part of the room containing the turbine is served by a 15 t. overhead crane. A small crane is also provided over the feed pumps which are located alongside of the boilers. A combination freight and passenger elevator gives convenient access to the various floor levels.

The main control board is attractively designed and equipped with an effective system of illumination. An electrically operated annunciator board on the wall above the turbine has a large indicator showing the load in megawatts, as well as high and low pressure steam indicators and 24 translucent glass indicators which light up in case of trouble on any major piece of equipment in the station.

The main turbo-generator, despite its rating of 6000 kw., is small in its physical dimensions, and in order to avoid stresses on the turbine casing from the heavy pipe connections, a specially designed flexible arrangement of pipe is provided. The inlet pipe line is first rigidly fastened to the foundation and from there a small loop connects to the turbine steam chest. Provision for expansion of the exhaust pipe connected to the desuperheater is made by placing the desuperheater on roller supports. To minimize danger from oil fires, all oil piping is located on one side of the turbine and all high pressure steam piping on the other.

The building itself is interesting because it is constructed of cinder blocks, that is blocks made of a mixture of concrete and cinders. With the exception of the water softener and the electrostatic precipitator which is enclosed in a steel casing above the roof, all equipment is contained in the building. The water softener is mounted outside of the building proper on

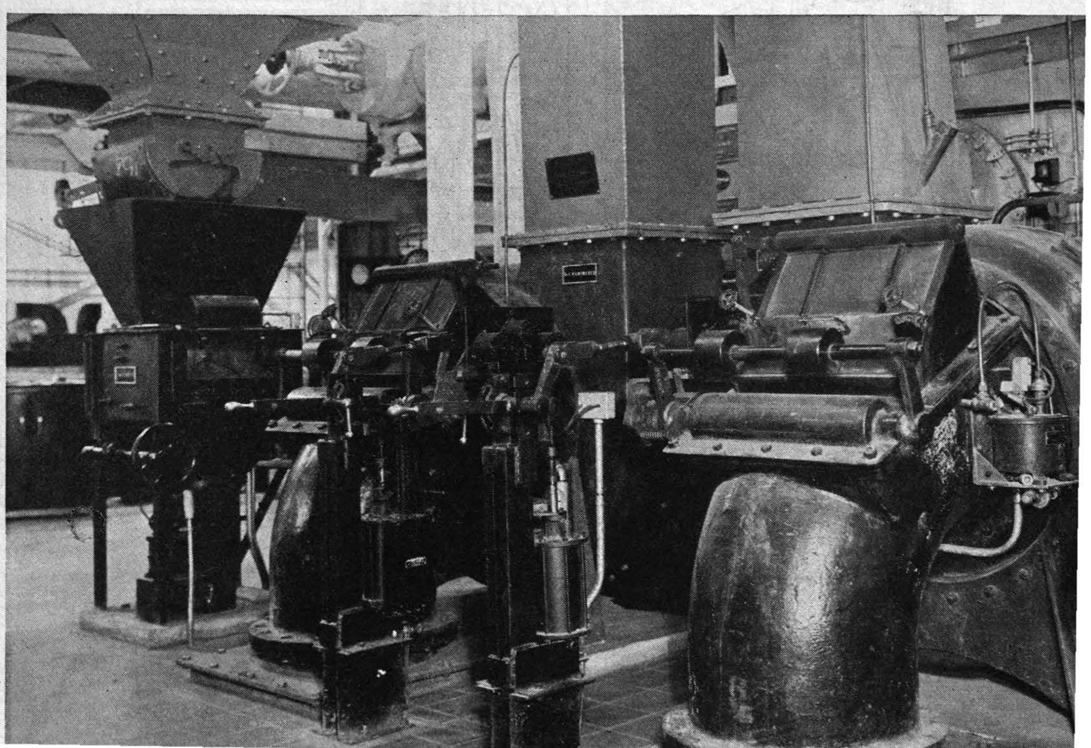


Fig. 2. The exhauster units showing automatic control actuating mechanism. The vibrating feeder is at the extreme left. These are controlled electrically from the air operated mechanism in the foreground

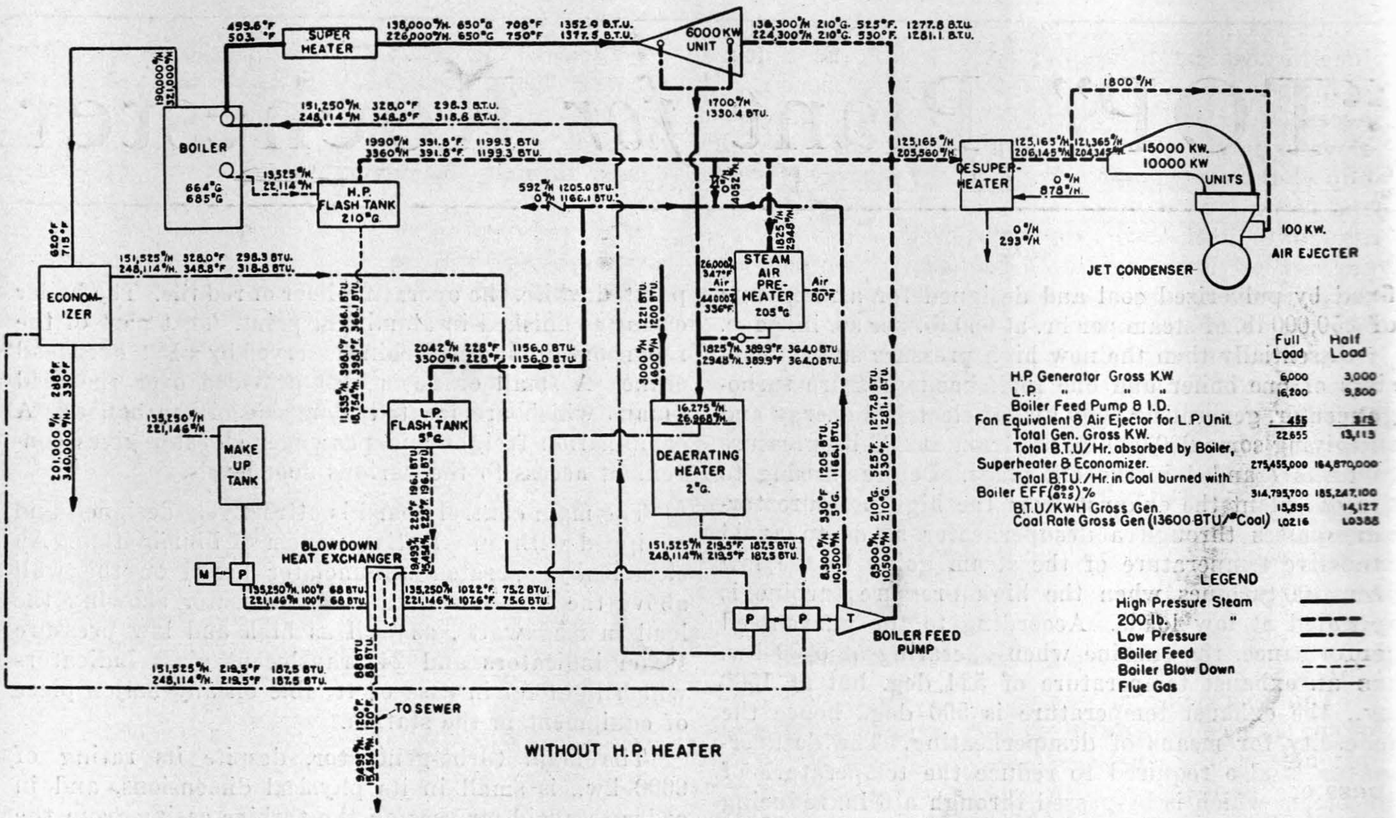


Fig. 3. Heat cycle diagram for full load and half load condition

a steel platform and partially enclosed as to valves and piping, by a corrugated steel enclosure.

The new building is located immediately adjacent to the old boiler house and for the present time makes use of one of the existing stacks. A horizontal breeching on the outside of the building carries the gases from the new boiler to the stack of the existing boiler plant.

The general character of the system involved in this station may be most easily understood by referring to the heat cycle diagram in Fig. 3. Water, it will be noted, enters the system from the makeup tank from which it is drawn by a small pump and delivered to the deaerating heater after first picking up some seven degrees of heat in the blow down heat exchanger. From the deaerating heater, the water passes to the primary feed pump which delivers it to the economizer. From the economizer it is drawn into the secondary feed pump which delivers directly to the boiler.

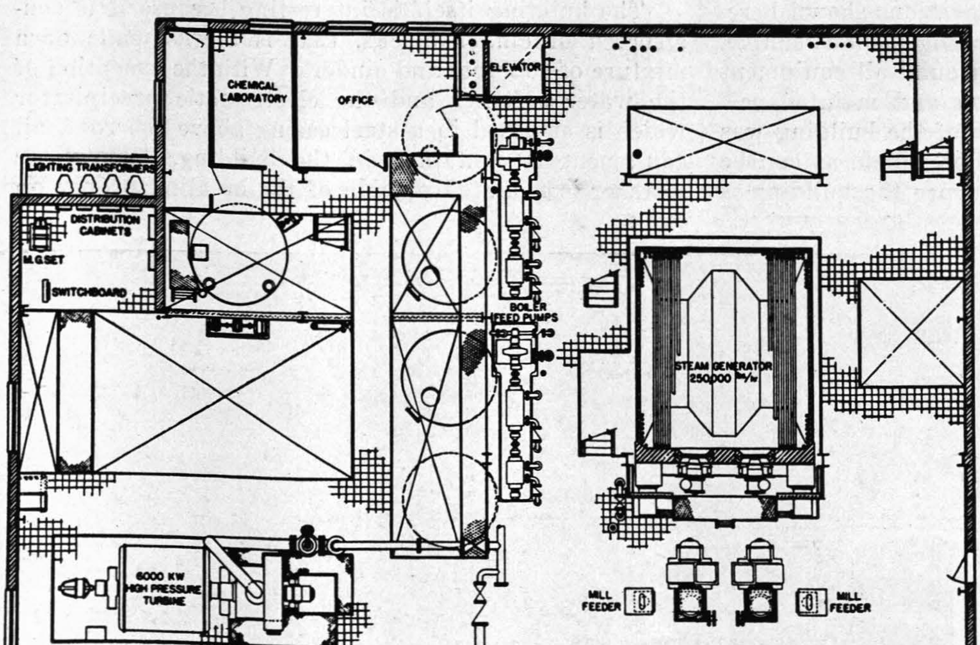


Fig. 4. Plan of operating floor

The steam leaving the boiler and superheater at a pressure of 650 lb. and a temperature of around 725 deg. is sent directly into the 6000 kw. high pressure turbine from which it exhausts at a pressure of 200 lb. The greater part—205,560 lb. per hr. at full load—of this 200 lb. steam passes through the desuperheater to the low pressure turbines.

Two hundred pound steam also goes to the steam air preheater, and to the boiler feed pump turbines as shown. Blow down from the boiler passes first through the high pressure flash tank, then through the low pressure flash tank and finally through a blow down heat exchanger to the sewer.

Coal is delivered by trucks into a receiving hopper located adjacent to the old boiler house and reduced to proper size by a hammer-mill type of crusher, if necessary, or the crusher can be by-passed. A bucket elevator carries the coal upward to a point above the hop of the coal bunker where it is discharged to one end of a belt conveyor. The elevator is supported by a structural steel tower, the upper portion of which is enclosed by Robertson protected metal. The belt conveyor receiving coal from the bucket elevator extends from the elevator tower, over the space required for future bunkers (outside of the present building) to the upper part of the present bunker where it is discharged through a movable tripper into the 500 t. raw coal overhead bunker shown in the elevations herewith. The equipment is designed to handle run-of-mine coal from western Pennsylvania through the feeder and crusher at the rate of 125 t. per hr. From the crusher to the bunkers the equipment will handle 125 t. per hr., 100 per cent of which will pass through a 1¼ in. ring.

Coal Handling and Firing Equipment

This coal handling equipment is electrically interlocked by means of auxiliary switches on the main circuit breakers, an auxiliary switch operated by the bypass or "flapper" gate on the coal crusher chute and a centrifugal switch on the coal crusher. Under normal conditions, the equipment can be started in the following sequence: 1, flight conveyor; 2, elevator; 3, crusher; 4, apron conveyor. Failure of No. 1 will stop Nos. 3 and 4. Failure of No. 2 will stop Nos. 3 and 4. Failure of No. 3 will stop No. 4.

From the raw coal bunker the course followed by the coal is evident from the accompanying elevations of the station. It is delivered from the bottom of the bunkers through the duplex bunker gates, 18 in. sq., into two receiving hoppers above the feeders. The feeders are of the Jeffrey vibrating type, allowing feeding rates from zero to full rating by simply varying the current through the integral vibrating motors by Variacs. The latter are small adjustable transformes controlled automatically from the combustion control system as will be described later. Each feed includes three vibrating units. From the feeders the coal passes through the coal spouts into the pulverizing mills.

The pulverizing mills are Tricone Ball Mills of the air-swept type with constant coal level within the pulverizer maintained by a controller actuating the coal feeder. The output of the mill is controlled independently of the feed rates by varying the air flow through the mill. Oversized material rejected in the classifier, which has been dried by its passage through

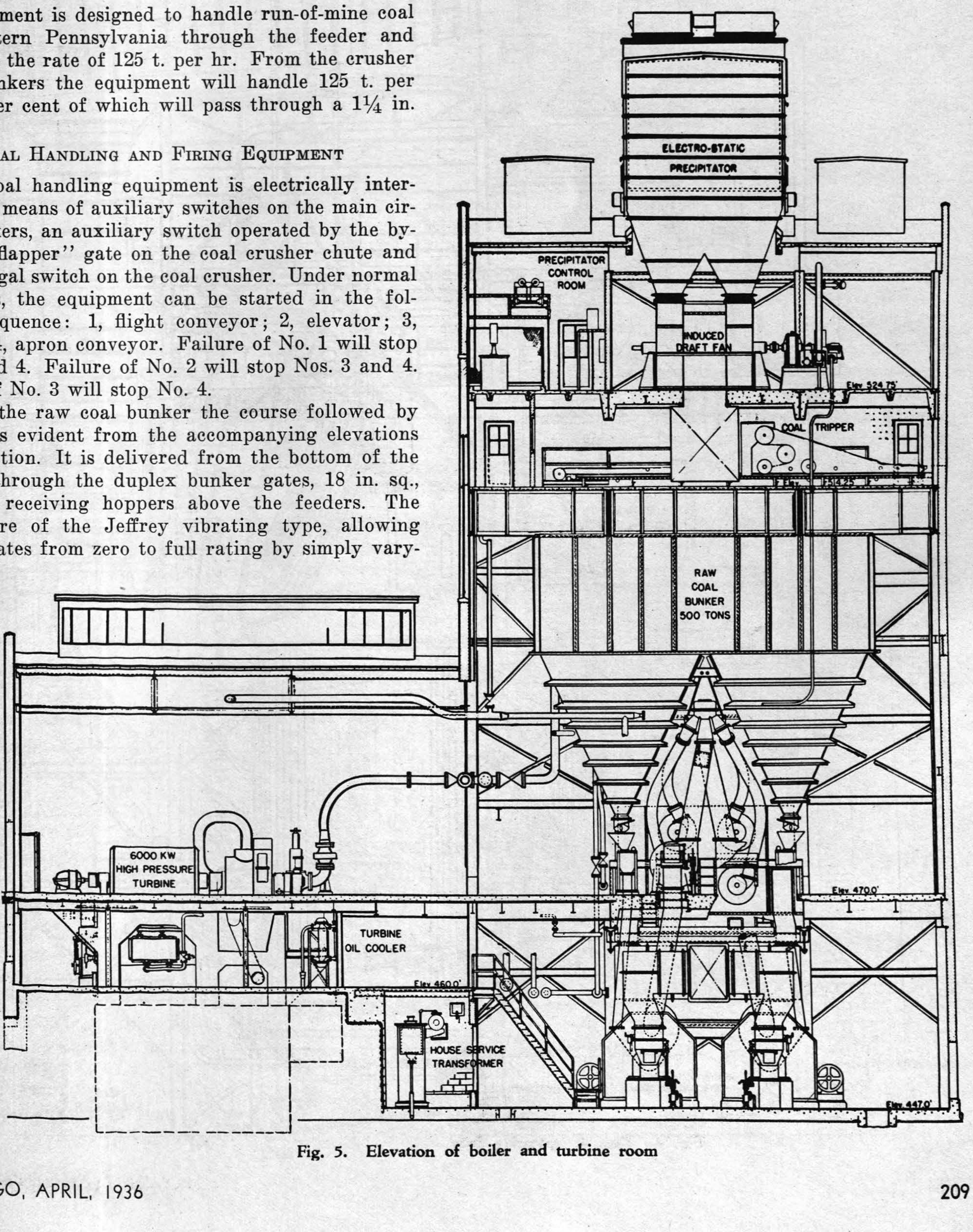


Fig. 5. Elevation of boiler and turbine room

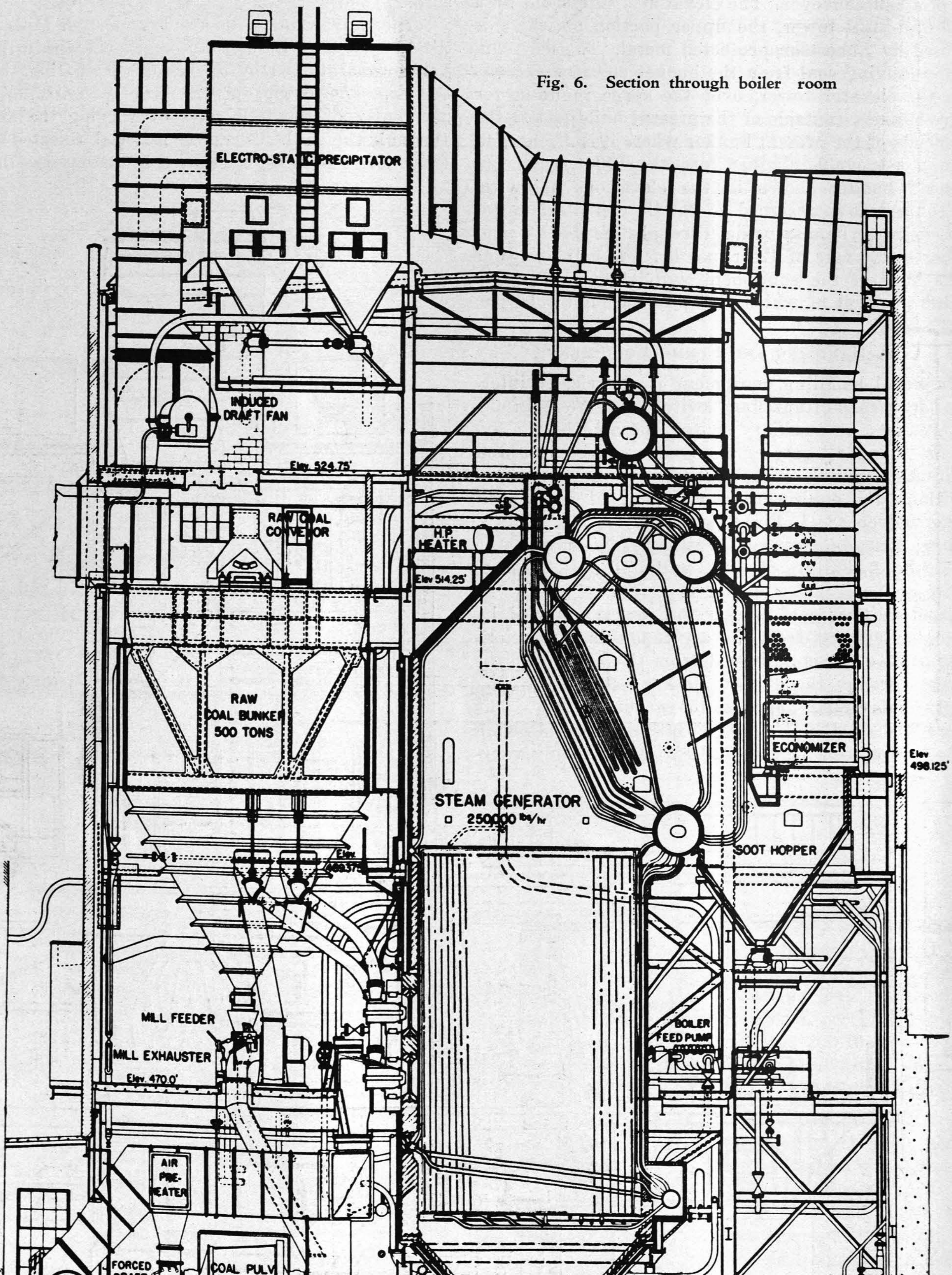


Fig. 6. Section through boiler room

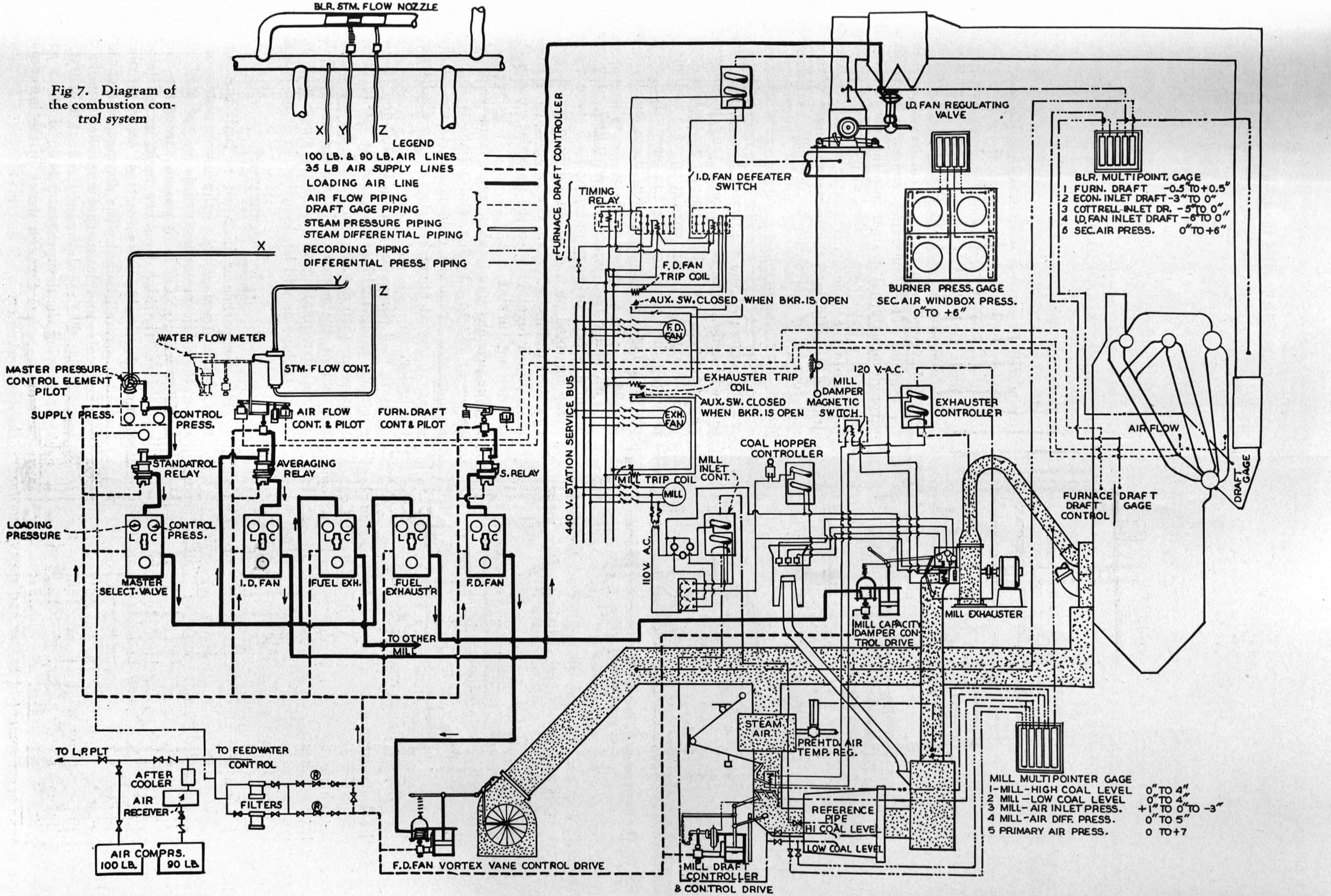


Fig 7. Diagram of the combustion control system

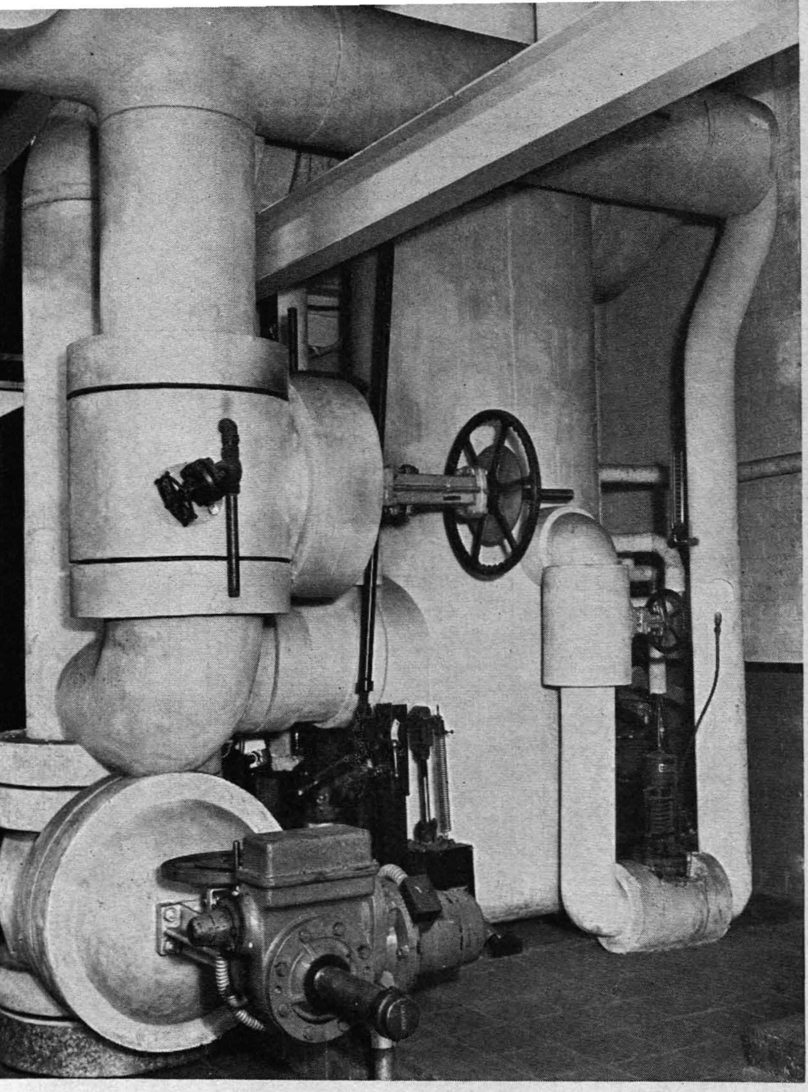


Fig. 8. The desuperheater, showing mechanism for automatic control of the butterfly valve

the mill, is mixed with the incoming feed before it enters the mills and partly absorbs the surface moisture of the fresh coal.

From each mill the pulverized coal and air pass through an exhauster to a distributor which divides the coal to two spouts supplying one burner each in the boiler front wall, or a total of four burners with two pulverizers.

Steam Generating Equipment

In the design studies an analysis of the various heat cycles indicated the most economical installation to be one in which the air for combustion is heated by a steam type air heater. Accordingly, the steam generating equipment consists of a boiler, superheater and an economizer together with a steam air preheater.

The boiler is a 4 drum, 15,300 sq. ft. bent tube boiler designed for a maximum of 250,000 lb. of steam per hour at 660 lb. pressure. It is provided with a completely water-cooled furnace with De Wolf refractory construction and insulated with 3 in. of rock wool all around. The outside casing is of steel plate.

A "fifth" washer drum is an interesting feature of this installation. This drum is located directly above the boiler and its function is to deliver steam with not more than 5 p.p.m. of solid matter when the water contains as much as 3000 p.p.m. of salts. The feedwater to the boiler is introduced into this drum. By means of a unique arrangement of baffles and sprays the feedwater is passed through the steam, after which it (the water) passes on to the boiler. The steam leaving the washer drum passes directly into the superheater and out to the main high pressure header to the turbine.

The furnace has four burners all in the front wall, as shown on the drawings. A ventilated cast iron furnace bottom is provided with two hoppers and ash is removed by means of a Hydrojet Ash sluicing system. The ash transport trench is made up of 18 in. wide nickel cast iron liners in a concrete trench. The trench has three transport nozzles supplied with water at 100 lb. pressure for removing the ash. Soot deposited in the economizer hopper and the precipitator hopper is removed by an A-S-H hydrovac system.

The continuous blow off system consists of a 2 in. forged steel needle control valve, high and low pressure flash tanks and a heat exchanger. In the high pressure flash tank, part of the concentrate is flashed at 210 lb. gage into steam which passes into the 210 lb. system. The remaining concentrate is drained through an external drainer into the low pressure flash tank where the steam flashed at 5 lb. gage pressure is piped into the deaerating heater and the concentrate drained directly into the heat exchanger with a loop seal formed by the outlet of the heat exchanger.

Feedwater System

The course of the feedwater has already been described briefly. From the make up tank, a motor driven pump delivers it to a 32,000 g.p.h. deaerating type, hot process water softener, consisting of a sedimentation tank together with feeding equipment for chemicals, phosphate and sodium sulphate, filters and wash water pumps.

Two boiler feed pumps are installed, each consisting of a 3-stage primary pump and a 5-stage secondary pump mounted on a common sub-base which also carries the driving turbines. The two pumps of each unit are coupled together with the secondary pump next to the driving turbine.

The primary pump takes water from the deaerating heater at 212 to 220 deg. and pumps it through the economizer. From the economizer it goes to the secondary pump at about 390 deg. which discharges into the boiler.

Both feed pumps are driven by 450 hp., 3450 r.p.m. non-condensing turbines operated at 210 lb. steam inlet pressure, 525 deg. F. and with 5 lbs. back pressure. The pumps are regulated by means of automatically controlled regulating valves in the steam supply lines to the turbine as will be described in detail below.

Desuperheater

The desuperheater installed to limit the temperature of the steam going to the low pressure turbines when the high pressure turbine is operated at low loads or when steam is by-passed through a reducing valve from the high pressure main, is a Blaw-Knox unit, or ductiwelded construction, 36 in. in diameter and 13 ft. overall height. The arrangement of turbine, reducing valve and desuperheater is shown in the drawing, Fig. 11. The regulation of the final temperature of steam leaving the desuperheater is obtained by passing part of the steam through water in the lower part of the desuperheater.

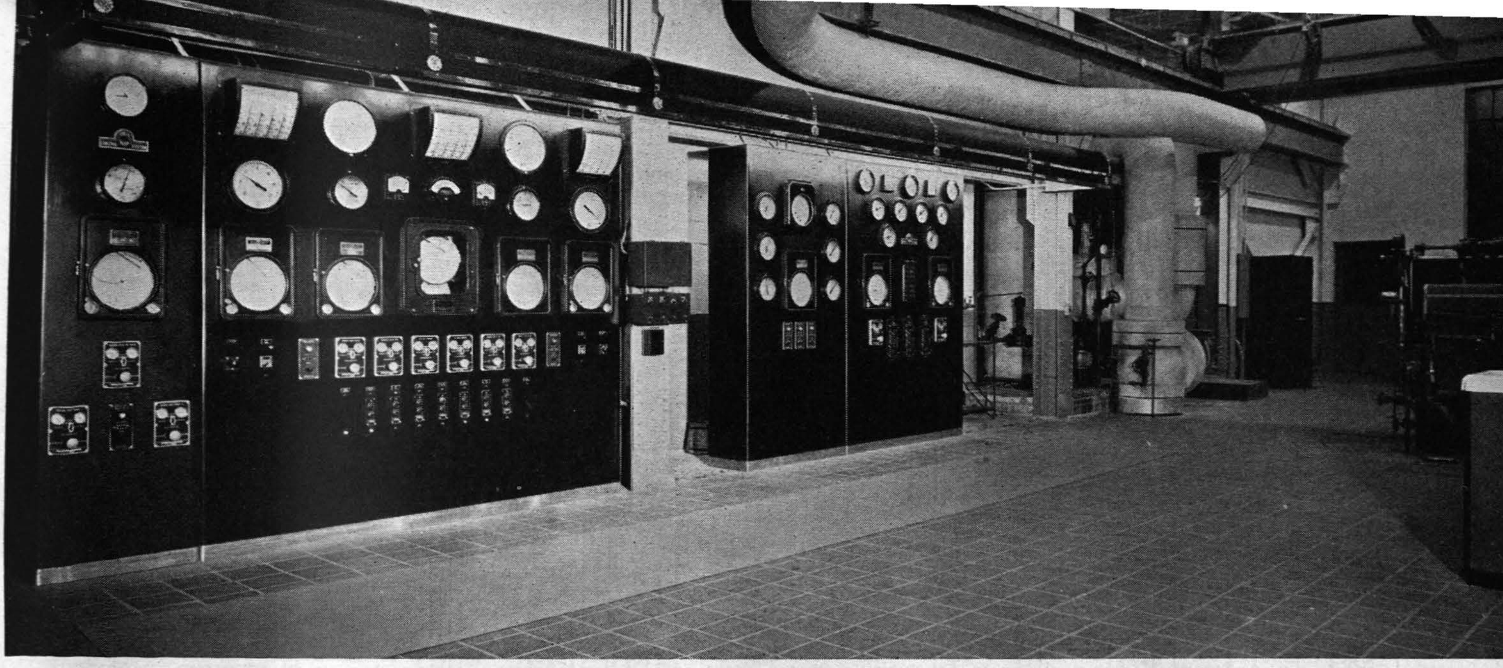


Fig. 9. Control of entire station is centralized in these panels. (Photo, Bailey Meter Co.)

The saturated steam after passing through elimination plates then mixes with the superheated steam passing directly through the upper part of the desuperheater. To insure uniform steam at the outlet of the desuperheater a thorough mixing of the saturated and superheated steam is assured by a helical plate in the outlet steam nozzle, giving the steam a whirling motion.

The steam by-passed through the desuperheater is controlled by the position of a 16 in. butterfly valve in the 16 in. main steam line which is regulated automatically through a temperature control device in the superheater exhaust line.

The feedwater for desuperheating the steam in the desuperheater is supplied directly from the economizer through a feed regulating valve. It was found that the pressure of the feedwater supplied from the economizer was sufficient for the desuperheater but a tap on the first stage volute of the secondary boiler feed pump also is provided which can supply feedwater at about 175 lb. higher pressure.

Feedwater supply is regulated so that a constant water level is maintained in the desuperheater. In order to keep down the concentration in the desuperheater a blowdown of 50 per cent of the water evaporated is provided for. For use in case of emergency, the desuperheater is also connected to the feedwater supply from the old plant at about 260 lb. pressure. Each of these sources are level controlled by thermohydraulic generators with metal bellows-operated regulator valves. The blowdown is controlled by a hand regulated "Flocontrol" valve.

Control of Equipment

The control features of this station, as indicated in the introductory paragraphs, are most complete and almost entirely automatic. The control is centered in the operating board which is arranged along one wall in full view of both turbine and boilers. All major operations are controlled from this position.

In general the control system may be divided into two parts: first, that which has to do with the combustion and fuel supply equipment and second, that involving feedwater level, excess pressure, pressure reducing valve operation and desuperheater temperature and level. At some points these two systems of control overlap and at these points they are coördinated but in general the two systems can be regarded as being separate. In each instance the Bailey System of control is used.

The combustion control diagram is shown in Fig. 7; the feedwater level, steam pressure and temperature and desuperheater control in Fig. 11.

In order to have a stable control of the steam generating equipment, the rate of combustion must be regulated in accordance with the demand on the boiler as indicated by the steam pressure. Any control must, therefore, regulate the rate of combustion in such a way that the steam pressure at a given point is kept substantially constant. In order to maintain the highest efficiency at any load, a correct ratio of excess air to

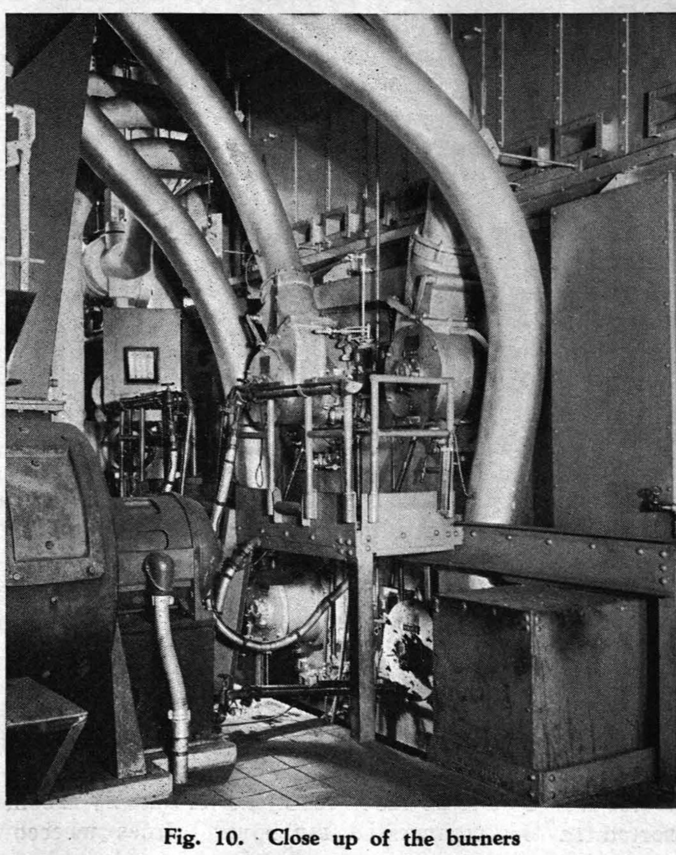


Fig. 10. Close up of the burners

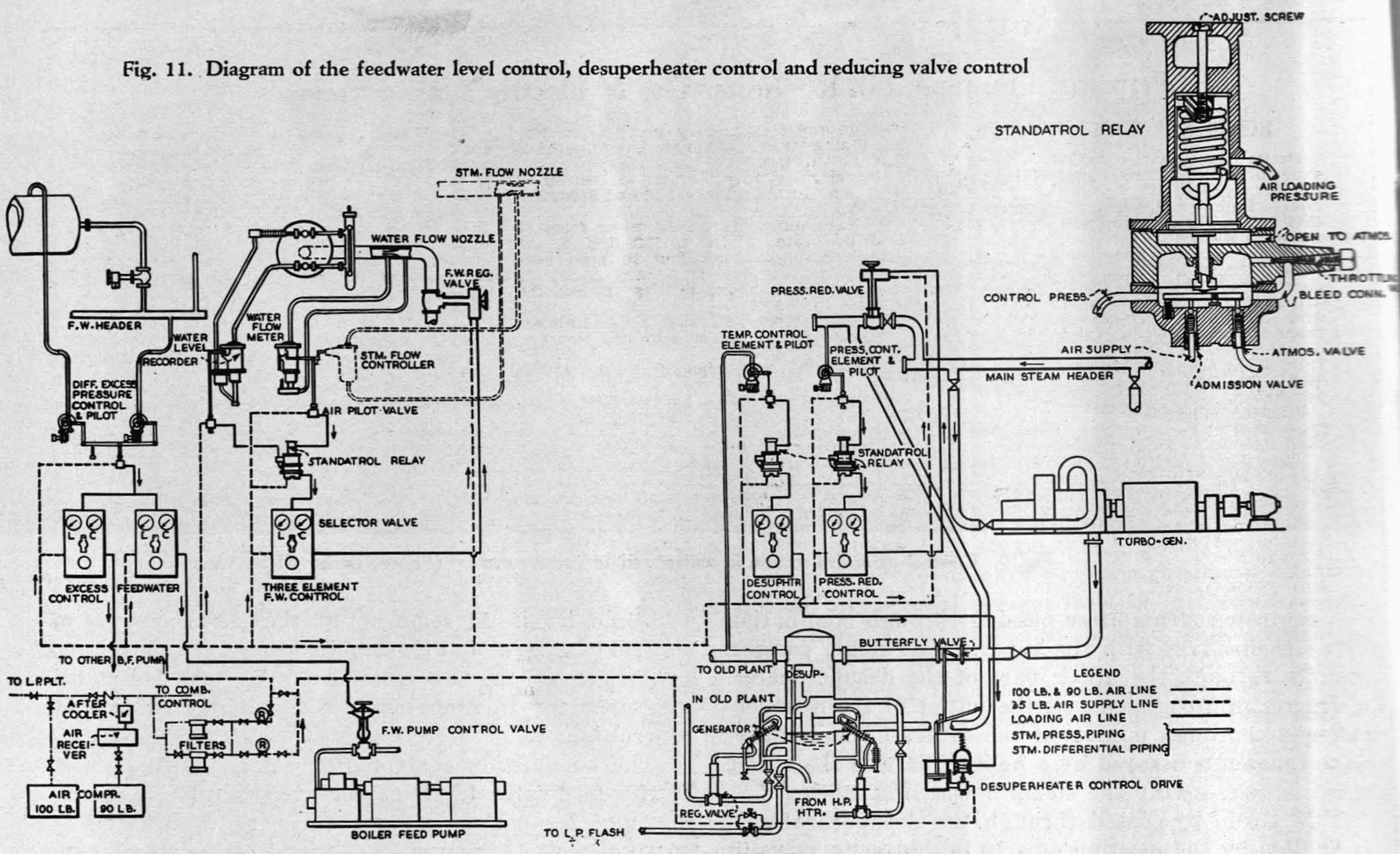


Fig. 11. Diagram of the feedwater level control, desuperheater control and reducing valve control

fuel rate must be maintained. In the Bailey control system this is accomplished by keeping the steam flow-air flow in the correct relation. The regulation of the different equipment is obtained through a compressed air system operating pilot valves and control valves.

A master steam pressure controller on the master panel regulates the pressure of the compressed air to the control system through a master air pilot and a Standatrol relay. The air to the control system passes through a master selector valve on the same panel which, according to its position, allows automatic control by steam pressure or hand control.

A steam flow mechanism on the boiler panel records the steam flow through an orifice in the main steam line and an air flow mechanism, the draft loss through the boiler. Since the correct relation of air flow to steam flow is the basis for efficient combustion at any load, the steam flow-air flow mechanism is, therefore, used to adjust the pressure of the compressed air for control of the induced draft fan to that controlling the fuel supply set by steam pressure.

Flexibility

Primarily, therefore, the steam pressure through a master pressure controller, determines the compressed air pressure regulating the fuel supply and, secondarily, the steam flow-air flow mechanism, adjusts the compressed air pressure controlling the speed of the turbine driven induced draft fan for a given load. The forced draft fan as will be noted from Fig. 7, is regulated by the pressure in the furnace which is maintained constant. These are the principal features of the control system. It is entirely automatic, but selector valves on the master and boiler panels are inserted in the compressed air control lines whereby the automatic regulation of air pressure can be cut out and the pressure regulated by hand, allowing manual control of all or part of the equipment.

Control of the Fuel Supply

The supply of fuel from the pulverizers is dependent upon the flow of air through the mill carrying the coal in suspension to the burners. The mill draft at the pulverizer inlet is kept constant by means of an adjustable damper in the air duct to the pulverizer regulated by means of a draft controller. With the draft at the mill thus kept constant, the output of the pulverizer is controlled by an automatic adjustable damper located in and part of the cast iron elbow in the exhauster inlet. The position of this damper with relation to the output is controlled by a lever connected to the air operated fuel control unit.

In order to roughly proportion coal input to output a second lever is located on the output damper shaft which, through a roller chain, actuates the feeder "Variacs." The "Variacs" of which there are three, one for each feeder, control the voltage to each of the vibrator feeders which regulate the feed to the pulverizers. Each of these Variacs is independently adjustable to allow a finer adjustment of the feed input.

To prevent the pulverizer from plugging, two level pipes are installed in the mill, identified as high and low level pipes. These pipes are connected to the bottom of the bell of the pulverizer feed controller. A connection is made at the top of the bell to a reference pipe also located within the pulverizer. When the coal level rises it will interrupt suction to the bottom of the pulverizer feed controller bell and atmospheric air will seep in through the small orifice tubes. This causes the

Principal Equipment in Rochester Gas & Electric Corp. Extension

BOILER AND FURNACE

Boiler—One Combustion Engineering Co., 4 drum, bent tube boiler, 250,000 lb. per hr. maximum capacity, fired with pulverized coal. Boiler 15,300 sq. ft., water walls 3990 sq. ft., superheater 4450 sq. ft., economizer 20,808 sq. ft.

Furnace volume 13720 sq. ft.

Boiler tube arrangement, 36 sect. of 20 each, tubes 3¼ in. O.D. No. 5 gage. Drums are steel plate, fusion welded joints, 42 in. and 48 in. dia., thickness of shell varying from 1⅛ in. to 3⅝ in., all welds X-rayed.

Steam washer drum 48 in. dia. x 23 ft. 7 in. long, connected to the rear drum by 34-3½ in. tubes, cap. 250,000 lb. steam per hr.

Furnace walls, bare tubes, plain and fin type, backed by refractory, insulation and steel casing.

Operating Conditions — Max. continuous output—250,000 lb. steam per hr., 660 lb. per sq. in. gage, total temp. 755 deg. F.

Feed water entering boiler at 388 deg. F.

Firing Equipment—Two Foster-Wheeler Tricone ball mills No. 4, each connected through one No. 40 Exhauster fan, 15,200 lb. per hr. capacity each, with bituminous coal. Coal feeders are Jeffrey vibrating type. Each mill driven by 150 hp., 870 r.p.m. Westinghouse motor through a Bethlehem snub coupling.

Mill Exhausters are of the paddle wheel type, cast iron casing, rotor is cast steel spider with mild steel blades, and is mounted directly on the shaft of a 75 hp., 1200 r.p.m., 60 cycle, 3 phase Westinghouse motor.

Forced Draft Fan furnishes primary air to the pulverizers and secondary air to the burners. Fan is Clarage Fan Company No. 4, full housed, double width, double inlet, inlets equipped with adjustable Vortex control, and is direct connected to a squirrel cage 75 hp., 860 r.p.m., 3 phase 60 cycle, 440 v. motor through a flexible No. 4 Fast coupling.

Max. cap. 69,000 c.f.m., 4 ft. 5 in. S.P.

Steam Air Heater by American Blower Corp. consists of 6 units of Aerofin heaters with tubes 3 ft. 0 in. long, containing 1921 sq. ft. of heating surface. Four units have 3 rows of tubes each, and 2 units of 2 rows of tubes each.

Calculated performance with mill pulverizing 15,200 lb. coal per hr. is 30,000 lb. air per hr., 80 deg. F. entering air, 347 deg. F. leaving air. Condensate 2390 lb. per hr.

Burners—Four Combustion Engineering type R forced draft burners arranged 2 high and 2 wide, 14 in. dia. requiring 4 in. static press. of the primary air at burner inlet when supplied with 7600 lb. coal per hr., and 3800 c.f.m. of air from the mill.

Superheater—The Superheater Company, 4450 sq. ft. made up as follows: 35 two-loop, semi-radiant elements, 1¾ in. O.D. tubes, 1330 sq. ft., 53 four-loop convection elements, 3120 sq. ft. 1⅝ in. O.D. tubes.

A 2½ in. dia. Consolidated type safety valve set at 745 lb. is provided at the outlet header.

Economizer — Foster Wheeler extended surface, counter flow, 20,808 sq. ft. of external H.S. 24 rows high, 17 wide, elements 17 ft. 0 in. long, 2 in. Tubes No. 11 gage, with cast iron gills. Diamond soot blowers, 4 horizontal rows, 16 soot blower elements.

Ash Handling Equipment — Allen-Sherman-Hoff Co. Hydrojet ash system on furnace bottom, Hydrovac fly ash system on Economizer and Electrical Precipitator, all ash being sluiced under pressure through a concrete trench lined with nickel cast iron liners to collection point.

Soot Precipitator — Cottrell Precipitator by Research Corporation, consists of two units of 11 ducts, collecting electrodes of the rod type with a Solenoid operated rapping mechanism, and installed ahead of the induced draft fan.

Induced Draft Fan—Clarage Fan Co. No. 16 full housed, double width, double inlet, bottom discharge, taking gases from Precipitator and discharging to existing stack.

Turbine drive, 200 hp. Allis-Chalmers, 3645 r.p.m. with a single reduction herringbone gear unit, coupled through a No. 4 Fast coupling to fan running at 685 r.p.m.

Turbine operates with steam at 210 lb., 525 deg.: F. and exhausts at 5 lb. gage into deaerating heater, regulation by Bailey Combustion control.

Boiler Feed Pumps—Two Allis-Chalmers pumps, each in two units, each pump consisting of a primary pump 5 in. by 4 in., 3 stage and a secondary pump 5 in. by 4 in., 5-stage on a common base including driving turbine.

Capacity primary 618 g.p.m. secondary 730 g.p.m. total dynamic head of secondary 1485 ft.

Primary pump takes feed water from deaerating heater at 212 to 220 deg. F. and pumps through economizer to high pressure contact heater, secondary pump receives water at about 390 deg. F. and discharges into boiler.

Pumps driven by one Allis-Chalmers, and one Moore steam turbine, non-condensing.

Allis-Chalmers turbine 496 b.h.&p. at 3000 r.p.m.

Moore turbine 450 b.h.p. at 3450 r.p.m., 210 lb. steam pressure 525 deg. F., 5 lb. back pressure.

Regulation by Bailey controlled regulating valves in the steam supply lines.

Water Purification Equipment—Cochrane 32,000 g.p.h. deaerating type, hot process water softener consisting of sedimentation tank with feeding equipment for chemicals, phosphate and sodium sulphate, filters and water wash pumps, with auxiliary equipment.

Sedimentation tank built of copper bearing steel, welded construction, feeding tanks built of Toncon iron, welded construction.

Desuperheater — Blaw-Knox ductiweld construction, 36 in. dia. of body by 13 ft. 0 in. high. Steam going to the present low pressure turbo generators must be reduced to 525 deg. F. whether coming from the high pressure turbine exhaust or by-pass steam from the boiler.

Feed water supply and blow down to reduce concentration are regulated by Bailey Thermo-hydraulic generators with metal bellows-operated regulated valves.

Continuous Blow - Off Equipment — Cochrane Corporation, consisting of one 2 in. forged steel needle control valve, one high pressure flash tank 24 in. dia. by 36 in. built for 250 lb. working pressure, one low pressure flash tank 48 in. dia. by 72 in. built for 50 lb. working pressure, one heat exchanger, 4 pass U tube type with 625 sq. ft. of heating surface, made up of 150—¾ in. copper tubes 21 ft. 6 in. long, built for 50 lb. working pressure.

Coal Handling — Robins Conveying Belt Co., capacity 125 t. per hr., consisting of apron feeder, Pennsylvania steel built, hammer-mill crusher belt and bucket elevator, belt conveyor and tripper, with electrical inlocking equipment for starting and shut down in the proper sequence.

Coal is delivered to steel plate, hopper bottomed bins, reinforced Gunite lined.

Coal crusher driven by 40 hp., 1200 r.p.m. Westinghouse a.c. motor.

Belt and Bucket Elevator, driven by 15 hp., 1200 r.p.m. Westinghouse motor through a Falk Herringbone speed reducer.

Link Belt duplex bumper gates.

BOILER AND SETTING

Combustion Engineering Corp. Sub-Contractor, Wm. Summerhays Sons Corp., Rochester.

Front Wall—18 in. firebrick to top of burners, above this point DeWolf Type "A", 9 in. refractory with 1 in. sticktite on back. Entire wall insulated with 3 in. rock wool blanket and steel casing.

Side Walls—DeWolf type refractory 9 in. and 7½ in. thick insulated with rock wool and steel casing.

Rear Wall—Above soot to upper rear drum 2 in. firebrick tile with 3 in. rock wool and steel casing.

Boiler and Furnace Roof carried on circulating tubes are 2 layers of 2½ in. firebrick insulated with rock wool and steel casing.

Side Water Wall backed by 2½ in. shaped firebrick to fit behind the fin tubes with 1 in. sticktite, air space, 3 in. rock wool and steel casing.

Rear Water Wall backed by 2½ in. of "Moldit" behind the fin tubes held in place by steel plate resting against the down-take tubes, 3 in. rock wall and steel casing.

Harbison-Walker refractories used.

BOILER ACCESSORIES

Water Columns—Two Diamond Power Specialty Corp. for 752 lb. drum pressure.

Water Level—One Diamond water level indicator connected to one of the water columns.

One 21½ in. vision length Diamond flat glass water gage with illuminator.

One 21½ in. vision length Diamond color water gage with reflector and floor mirror.

Blow-Down—3 Cochrane forged steel blow-off valves for 900 lb. press. One 2 in.—1500 lb. Edward forged steel needle valve.

Safety Valves—3 Consolidated Ashcroft Hancock 900 lb. pressure, set at 750 lb., 755 lb. and 760 lb. gage, respectively.

Soot Blowers—Diamond automatic valve-in-head 16—1½ in. units in Boiler—16—2 in. units in economizer.

Ducts and Breechings—Connery and Company.

Elevator—Graves Elevator Co., Rochester, combination freight and passenger.

Turbine Room Crane—Shaw-Box Crane and Hoist Co., 15 T. electrically operated.

Station Heating Units—Clarage Fan Co., Unitherm unit heaters.

Structures—A. W. Hopeman & Sons Co., General Contractor. Structural steel by Genesee Bridge Co.

River Water Strainer—1 B-10 rotary strainer, capacity 1050 g.p.m. for generator air cooler, transformers and house service water.

Temperature Recording Instruments and Gauges—Taylor Instrument Cos.

All piping fabrication and erection by W. K. Mitchell & Co., Inc.

High Press. Steam—Seamless steel pipe A.S.T.M. Specification A-106-34 T. Schedule 80.

Gaskets, steel ring, dead soft $\frac{1}{32}$ in. thick.

Lunkenheimer valves, Edwards non-return valve.

Serrated faces on valves, and flanges where used, all other joints welded.

High Press. Exhaust — Seamless steel pipe, A.S.T.M. Spec. A-106-34 T. Schedule 20.

Gaskets, Klingerite $\frac{1}{16}$ in. thick.

Valves, Reading, Pratt and Cady Co.

Boiler Feed Discharge—Pipe and gaskets same Spec. as High Press. steam, Lunkenheimer valves.

CONTROL EQUIPMENT

Bailey control system, entirely automatic (supplemented by hand). Primarily, the steam pressure, through a master pressure controller, determines the compressed air pressure regulating the fuel supply, and secondarily, the steam flow—air flow mechanism adjusts the compressed air pressure controlling the speed of the turbine driven induced draft fan for the coal given. The forced draft fan is regulated by the pressure in the furnace, which is maintained constant.

MAIN TURBO GENERATOR

General Electric Co. 6000 kw., .8 power factor, 3 phase, 60 cycle, 11,500 v., 3600 r.p.m., impulse type, non-condensing unit, with direct connected exciter.

Air for the generator ventilation is cooled by a 6 pass generator air cooler of 3350 sq. ft. surface, requiring 160 g.p.m. cooling water at 80 deg. F.

The exciter is directly coupled to the generator shaft with thrust bearings and separate bedplate, designed for 40 kw., 320 amperes, with 4 poles.

Steam at throttle 650 lb. gage, 750 deg. F. total temperature, exhausting at full load at 210 lb. gage, 530 deg. F. This gives the desired conditions for the present low pressure turbines.

Valve Control—Limitorque, Philadelphia Gear Works.

Station Power Transformers—1500 kva. 3 phase, 11,000/440 v. and 4150/440 v. inert gas. Allis Chalmers Mfg. Co.

Station Lighting Transformers—25 kv-a. single phase, General Electric Co.

Emergency Lighting—D.C. from Station Battery.

Generator Oil Circuit Breaker—600 amp. 15 kv. General Electric FHK-230-20B.

Generator and Transformer Cables—Paper and lead, 15 kv., General Electric Co. and Safety Cable Co.

Station Auxiliary and Lighting Conductors—2500 v. Kerite, Kerite Insulated Wire & Cable Co. 600 v. Kerite, Kerite Insulated Wire & Cable Co. 600 v. Rockbestos, Rockbestos Products Corp.

Motor Generator Set—5 kw. 125 D.C., Electric Products Co.

Variacs on fuel control system, General Radio Co.

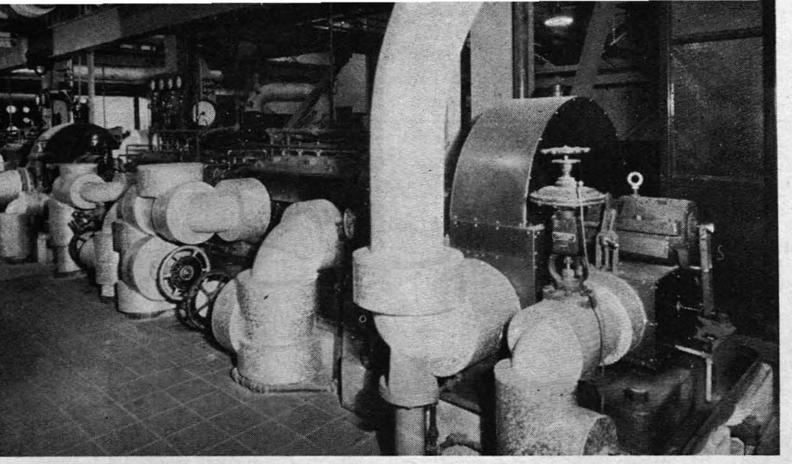


Fig. 12. Each boiler feed pump consists of a 3-stage primary and a 5-stage secondary pump connected together and mounted on one base and driven by a steam turbine. The two units are shown here

bell to rise and thereby trip the two mercoid switches interrupting the 110 v. current to the feeder units and cut in the current to a signal light on the boiler board.

As already mentioned, the forced draft fan is regulated to keep a predetermined draft pressure in the furnace. This is accomplished by Vortex control of the constant speed fan, the position of the vanes being regulated through a control unit by a compressed air piston motor.

The induced draft fan is turbine driven. A diaphragm operated steam flow valve in the steam line to the fan turbine regulated by the control system, regulates the speed of the fan to maintain the proper draft in the furnace.

The air supplied from the forced draft fan is passed partly directly as secondary air to the burners and partly as primary air to the pulverizer after being preheated in the steam air preheater. The amount of preheat is regulated by thermostatic control from the pulverizer exhaust duct which actuates the steam supply valves to the preheaters.

The foregoing presents the principle features of the combustion control system. In addition to the elements mentioned the system is also fully equipped with electrical interlocks to insure proper sequence in starting the equipment and to stop the equipment in proper sequence in case of failure of any part of the system.

Feed Level and Flow Control

The feedwater level control is shown at the left of the diagram in Fig. 11. This makes use of the Bailey three element control, which takes into account not only changes in water level in the boiler but also the ratio between main steam flow (the load) and the water flow to the boiler. The primary impulse in this system is obtained through the differential excess pressure control which operates directly upon the speed of the boiler feed pumps through the feedwater pump control valve. Either a drop in water level or an increase in steam flow (reduction in pressure in the boiler) will cause the speed of the feed pumps to increase. This increases the water flow to the boiler, raising the level which through the water level recorder and the water flow meter initiates an impulse tending to close the feedwater regulating valve, through the Standatrol relay which tends to delay the action. It will be noted that the Standatrol relay is also connected to the steam flow controller and as long as the normal ratio between the water flow and the steam flow is upset, the steam flow controller will prevent the Standatrol relay from closing the feedwater regulating valve.

The action is somewhat complicated but by means of this three element control not only the water level but also the correct ratio between steam flow from the boiler and water flow to the boiler is maintained at the proper value.

The control of the desuperheater temperature and level and the reducing valve between the high and low pressure systems is also shown in Fig. 11, at the right. This is simpler and is entirely independent from the feedwater control. The action of the desuperheater has already been explained briefly. The amount of superheated steam which flows through the upper part of the desuperheater, and consequently the amount which is desuperheated in the lower part, is controlled by means of a butterfly valve in the superheated steam line through a temperature control element acting through a Standatrol relay. The action of the reducing valve is similarly controlled except that in this case the actuating element is a pressure control element.

Conclusion

While we have been able to consider only the principal features of this new extension to Station No. 3 of the Rochester Gas and Electric Co., it will be apparent to anyone familiar with modern power plant practice that this station represents the best that present day engineering practice has to offer. Both the engineer and officials of the Rochester Gas and Electric Corp. and the E. M. Gilbert Engineering Cor-

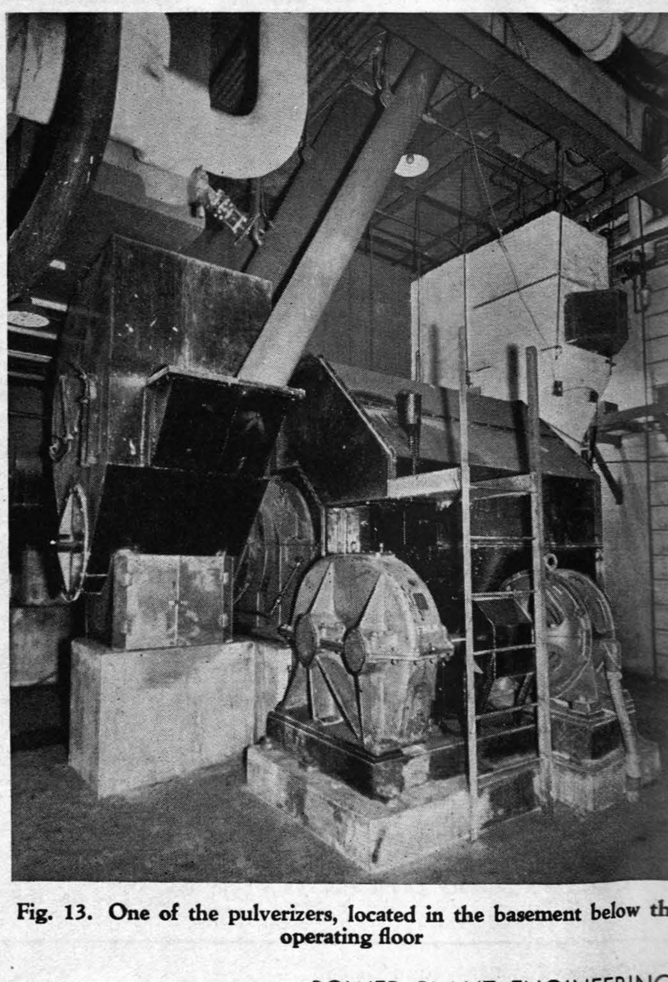


Fig. 13. One of the pulverizers, located in the basement below the operating floor

poration, who designed it, are to be complimented upon having produced so fine an example of modern power plant practice and to both of these organizations we express acknowledgment for courtesies and assistance rendered us in the course of preparing this article, and for the data, drawings and photographs involved in its construction. Acknowledgment is also made to the Bailey Meter Co. for photographs furnished.

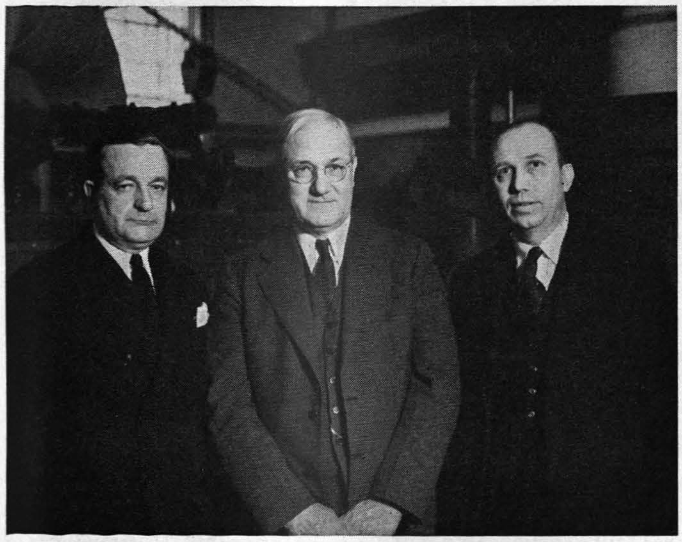


Fig. 14. The Three Powells

The three Powells, concerned in the design and construction of the station. Left to right: Shepard T. Powell, consulting feedwater engineer and chemist; Ivan E. Powell, supt. of steam generation, Rochester Gas & Electric Corp.; supt. of steam generation, Rochester Gas and Electric Corp.; James A. Powell, E. M. Gilbert Engineering Corp. They are not related.

Particular attention is directed to the drawings and diagrams, these are unusually comprehensive and the reader will find much in them that necessarily was left unsaid in the article. The accompanying list of equipment also contains detailed data which could not be duplicated in the body of the article.

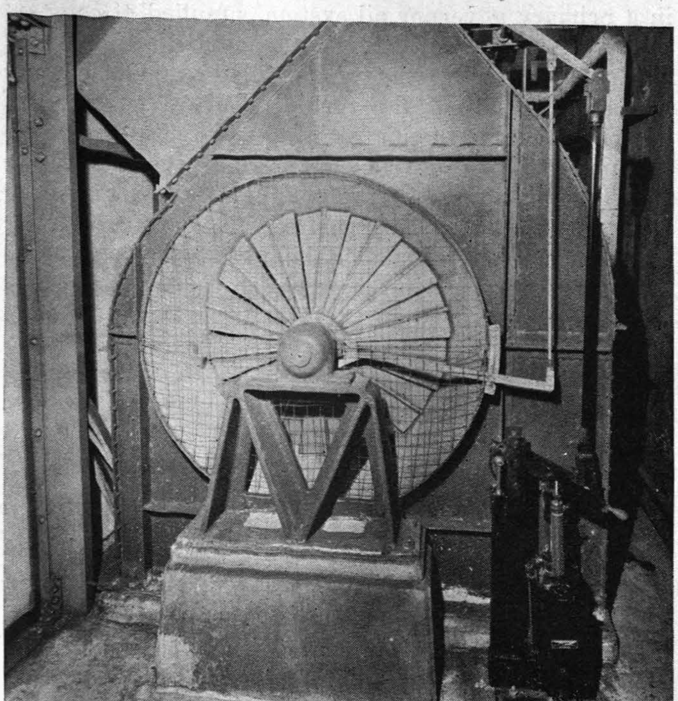


Fig. 15. The induced draft fan showing the Vortex control and the automatic actuating mechanism.

Hydrogen As an Auxiliary Fuel

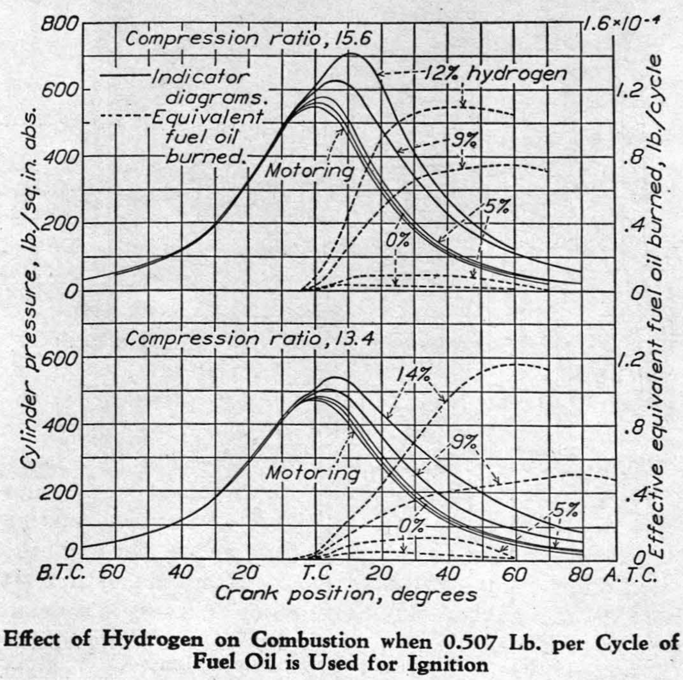
An Investigation was made at the Langley Memorial Aeronautical Laboratory (reported by Harold C. Gerrish and Hampton H. Foster in N. A. C. A. Report No. 535) where the performance of a single cylinder, four-stroke cycle compression ignition engine operating on fuel oil alone was compared with its performance when various quantities of hydrogen were induced with the inlet air.

Hydrogen could be burned satisfactorily in all loads up to and including cruising at a compression ratio of 13.4 and 15.6 in sufficient quantities to compensate for the increase in lift due to the consumption of the fuel oil. If hydrogen can be burned in the engines of an airship with the same efficiency as liquid fuel the fuel weight would be reduced 17.6 per cent and allow a proportionate increase in pay load.

Compensation for Weight of Burned Fuel a Serious Airship Problem

In the cruising range the mixture of fuel oil and hydrogen burned as efficiently as the fuel oil alone. At smaller power outputs the mixed fuel oil and hydrogen burn less efficiently than the fuel oil alone whereas for power outputs greater than that required for cruising the mixture of fuel oil and hydrogen burn more efficiently than the fuel oil alone. For all loads except idling there was present in the exhaust, water vapor weighing more than the fuel oil burned; when burning the maximum amount of usable hydrogen with the fuel oil, the weight of vapor was 80% more at full load and 200 per cent more at small load.

The engine always stopped firing when fuel oil was cut off. Throughout the limits of the test conditions, it was never possible to auto-ignite the various mixtures of oil and air but the injection of even a minute quantity of fuel oil would cause the mixtures to burn. The engine showed no ill effect through the use of hydrogen and no change in engine operation was apparent.



Effect of Hydrogen on Combustion when 0.507 Lb. per Cycle of Fuel Oil is Used for Ignition