# The S-2 Steam Heating Station of the Edison Electric Illuminating Company of Boston

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THE first part of a large boiler plant supplying steam to Metropolitan Boston was put in service during the month of October, 1930, by the Edison Electric Illuminating Company. Covering an area of 16,977 square feet of land at Kneeland and Utica Streets adjacent to the Boston & Albany Railroad tracks, this station which will ultimately contain six boilers, fired by pulverized coal and including many of the most modern features, is especially interesting, as it is built solely for the purpose of furnishing district steam heat. Figure I is the architect's drawing of the station, and Figure II is a photograph of the completed portion.

The problems confronting the designer of steam-heating equipment are radically different from those of the power-plant engineer, because of the extremely low load factor. The high peak of the zero day must be balanced against the medium load of spring and fall, and the condition of almost no load in summer. The daily steam peak comes just before noon, differing from the electrical peak. These load-variations make it impractical to use any large amount of turbo-generator exhaust for steam heating. In fact, it is not economical to lay out capital for the last increments of efficiency. The central steam generating station by its very nature, will have a low direct-operating cost compared to the small individual plant it replaces. It is on the reduction of the carrying charge of the capital investment that the design must be based. One further complication comes from the fact that there are no condensate returns from the distribution mains. This condition is not peculiar to the Boston system, for few district heating plants in the country find it economical to return condensate to their boilers.

How these problems were met in the S-2 Station may be seen from the detailed description of the plant which follows.

The first section of the S-2 Station contains two boilers, each of which is capable of evaporating 250,000 pounds of water per hour continuously, when operating at a pressure of 200 pounds per square inch gauge. A cross section of the station is shown in

Figure III. The boilers are of Stirling type, 3 drum, 42 tubes wide. The boiler heating surface is 19,030 square feet. The tubes in the lower row are spaced to form a slag screen. The hot gas make three passes in going through the boiler. There are no soot-blowers installed, as the boilers will be cleaned with a hand lance.

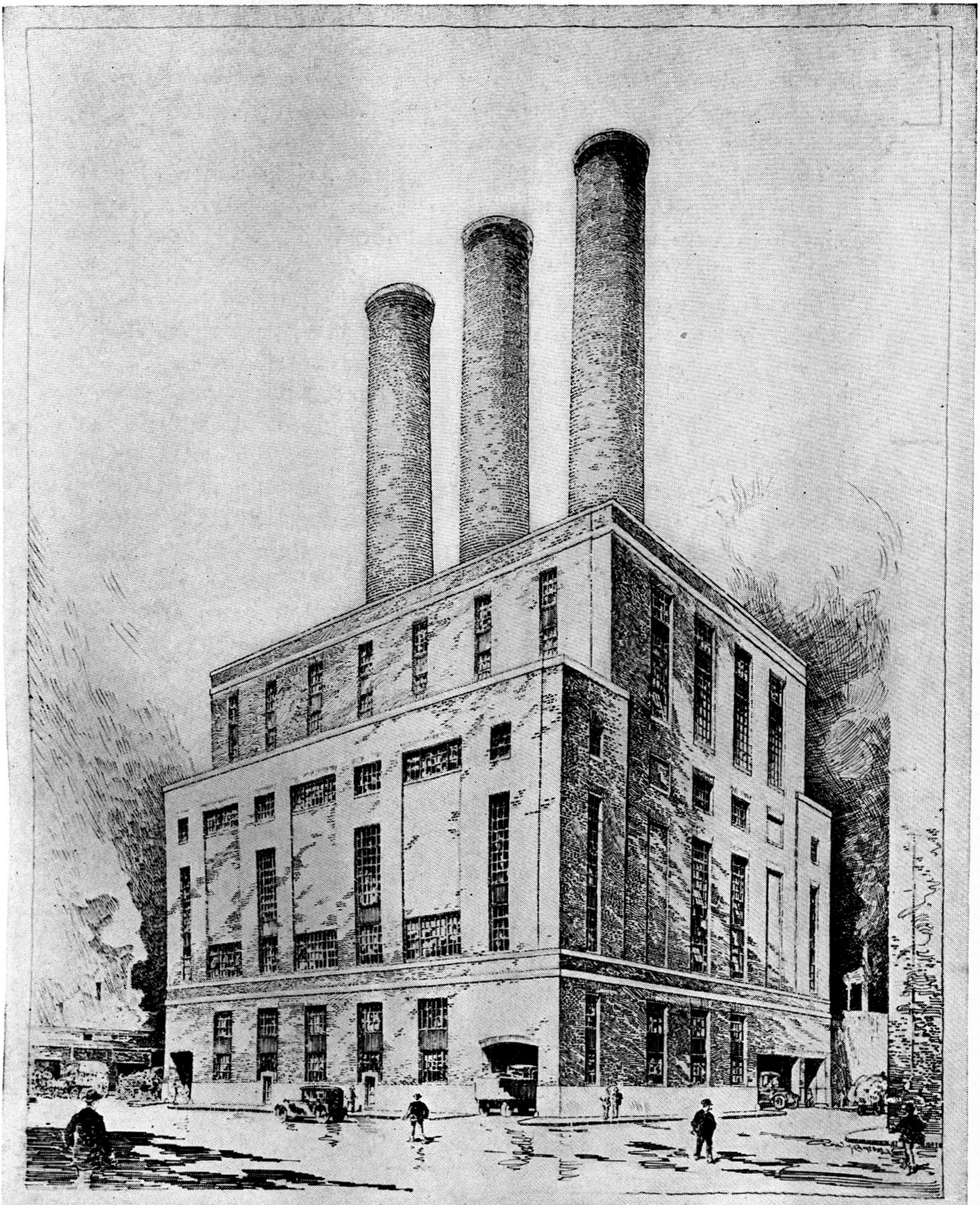
The furnace has an effective volume of 12,500 cubic feet, is water-cooled on three sides and on sloping hearth. These walls are made up of 3¼″ tubes covered with cast iron blocks and backed with refractory and insulating materials. The tubes are connected through headers into the regular boiler circulation, giving additional evaporating surface of 1943 square feet. The hearth cools the ash as it falls to the ash pit, thus eliminating trouble from moulten ash. The four horizontal turbulent burners are set in the refractory wall below the mud drum.

From the boiler the hot gases go through the tubes of the air heater, which have a surface of 16,920 square feet. All the air required for combustion is heated from 50 to 489 ° F. by this heater at maximum rating.

The modern tendency in boiler design towards expansion upwards is well illustrated in this station. The operating floor is at grade 1′ 8″, the ash pit at grade 17′ 3″, the gauge glass at grade 72′, the roof at grade 139′, and the top of the stock at grade 265′, while the boilers are only 21′ wide.

The fuel burned in this plant is semi-bituminous coal. Crushed coal is delivered by trucks in special 7½-ton containers. An electric crane, with a capacity of 15 tons and speed of 100 feet per minute hoists these containers to the top of the boiler house and dumps the coal in either of two concrete bunkers of 300-tons capacity each. The coaling operation is so timed that the station's maximum coal demand of 600 tons per day can be supplied by three trucks, working continuously.

From the bunkers the coal flows by gravity to the atrita duplex unit pulverizers, which are driven by 125 h.p. constant-speed turbines. There are two pulverizers per boiler with two feeders and two outlet pipes to the burners for each pulverizer. Thus either or both sides of the pulverizer and the burners connected can be operated independently at any rating. The coal falls on the feeder disk which may be driven at two different speeds. An adjustable knife scrapes the desired quantity of coal from the disk and allows it to fall to the pulverizing chamber over a magnetic separator for the removal of tramp iron.



*Steam Heating Station S–2, at Kneeland and Utica Streets, Bostor*

Fig. I

In the pulverizing chamber the coal mixes with the hot primary air, is dried and pulverized to a high degree of fineness, and, mixed with the air, is blown by fans integral with the pulverizers to the burners above. The secondary air, the balance needed for combustion, is added in the burners.

The burners are lighted by oil torches. The range of coal feed is from 750 to 12,500 pounds per hour per pulverizer, representing a maximum heat release of 28,000 B. T. U. cubic feet of furnace volume.

The station ash-handling system is hydraulic throughout. The ashes are washed from the ashpit and third pass of the boiler by jets of water, and carried through hydraulic sluices to the ash sump. A vertical dredge pump of 1000 gallons per minute capacity against a 68′ head driven by a 50 h. p. motor, draws the ash and water from the sump and discharges to the ash tanks. The water drains from the ash tanks back to the sump and is recirculated to the sluicing system by a pump similar to the dredge pump.

The ash settling tanks are of wood, and are equipped with water-tight, cast iron, hydraulically-operated gates. After the ashes are drained, they are dumped through the gates to trucks below.

The air necessary for combusion is drawn through windows into the fan room, which is above the top of the boilers. One forced-draft fan is provided for each boiler. They are of super-turbo, double-inlet type, capacity, 80,000 cubic feet per minute against a static pressure of 12″ of water, and driven by variable-speed turbines. From the fan the air passes across the tubes of the air heater which they leave at a temperature of 489° F., as has been said.

Most of the pre-heated air goes directly through the burners to the furnace, but a small amount mixes with the coal in the pulverizers, and about six per cent is bypassed to the induced-draft fans for purposes as explained below.

From the furnace the products of combustion go through the three passes of the boiler, through the air heater, and at about 500° F. enter the gas scrubbers. These gas scrubbers, for the purpose of removing fly ash, are of the wet type. There are two for each boiler. The water-atomizing device in two of the units are rotating disks, and in the other two, spray nozzles. The scrubber body is 11′ in diameter, 22′ high and is lined with brick, the bottom 2′ being protected from corrosion by lead sheets. The water will be recirculated by pumps of 300 gallons per minute

*Completed Portion of the Station*

Fig. II

capacity, ash and water being bled from the system to the ash tanks below.

From the scrubbers the flue gases, at 135° F., saturated with water, go to the induced-draft fan. As it is not desirable to send saturated gas to the stack, some of the preheated air from the air heater mixes with the gas at the fan inlet, giving a temperature of about 155° to the stack. The induced-draft fan, one per boiler, is of the super-turbo double-inlet type, capacity 145,000 cubic feet per minute against a static pressure of 12″ of water, and is driven by a variable-speed turbine.

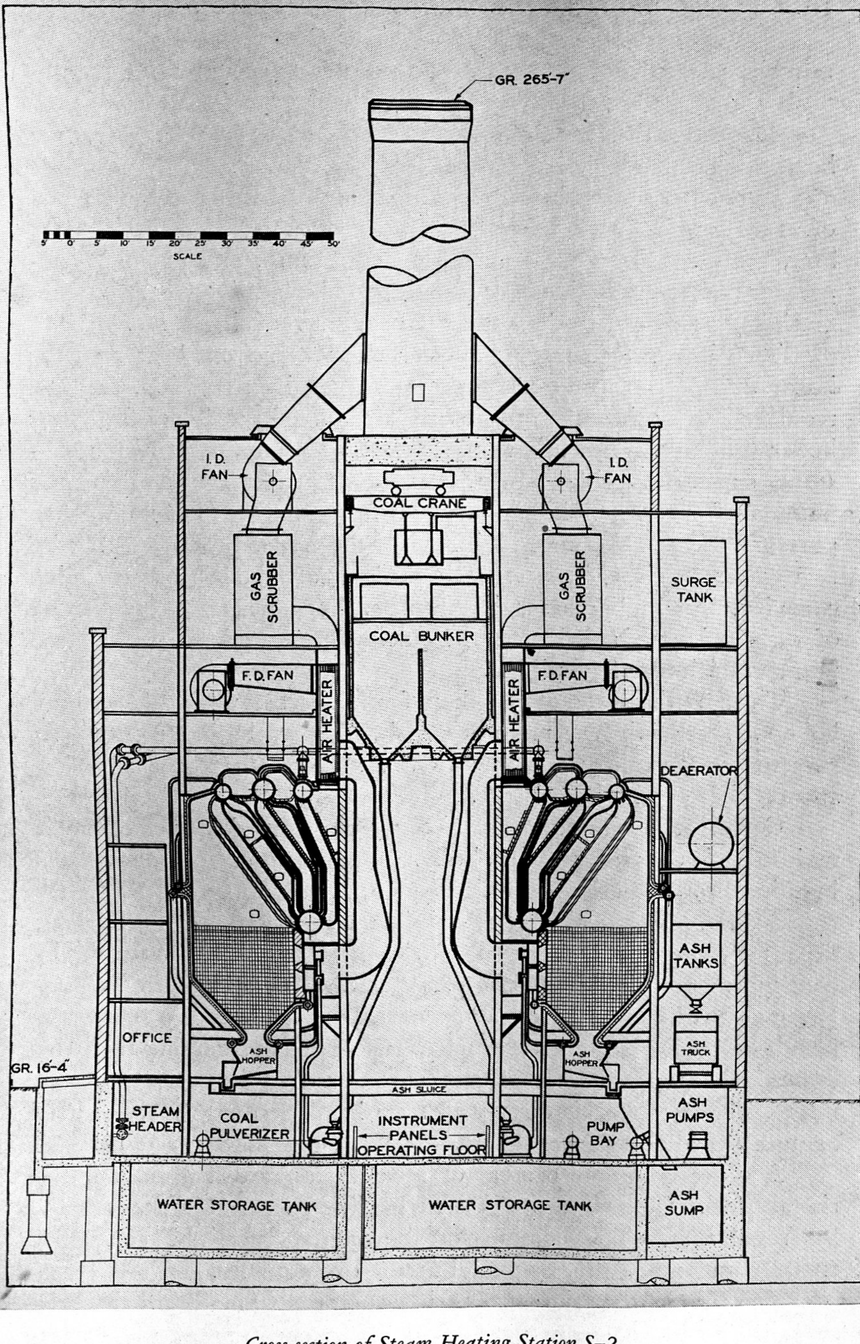
One stack, which serves both boilers, is a superimposed, radial-brick chimney, with an inside diameter of 15′ at the top, and reaches to a height of 250′ above the street.

As has been stated, there is no condensate return from the steam delivered to the distribution mains. Station steam-driven auxiliaries use about 16 per cent of the gross steam output, which leaves 84 per cent of the boiler feed to be supplied by city water. Three water lines enter the plant, two from the low-pressure and one from the high-pressure main.

Although Boston water is of very good quality, because of the high proportion of makeup, it must be given extensive treatment. The water is softened by a three-unit zeolite system. Each unit is 10′ in diameter and 10′ high, and contains a bed of natural zeolite 30 inches thick. The flow of water is downwards at a maximum rate of 23,000 gallons per hour per unit, and will at this rate completely soften Boston city water having an initial hardness of two grains per gallon.

The zeolite changes the scale-forming magnesium and calcium salt in solution, to sodium salts. From the softeners the water goes to a storage tank of 60,000-gallons' capacity, or about one hour's supply at full load.

Two single-stage, volute, service pumps, one driven by a 75 h.p. turbine, and the other by a constant speed-induction motor, take their suction from this tank and discharge to the deærating heater. The capacity of each pump is 600,000 pounds per hour against 165-foot head. Sodium sulphate for the prevention of caustic embrittlement by maintaining a 2.8 ratio of sulphates to alkalinity, is added after the pumps. The sodium sulphate solution is fed in proportion to the flow of water by a displacement tank piped across an orifice in the line. The water passes through a heat exchanger, where the heat in the 5 per cent continuous blow down is recovered. The service pumps also main-




*Cross-section of Steam Heating Station S–2*

Fig. III

tain the water level in the 250,000-pound-capacity reserve storage tank above the deærator.

The deærating heater consists of a vent-condenser, barometric heating head, in which the water mixes with the auxiliary exhaust and an open-contact deærator. This heater delivers 500,000 pounds of 215° F. feed water, having not more than .03 cc. of oxygen per liter, with steam at one-pound gauge pressure, and an inlet temperature of 50°. Besides the auxiliary exhaust, live steam is automatically admitted to the heater through a reducing valve.

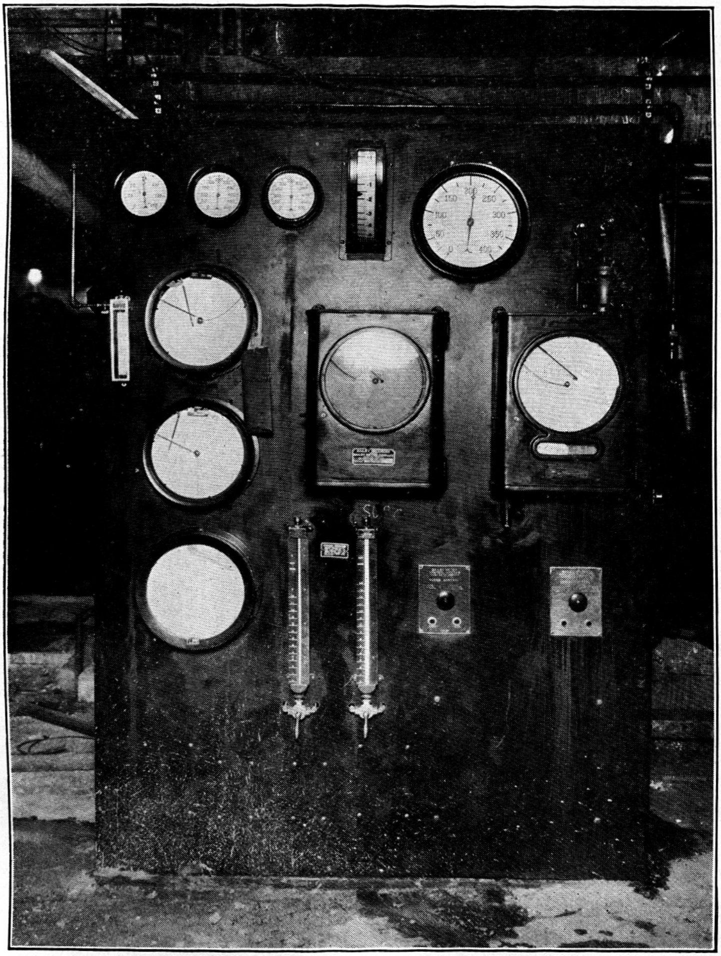
Two boiler feed pumps deliver the water from heater to the boilers. One is a three-stage pump driven by a 350 h.p. turbine, regulated to maintain a 50-pound margin of the boiler feed over boiler pressure. The other is a four-stage pump, driven by a constant speed-induction motor. Each has a capacity of 600,000 pounds of water per hour at 215° F., against 325 pounds' gauge pressure. Thus the dependability of the boiler feed is insured by two water services, by a storage tank of one hour's full steaming capacity, by duplicate service pumps, by a reserve storage tank of one-half hour's full steam capacity, by duplicate boiler feed pumps and boiler feed piping.

The auxiliary steam is taken from the steam line from both boilers, which join the main steam header in the basement. At present there is only one line to the street, but in the complete station there will be two more.

Continuous blow down of about 5 per cent of the net steam is maintained to prevent the boiler concentration of solids from building up. This blow down goes to a flash tank connected with the auxiliary exhaust, the remaining water passing to the heat exchanger already mentioned in the line to the deærator. The cold blow down is sent to the dirty-water storage tank in the subbasement, which has a capacity of 60,000 gallons. Wash water from the zeolite softeners, which is used in considerable quantity during the regeneration of the softeners required every eight hours, also goes to this dirty-water tank. The dirty water is used as makeup to the gas scrubbers.

A quite complete system of automatic control is installed in the station. The water level is maintained entirely automatically by regulators. The combustion equipment may be controlled entirely automatically, by push button, or manually.

The function of the automatic control is to maintain the pressure in the main steam header within 2 per cent of the desired value (200 pounds). In doing this, the fans and pulverizers on



*Control Board*

Fig. IV

This photograph shows the control panel of Boiler No. 2. On the right are mounted the boiler pressure indicating gauge, steam-flow air-flow recorder, and the boiler control switch. On the left are three small indicating gauges, one giving the service water pressure, and one on each of the boiler feed headers. Below these are the recorders for boiler feed pressure, temperature and flow. There are two draft indicators, one for forced draft pressure and one for furnace draft. In the center of the panel is the master pressure contactor with recording chart and below this indicators of the water level in the soft water storage tank and the reserve water storage tank. The master control switch is to the right of these indicators.

The control panel for Boiler No. 1 is somewhat smaller, and has mounted on it the boiler indicating pressure gauge, indicating draft gauge, steam-flow air-flow recorder, control switch and the station steam output recorder, the reducing valve relay, and the recording gauge showing the pressure at the system load center.

Each boiler control panel includes a boiler water-level indicator.

all boilers on the line are so governed that the excess air does not vary more than 5 per cent from the desired value, and the furnace draft not more than one-tenth of an inch. The push-button control is such that from the operating panel in the basement (shown in Figure 4), fans and pulverizers can be so governed as to maintain proper conditions.

A master steam-pressure contactor, actuated by the pressure in the main steam header, controls the pulverizers and forced- and induced-draft fans on all boilers on automatic control, to hold the desired pressure.

A steam-flow air-flow, and furnace-draft contactor on each boiler readjusts the fans to give the proper excess air and furnace draft to each individual boiler.

These contactors actuate the electric control-drives on the cam shaft of the fan turbine nozzles valve, and on the pulverizer feeder knives. The control drives have hand wheels for manual operation.

The automatic control devices have the following safety features:

1. When the maximum capacity of air supply is reached, an interlock prevents further increase of coal feed.

2. When the coal feed is reduced to a minimum, an interlock prevents the air supply from being reduced below that necessary for complete combustion.

3. Travel limits are provided on all control drives.

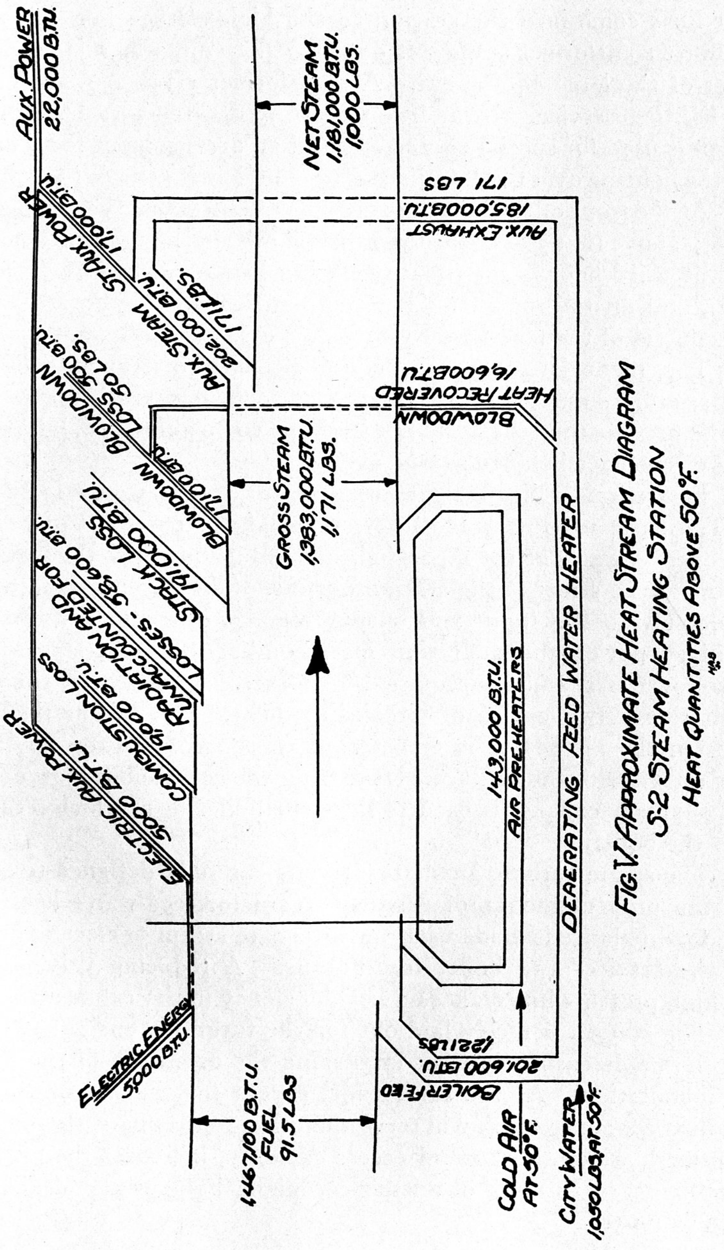
4. Under both automatic and push-button control, a time-limit device prevents more than a 3 per cent change in the air or fuel supply under one electrical impulse. This is to guard against short circuits. To cause a greater change than 3 per cent, intermittent electrical impulses are signaled to the drive either by the contactor or push-button control.

5. The forward and reverse clutches in the drive cannot be thrown at the same time.

6. In case of electrical supply failure, no change in the position of drive occurs, and hand control may be used at once.

The steam pressure to the street varies somewhat with the load. A remote recording gauge on the control-board shows the pressure at the load center. The automatic reducing valve relay, also on the control board, is set by hand to maintain this pressure at 100 pounds gauge. This necessitates, under our present load, from 110 to 150 pounds gauge to the street. Once the relay valve is set, the reducing valve maintains this street pressure.

Considerable electric power is used in the plant. Two 13,800-




*Heat Stream Diagram of the Station*

Fig. V

volt lines come into the station to the high-voltage bus. A 750-kilowatt transformer steps this down to 440-volt, which is used for most of the large equipment. A transformer gives 220/110 volts for lighting service. In addition there is a three-wire D. C. line which is used for special equipment and an arrangement for throwing the lighting over to D. C. in case of trouble with the A. C. supply.

At the front of the building, on the street level, is the engineers' office; above that the washroom, with showerbath and locker room. On the third floor is the Steam Heating Department's meter test-shop, and on the fourth floor a complete chemical laboratory for the control of the feed-water treatment, etc.

The plant is adequately equipped with instruments of all kinds, and complete records of the performance are being made. At the present time these are not in shape to be published, but some idea of the heat balance can be given.

Figure 5 is a heat-stream diagram of the station. It shows B. T. U. per 1000 pounds of net steam above 50° F. Coal, electric energy, water at 50° F., and air at 50° F., come into the station. Steam to the street is the station output. The difference between the heat values of input and output represents steam and electric auxiliary power and radiation loss, combustion loss, stack loss, blow down loss, and unaccounted-for losses. In addition, the diagram shows two cycles of circulating heat. Heat from the flue gases in the air heater is transferred to the combustion air, and thus returned to the furnace. Heat from the continuous blow down and auxiliary exhaust is used to heat the boiler feed, which returns it to the boiler.

The steam turbine auxiliary drive is carefully designed to supply the proper amount of exhaust steam for feed-water heating. The final balance is made with the alternate steam or electric drive for the service- and boiler feed-pumps. A reducing valve from the high pressure line makes up any deficiency in the exhaust steam.

The station is nicely laid out for the future extensions, which may be made easily, without disturbing the operation of the present installation. At the same time, except for the ash- and coal-handling systems, which will serve the other four boilers, there is no equipment which, because of excess capacity, increases the present investment, or through obsolescence, might hamper the design of the new units.