BOILER INSTALLATION AND OPERATION

by

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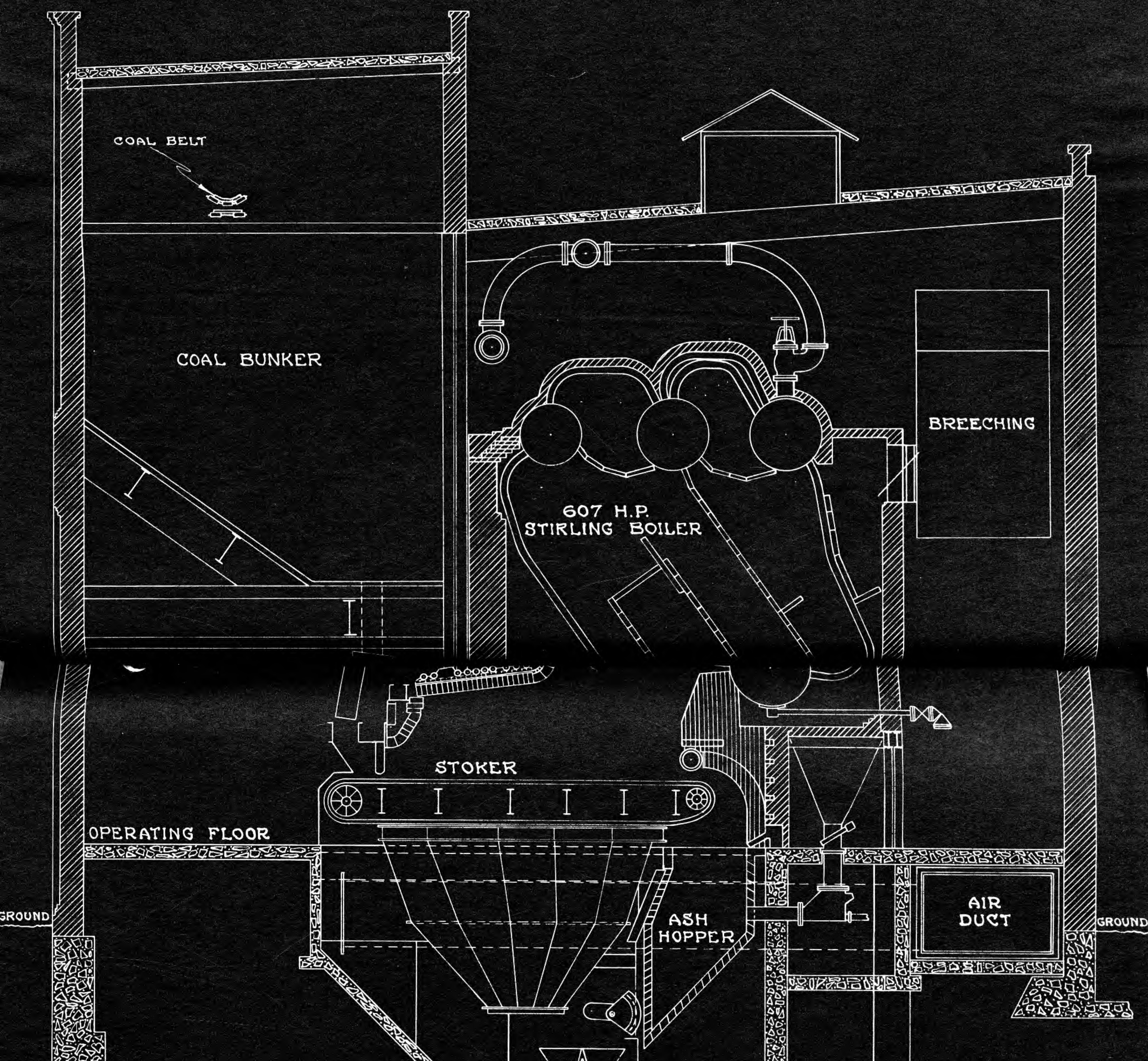
The modern manufacturing plant depends to a great extent upon its Boiler Room. As the Boiler Room runs, so does the remainder of the plant. If the Boiler Room shuts down, the plant does the same; if the cost of producing steam is high, the cost of the finished product is also high; if the cost of the steam is low, the cost of the finished product is low. It is therefore correct to say: The Boiler Room is the heart of the plant.

Although the following treatise on Boiler Installation and Operation is the result of problems met and solved in the Boiler Room of the Procter and Gamble Manufacturing Company's Kansas City plant, these same problems must be met and solved during the installation and operation of boilers in any other manufacturing plant.

SELECTION OF EQUIPMENT

Steam generated at 160 pounds per square inch guage and at 99% quality when used in process work cannot be returned to the generating equipment due to danger of contamination. Thus 95% of the water fed into the boilers of the Procter and Gamble Manufacturing Company's boilers at the Kansas City plant is treated raw water. With these



CROSS SECTION OF BOILER ROOM

1929 FIGURE I V.H.B.

facts in mind and considering the desirability of quick steaming boilers due to ever changing loads, the selection of four new boilers to replace six 350 H. P. Type F.-B. & W. Stirlings was given much thought.

These old boilers were set very low, using Green natural draft chain grate stokers, and had a marked tendency to prime when operating above 125% rating. The ultimate rating obtainable was close to 150% with a draft of 1.4 inches of water at the stack. The steam generating equipment consisted of four Type M-521 H. P., six Type F-350 H. P., and two Type S-450 H. P. Stirling boilers, a total of 12 boilers with a total rating of 5084 H. P. at 100% boiler rating.

After considerable investigation it was decided that because of lack of room between the concrete coal bunkers and back Boiler Room wall and the desire to standardize on boilers, four Class 22-607 H. P. Stirling boilers were to be installed, replacing the six Type F boilers. These boilers were accordingly ordered with Tracifier steam separators and B. & W. Water Backs. A cross sectional view of the Boiler Room showing these boilers when completely installed is shown in Figure I.

The question of stokers was settled by ordering B. & W. Forced Draft Chain Grate stokers driven by 7½ H. P. A. C. variable speed motors. The use of Kansas coal from the Pittsburg district necessitated 20% chain openings.

Plans called for the settings to be built of #2 Laclede King fire brick with #1 Laclede King brick for lining. Flat suspended arches were considered and ordered, two of the Bigelow type and two of the Dietrich type. Side wall cooling was contemplated through the use of Drake Air Cooled walls set up to a height of two feet from the stoker ledge plates.

DISMANTLING OLD EQUIPMENT

The dismantling of the old boilers and installation of the new ones required careful planning so as not to interfere with the normal operation of the Boiler Room. The first problem to be solved was that of installing a new breeching over the six Type F and the two Type S boilers. This new breeching was made necessary by the use of the new 607 H. P. boilers due to the larger volume of gasses they were to produce when operating at high ratings. This breeching was assembled above the old breeching during week days, and was connected into that part over the Type M boilers during a week-end when these boilers were banked. Connections were also made from all the other eight boilers with the exception of the first two which were to be dismantled.

Since all of the boilers were set in batteries of two it was planned to dismantle two boilers at a time, but this was changed when it was found that the space was very limited for the installation of the two turbine driven forced draft fans. Therefore, three boilers were dismantled at once--all piping removed, settings torn down, and the drums and tubes removed. The use of the acetylene torch for cutting piping, drums, and tubes was found to facilitate the work to a high degree. A locomotive crane was used to load all dismantled equipment and fire brick into railroad cars in order that valuable space in front of the Boiler Room be kept clear. Thus this material was removed as quickly as it was dismantled.

INSTALLATION OF NEW EQUIPMENT

After the boilers were dismantled and the old concrete foundations were cut out by means of concrete pavement breakers, excavations were carried to a depth of 10 feet below the Boiler Room floor. At this point solid earth was encountered which eliminated the sinking of piling for the new foundations. During the excavating sheet piling or cribbing was used to prevent caving. This part of the work was done very carefully so as to prevent the boilers in operation from sinking.

While the excavating was going on, the forms for the concrete were made up in panel form. This speeded up the work as it allowed the forms to be placed quickly.

Since the new operating floor was four feet above the old Boiler Room floor, due to the forced draft air ducts and the ash tunnel, the total height of the concrete forms was 15 feet above the foundation footings. For the battery set boilers a total of 90 yards of concrete was poured into the foundation. The single set boilers required 50 yards of concrete in the foundation. This was all of a 1-2-4 mix and of standard consistency based on the cement-water ratio.

The foundations were poured to within 20 inches of the top of the forms, and after the concrete had set sufficiently, the 15-inch I beams, which were the frame work of the Allen-Sherman-Hoff Ash Hoppers, were placed and leveled. The forms were then poured to the top, imbedding the I beams and thus protecting them against corrosion.

The erection of the boilers proper was begun by placing the boiler supporting steel in position. All lifting was done by means of five-ton chain hoists fastened to the Boiler Room roof as this eliminated gin poles and booms. All boiler supporting steel, that is, columns, I beams, and strut braces were erected and were leveled before any of the steam drums were placed in position.

All three steam drums were hoisted, placed in position, and leveled on the supporting steel. The mud drum was then shored into exact position, and one row of tubes on each end of this drum was rolled. These two rows of Tack tubes, along with the steam circulator tubes in the steam drums, held the boiler in exact position for the remainder of the tubes--400 in all. The Water Back tubes and Water Backs were installed at this time. Tubes were placed in position during the day and were rolled at night as it was found that both crews could not work conveniently at the same time.

After all tubes had been rolled and the boiler nozzles blanked off, a hydrostatic test of one and one-half times the working pressure was given each boiler. All leaking tubes were noted and rerolled.

The boiler specifications are as follows:

Effective heating surface	6074 sq. ft.
Horse Power 607	W. S. P. 160#
Width--20 tube sections	
Furnace width--10' 0"	
2 steam drums--42" diameter	11' 9½" long
1 steam drum--36" "	11' 9½" "
1 mud drum--48" "	11' 10½" "

Drums connected by 400 tubes--3¾" diameter #11 guage

Since the use of superheated steam in process work is detrimental to the quality of the product manufactured, superheaters were not used in connection with these boilers. The lack of space prevented the use of air preheaters for the forced draft stokers.

Boiler Guarantee

Percent rating	100	200	300
Steam pressure	160	160	160
Temperature Flue Gas °F	500	615	755
Efficiency of boiler and furnace %	77.2	72.7	68.4
Draft loss through boiler inches of water	.13	.82	2.02

During this period of boiler erection, foundations were placed for the two No. 8½ Buffalo Turbo-Conodial Forced Draft fans and the Fan drives--50 H. P. General Electric steam turbines. All air ducts were installed by means of electric welding. The ash handling system consisted of refractory lined Allen-Sherman-Hoff Ash hoppers with quenchers and balanced gates discharging into ash buggies in the ash tunnel. All work in the ash tunnel had to be timed so as not to interfere with the removal of ash and cinders from the boilers in operation and was carefully planned before any work was started.

After a boiler had been tested the work of installing the B. and W. Forced Draft Chain Grate stoker was started. The stoker base-channels were placed, leveled, bolted to the foundation, and grouted. Upon these base-channels the stoker was erected. In the battery type boilers the expansion side of the stoker was to the battery wall; that is, the stoker expanded away from the drive.

Stoker specifications are as follows:

Stoker width	10' 0"
Stoker length	15' 3"
Grate area	152.5 square feet
Drive	7½ H. P. variable speed A. C. motor

Space between the upper and lower chain divided into five compartments or blast boxes.

Stokers were designed for 20% air space when burning coal having an analysis not less favorable than the following:

Carbon	61.00
Hydrogen	3.27
Sulphur	.80
Oxygen	13.78
Nitrogen	1.15
Moisture	11.00
Ash	9.00
	100.00

B. T. U. as fired 10,040.

Upon completion of the stoker erection all piping and boiler accessories were attached to the boiler. In the piping layout only extra heavy pipe and steel fittings were used. The soot blowing system consisted of six Diamond Soot Blowers, Type G-9, with three of these units aluminum alloy and three plain extra heavy steel. On the blow-off line Yarway Blow-off valves were installed as previous experience indicated that these valves were very satisfactory, both from an operating and from a maintenance standpoint. For the Boiler Valve a steel 8" Golden-Anderson non-return valve was used. Between this valve and the Boiler Room steam header a steel 8" Crane Gate Valve was placed in the line.

The instrument panel was located at the front and to one side of each boiler and carried the following boiler instruments:

Steam guage graduated from 0 to 300#.

Seven point Hayes draft gauge with five pointers for the five stoker compartments reading from 0 to 6 inches of water. The "Over the Fire" scale reading from 0 to plus and minus .5 inches of water and the "Last Pass" scale reading from 0 to 2 inches of water.

A three pen Bailey boiler showing boiler rating, flue gas temperature, and air flow.

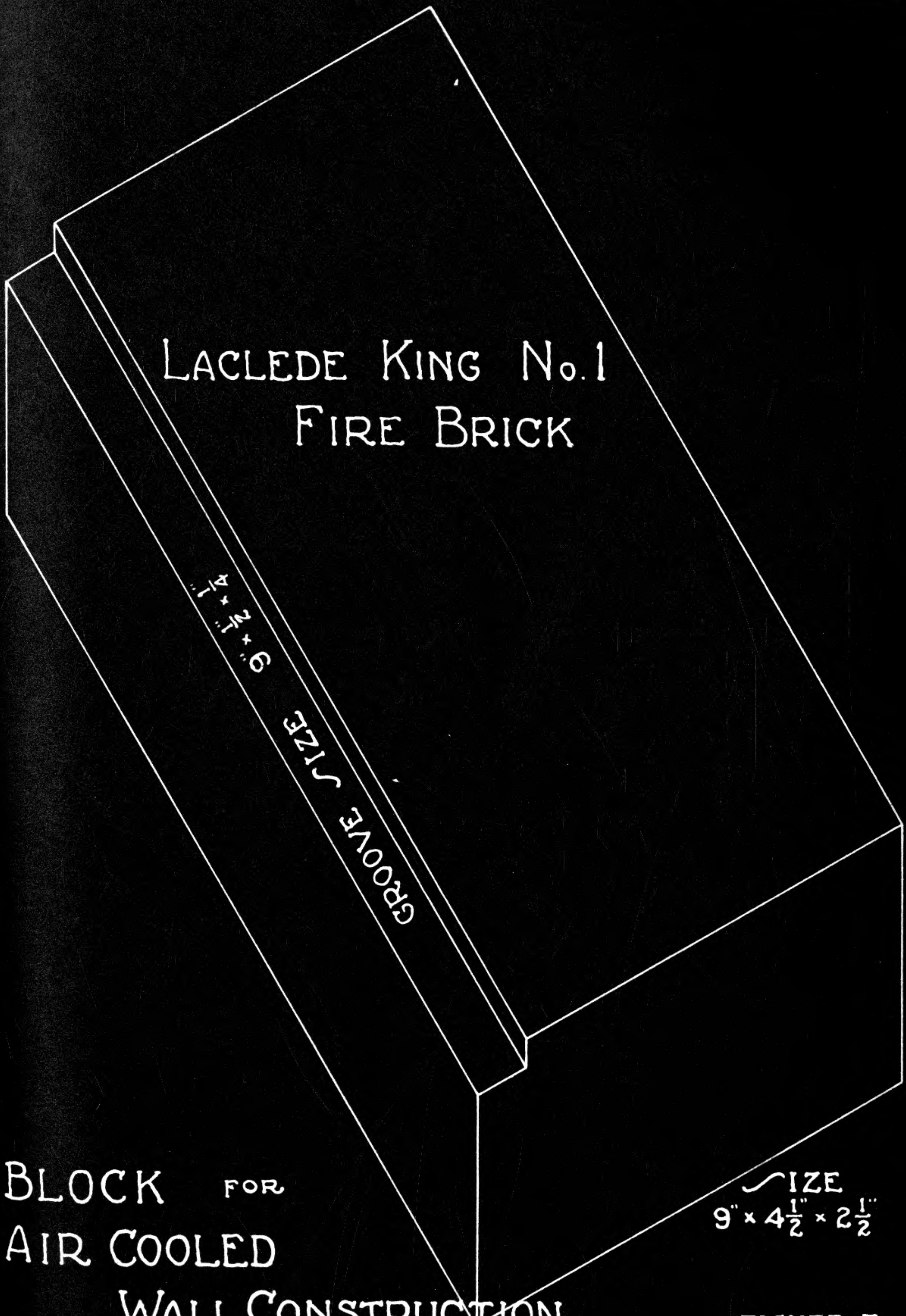
During the construction of the brick setting, care was taken to see that the inside of the furnace walls received the greatest attention. Only perfect Laclede King #1 fire brick were used for the furnace refractory while for the remainder of the setting Laclede King #2 fire brick were used. Brick pilasters supported the stoker ledge plates and the boiler walls were built up on the plates. The Drake Air-Cooled wall blocks were used and were placed directly on the ledge plates. Care was taken to have the Blow-off Line and the mud drum free from the brick work so as to allow for the downward expansion of the boiler tubes.

Upon completion of the brick work a slow drying fire was built, and the setting allowed to dry for seven days. A solution of Soda Ash was added, and the boiler cleaned out. After a thorough boiling, the water was drained, and fresh water run in. The boiler was then ready to be used as a steam producer. (See Figure I)

OPERATING DIFFICULTIES

The boiler was allowed to idle on the line for approximately a week at 100% rating before the rating was raised to 165%. It was found that this was the maximum average rating obtainable due to melting of the furnace refractory. Momentary peaks of 200% rating could be obtained but could not be maintained for any length of time.

This condition seemed very peculiar inasmuch as the boiler was guaranteed for a much higher rating but was explained when the draft loss through the boiler was found to be .8 inches of water with a draft of 1.4 inches of water at the base of the 226-foot stack. The "Over the Fire" draft was a positive pressure of .15 of an inch of water, in other words, a nearly balanced pressure. The problem of low rating was solved somewhat by eliminating the baffle shelf between the first and second banks of tubes. This



BLOCK FOR AIR COOLED WALL CONSTRUCTION

FIGURE II

relieved the "bottling effect" of the furnace and gave longer refractory life.

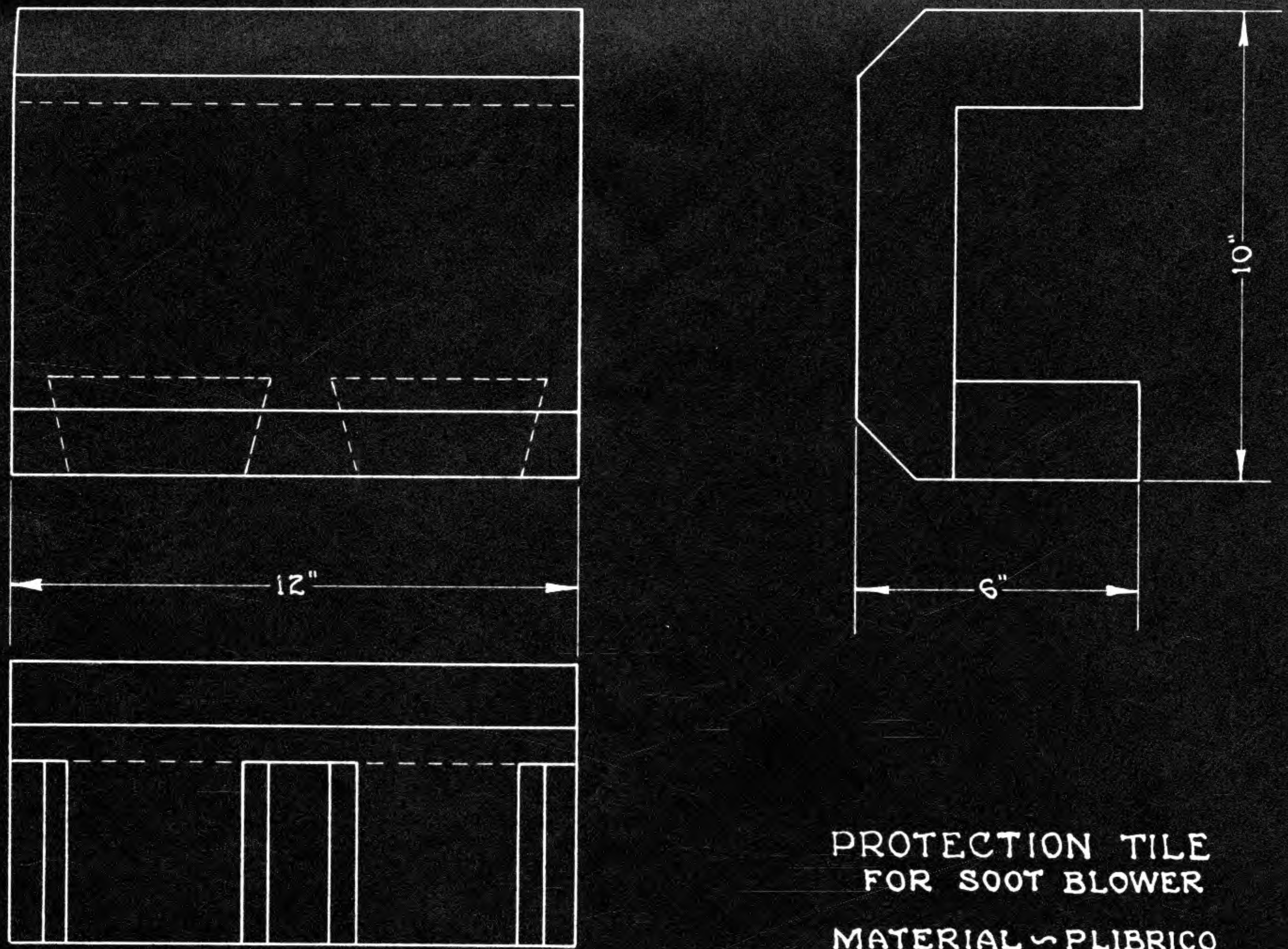
During this period the Drake Air Cooled sidewall blocks proved unsatisfactory inasmuch as the life of these blocks was only 600 hours. After much experimenting, grooved Laclede King #1 fire brick as shown in Figure II were used in place of the Drake blocks. These brick were much cheaper than the Drake blocks and have given from 3,000 to 3,500 hours of service in the sidewalls.

As the rating was increased, the center boiler column and the Bunker column on the battery setting began to heat, and an air blast was used to keep these members cool. As there were only seven inches on one side and nine inches of fire brick on the opposite side, it can readily be seen that the heat in the furnace would soon distort these columns. Carbofrax (Carborundum) brick were resorted to in an effort to check the cutting action of the fire, but as the coefficient of heat transmission of this brick is approximately eight times that of ordinary fire brick, these Carbofrax brick were finally discarded. After all of these methods to protect the columns had failed there was only one alternative left and that was to remove both columns. This was accordingly done.

The battery wall was partly removed, and the front walls and center walls shored while the columns were cut off. Two plate girders, one 48-inch and one 36-inch, 27 feet long, were fastened to the outside columns, and the center columns were then supported by these girders. As these girders are above the arches there will be no question of their heating. All brick work was replaced, and the boilers were again placed in service. It must be understood that this last problem was encountered only on the battery set boilers and not on the single settings as these latter do not have center columns.

The next question pertained to coal segregation on the chain grates. In all installations using the fan type coal-spreader to place coal in the stoker hopper there is a marked tendency for the coal to segregate, that is, the larger particles of coal tend to go to the outside edges while the fine particles remain in the center. These large particles on the outside edges cause a rapid combustion to take place, and the flame produced by this combustion is torch-like in action on the sidewalls and particularly on the ignition arches. On the walls this action has a washing effect which rapidly cuts them away, while on the arches the action is more of a channeling effect.

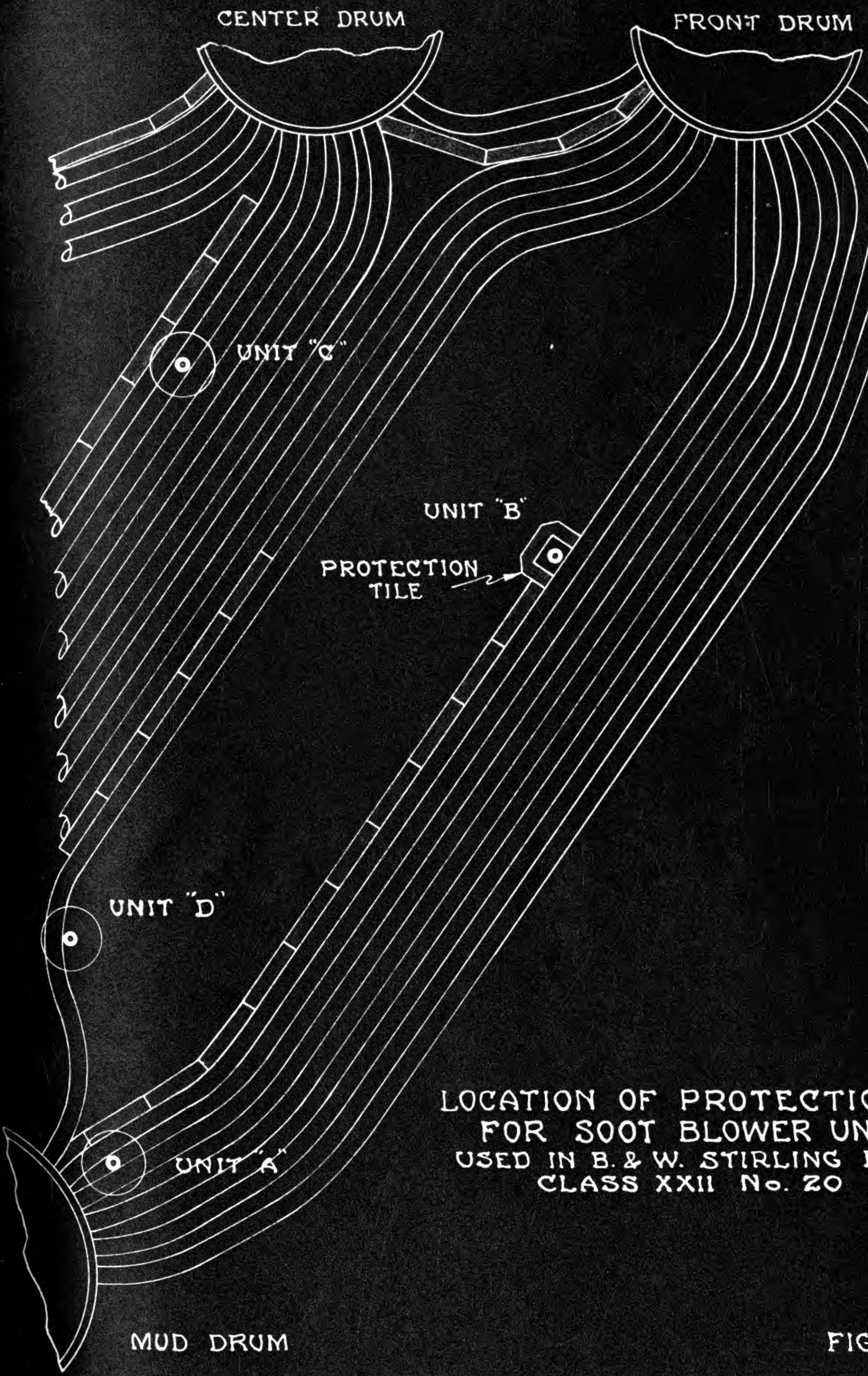
After 600 hours the walls were found to have been cut back from six to nine inches, and the arches were cut or channeled five inches deep. The action on the walls was overcome by the use of the grooved air cooled brick men-



PROTECTION TILE
FOR SOOT BLOWER

MATERIAL ~ PLIBRICO

FIGURE III



LOCATION OF PROTECTION TILE
FOR SOOT BLOWER UNIT "B"
USED IN B. & W. STIRLING BOILERS
CLASS XXII No. 20

FIGURE IV

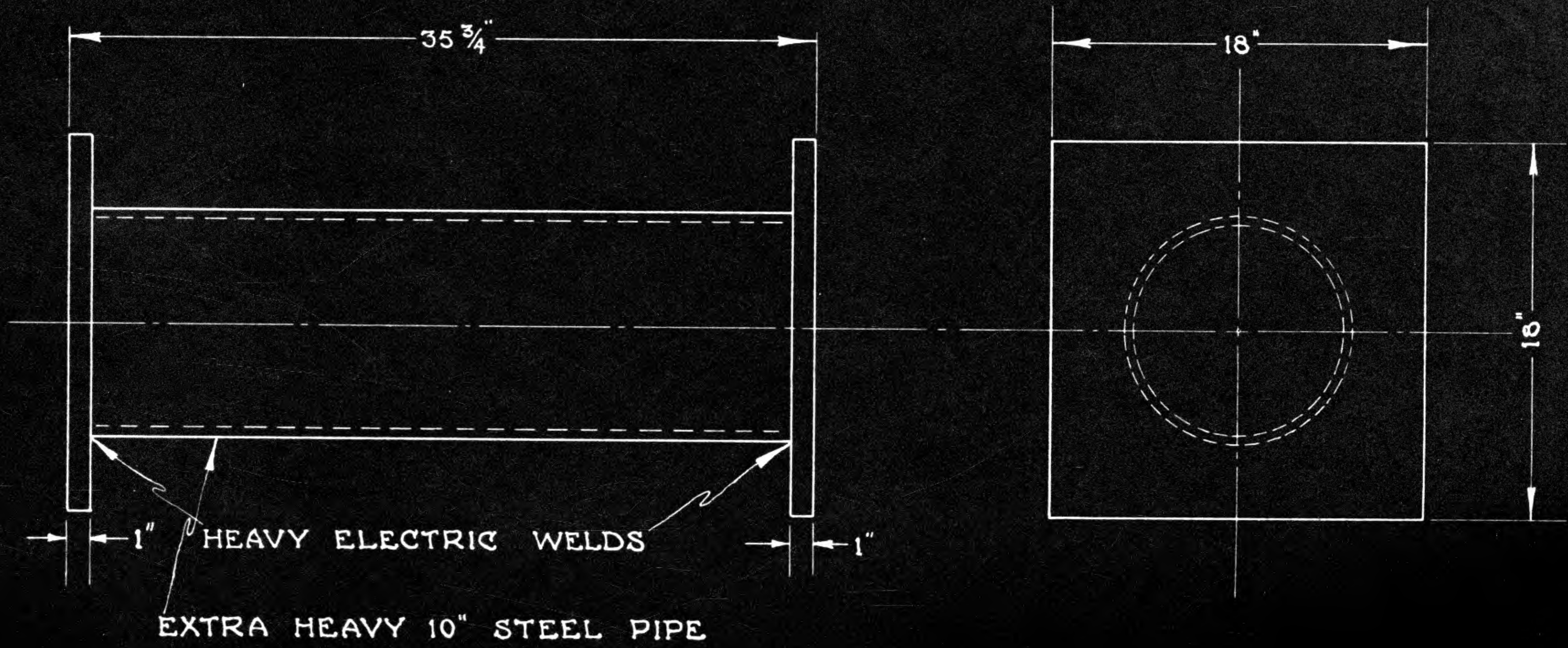
tioned above as the air kept the flame from coming in contact with the refractory.

However, the arches had to be treated in a different manner as the introduction of air in the walls did not keep down the blow-torch action on the arches. The fan type spreaders were divided into sections so that the segregation would be equally distributed across the chain grate, and this relieved the situation slightly. It caused the arches to channel out in more places than before though not so deeply. The problem was solved by raising the arches 10½ inches and installing a patented Gardner Non-Segregating Coal Distributor. In this manner the life of the arches was increased from approximately 600 hours to 3,500 hours of service. The original furnace volume was increased by raising these arches, and this has given a better combustion than formerly.

Another difficulty encountered early was the short life of the Soot Blower unit. This unit is located at the top of the first bank of tubes a few inches above the front baffles and is in the direct path of the hot gases going over into the second pass of the boiler. Even though this unit was a calorized element the length of life was only 100 hours after which it had to be replaced. As these units are expensive, a protection tile as shown in Figure III was designed to cover the unit (Figure IV) and has proven very satisfactory, increasing the life to 2,000 hours.

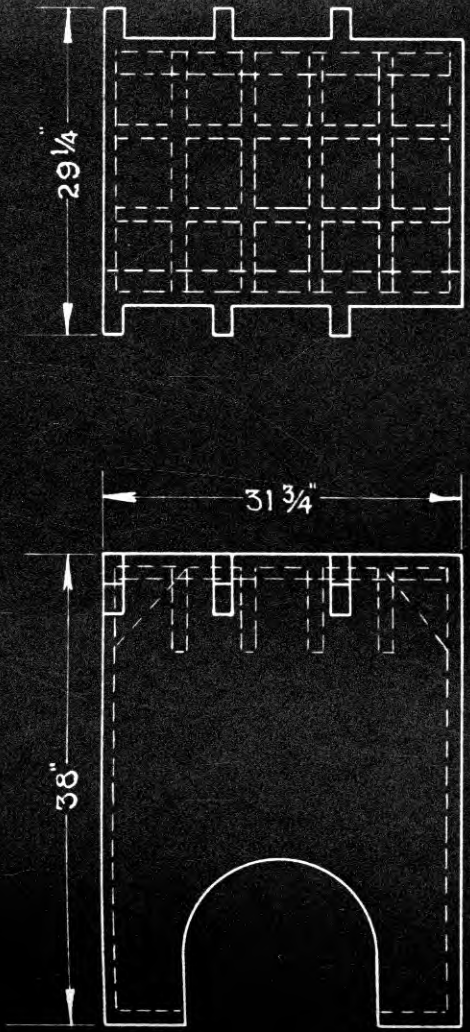
After the first three boilers had been in operation for 18 months the shear pins in each stoker drive began to give way. A close examination showed that the sidewalls of the boilers were slipping out at the foundation line and had a bulge in them up to a height of approximately six feet. An internal examination of the chain grate gave evidence that the grate was tight between the side guides and that the ledge-plates were resting on the stoker side frames. This latter condition prevented the proper expansion of the chain and caused the pins to shear.

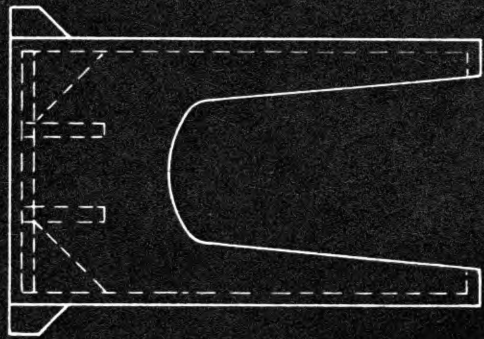
When the ledge plates were originally installed the clearance between these ledge-plates and stoker side frames had been 1/8 of an inch and the clearance between the brick supporting pilasters and the side frames had been 1½ inches. During the examination it was found that fine ash had sifted between the ledge plates and stoker side frames and with each expansion and contraction of the stoker, these siftings had packed tighter and tighter with the result that the walls had been moved out and the ledge-plates had dropped on the side frames. On the battery set boilers the natural expansion of the stokers was to the inside. With no room for expansion, due to the siftings, the battery wall was not disturbed. Only the outside walls were moved while in the single setting both walls were shifted on the foundations.



OUTSIDE BOILER WALL SUPPORT

FIGURE V





CENTER BOILER WALL SUPPORT

FIGURE VI

Upon tearing part of the walls out and shoring the remainder, it was found that all stokers had shifted on their foundations and, in two cases, that part of the foundation was cracked by the stresses set up during the expansion and shifting of the stokers.

This necessitated jacking the stokers back in line and anchoring the base channels on the non-expansion sides to the 15-inch foundation channels by means of electric welding. The next problem was that of designing supports for the ledge-plates as it was decided that the brick pilasters were unsatisfactory, inasmuch as they had a tendency to settle and allow the ledge-plates to come in contact with the side frames. These old pilasters had also been of such a shape that it had been impossible to inspect behind them to ascertain the amount of siftings deposited.

The outside wall supports were accordingly designed and constructed of 10-inch pipe (Figure V) with flat steel caps welded on each end. These allow no settling and give clearance between the side frames and supports. The battery wall supports were constructed of cast iron in the shape of tables (Figure VI) and were well reinforced. This construction permitted an inspector to crawl under the entire length of the battery wall to examine the side frames and to blow out, by means of compressed air, any siftings that might accumulate.

The ledge-plates were then bolted to these supports through slotted holes to allow for expansion and were given 3/16" clearance above the side frames. This 3/16" clearance was caulked with asbestos rope, held in place by means of copper clips, to prevent siftings from filtering through.

After these changes were made the boilers were again placed under operating conditions and no trouble has been experienced with the stokers.

FEED WATER

Boiler feed water is obtained from the plant's reservoir and passes through a Scaife Cold Process Treatment Plant before being introduced into the boilers. The soap hardness of the untreated water averages 20 grains per gallon and is brought down to a soap hardness of 1.6 grains per gallon in the Treatment Plant. The Scaife Cold Process system consists of treating raw water with Lime, Soda Ash, and Sodium Aluminate and then passing the water through a filter bed composed of sand and gravel.

After passing through the Treatment Plant the treated water is pumped into a storage tank from where it flows by gravity into the open type feed water heaters. These heaters are located on the second floor of the boiler feed pump room and thus a head of approximately 15 feet of water is obtained on the boiler feed pump suction line.

The two feed water heaters are heated by means of exhaust steam at six pounds per square inch guage pressure, and under normal operation enough exhaust steam is generated by the feed water pump turbines and the forced draft fan turbines to heat the feed water to a temperature of 200° F. These heaters are also connected to the six pound factory exhaust main, and should the Boiler Room auxiliaries fail to supply the heaters with sufficient steam, an automatic diaphragm controlled valve admits steam into the heaters. Since only one heater is required, the additional heater serves as a standby unit.

Three feed water pumps are used and have the following characteristics:

Two 3 Stage Centrifugal Pumps

Head in feet	460
R. P. M.	2,500
G. P. M.	600
Prime movers	120 H. P. Turbines

One 2 Stage Centrifugal Pump

Head in feet	460
R. P. M.	2,500
G. P. M.	800
Prime mover	125 H. P. Turbine

The 2 stage pump is used for stand-by service and also as a test pump when hydrostatically testing boilers and during boiler performance tests.

All boiler feed water fed to the boilers, except during a performance test, is measured by means of a $2\frac{1}{2}$"x 5", 300,000 pounds per hour capacity, indicating and recording Venturi Meter. A recording thermometer registers the temperature of the water being pumped to the boilers.

Before the old type boilers were removed and the new 607 H. P. boilers were installed, this feed water equipment was located directly in front of the old boilers. The installation of the new boilers necessitated the moving of this equipment to a new feed water pump house located at one end of the Boiler Room. One heater and pump were moved at a time and connected so as not to interrupt Boiler Room operation.

Each boiler is equipped with a Copes Feed Water Regulator which holds the water at the proper level in the boiler. Experience has shown that the best operation is obtained when the boiler gauge glass shows 1/3 of a glass of water. All boilers are equipped with two feed lines, a service line and an auxiliary line, the latter to be used in emergencies. Also, for emergency use, a line from the city water main is connected to the feed water lines, but this cannot be used unless the steam pressure is below 100 pounds.

BOILER TEST DATA

Time	Gas Analysis Boiler Outlet (Dry) CO_2	O_2	CO	N	Press. Air duct	Press Last Pass	Press Over Fire	Press 1st Comp	Press 2nd Comp	Press 3rd Comp	Press 4th Comp	Press 5th Comp	Comb Air Temp	Room Temp	Fire Depth	Water Gals. Gr/Gal	Gage Press. Boiler	Gas Temp Leaving Boiler	Temp Of Feed Water	Percent Rating	Fuel Per Hr. As Fired	Fuel/□' Grate Per Hr. (as fired)	Comb Space Per #F/Hr.	Actual H_2O Per Hr.	Steam Quality
8:05					15		.15	.20	.75	.30	0	-.20	70	72	6½	32	149	580	140	200					.998
8:20					6		.17	.20	.50	.40	0	0			6½		155	585	172	200					.997
8:35	.15	.032	0	.818	8		-.2	.20	50	40	0	0			6½		157	585	185	220					.997
8:50					.7		-.12	.10	.25	.10	0	0			6½		156	580	188	170					.997
9:05	.152	.026	0	.822	.5		-.06	0	.20	0	0	0	70	72	5½	32	158	560	193	175	6053	39.7	5.17	55819	.998
9:20					.9		-.09	.10	.40	0	0	0			5½		152	570	193	180					.998
9:35	.146	.042	0	.812	1.3	-.5	-.14	.10	.20	0	0	0			5		150	520	192	145					.998
9:50					.8	.55	-.15	.10	.15	.05	-.1	-.10			5		155	550	192	150					.996
10:05	.124	.062	0	.814	1.0	.52	-.15	.15	.20	.05	-.1	-.10	70	72	5	34	157	550	191	150	4040	26.4	3.44	38742	208°F
10:20					1.1	.52	.10	.20	.40	.05	0	0			5		155	555	194	170					.998
10:35	.120	.062	0	.818	1.1	.50	.09	.15	.50	.01	0	0			5		152	560	188	138					.998
10:50					.7	.50	.15	.10	.20	0	0	0			5		155	555	188	145					.997
11:05	.126	.063	.001	.810	.5	.50	.19	.10	.30	0	0	0	74	74	5	44	158	540	189	140	4090	26.8	3.49	28907	.998
11:20					.9	.50	.15	.30	.50	0	0	0			5		157	545	189	140					.998
11:35	.130	.055	.003	.815	.7	.50	.16	.40	.50	0	0	0			5		157	545	190	145					.996
11:50					.7	.50	.20	.30	.50	.20	0	0			5		155	525	190	140					.998
12:05	.122	.066	0	.812	.9	.50	.60	.50	.70	.40	0	0	74	74	5	50	154	550	189	155	3215	21.0	2.73	33744	.998
12:20					1.7	.51	.15	.30	.70	.30	.05	-.10			5		150	555	189	150					.998
12:35	.138	.052	0	.809	1.7	.76	.11	.40	.70	.60	.10	0			5		147	560	188	180					.997
12:50					1.1	.75	.10	.30	.90	.60	.10	-.10			5		152	570	188	170					.997
1:05	.136	.052	0	.812	.95	.75	.15	.30	.70	.40	.10	-.10	74	76	5	57	152	580	190	160	5035	32.9	4.29	36129	.997
1:20					.5	.80	.20	.10	.55	.30	0	-.20			5½		167	580	190	162					.997
1:35	.150	.040	.001	.809	1.0	.90	.10	.40	.90	.70	.10	0			5½		155	575	191	210					.998
1:50					1.3	.90	.10	.40	1.0	.70	.10	-.10			5½		152	585	192	190					.998
2:05	.149	.047	0	.84[illegible]	[illegible]	.90	.09	.60	1.3	.80	.10	.10	78	78	5½	[illegible]	155	590	191	210	5040	[illegible]	4.30	45859	.997
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3:20					1.6	.60	.15	.40	.70	.50	0	-.20			6		153	580	195	188					.999
3:35	.155	.019	0	.826	1.9	.60	.90	.20	.70	.30	0	-.10			6		149	580	195	175					.999
3:50					1.7	.60	.10	.20	.70	.40	0	-.20			6		150	575	190	175					.998
4:05	.148	.045	0	.802	1.5	.80	.10	.50	1.0	.60	0	-.20	78	78	6	59	150	570	190	195	4040	26.4	3.45	45917	.998
4:20					.8	.80	.15	.30	.70	.50	.05	-.10			6		157	580	194	190					.998
4:35	.138	.048	0	.814	.7	.60	.20	.20	.40	.10	-.20	-.20			6		160	560	192	190					.997
4:50					1.3	.55	.20	.20	.30	.50	0	-.20			6		154	560	196	190					.998
5:05	.150	.032	0	.818	1.5	.55	.80	.80	.40	.80	0	-.10	78	78	6	59	155	560	192	140	4045	26.5	3.46	36243	.997
5:20					1.1	.55	.16	.16	.20	.60	0	-.10			6		151	550	194	170					.997
5:35	.148	.038	0	.814	1.2	.55	.13	.13	.20	.50	.05	-.10			6		155	560	192	150					.997
5:50					1.3	.55	.13	.13	.20	.50	0	-.20			6		153	555	192	150					.997
6:05	.150	.036	0	.814	1.4	.60	.15	.15	.20	.70	0	-.20	78	78	6	60	153	560	194	165	4035	26.3	3.44	41220	.997
6:20					1.1	.65	.19	.19	.10	.50	0	-.20			6		157	560	194	155					.997
6:35	.138	.048	0	.814	1.0	.60	.15	.15	.20	.50	0	-.20			6		157	560	194	150					.997
6:50					1.0	.60	.14	.14	.20	.50	0	-.20			6		160	555	196	150					.996
7:05	.142	.036	0	.822	.9	.50	.15	.15	.10	.50	0	-.20	78	78	6	60	157	550	192	150	5070	33.2	4.34	33814	.997
7:20					1.4	.43	.10	.10	.20	.60	0	0			6		156	550	192	140					.997
7:35	.112	.056	0	.832	1.4	.50	.12	.12	.20	.60	0	-.20			6		155	550	190	145					.997
7:50					1.1	.40	.15	.15	.20	.50	-.10	-.20			6		155	545	189	140					.997
8:05	.138	.042	0	.862	1.3	.40	.14	.14	.20	.50	0	-.10	78	78	6		155	540	185	140	2000	13.1	1.72	29906	.997
Total Time 12 Hrs.	Ave. 13.4%																Ave. 154#/□"	Ave. 564°F.	Ave. 190°F.	Ave. 170%	Total 52723#	Ave. 28.8#	Ave. 3.75	Total 467294#	Ave. 99.8%

Descriptions, Totals, And Averages

Date of test-	3-25-31
Location-	Kansas City, Kan.
Owner -	Procter & Gamble Mfg. C[illegible]
Make & Type of Boiler-	Stirling Class 22 Type
Type of Water Wall-	None (Air Cooled)
Type of Fuel Burner	B.&W. Chain Grate Stoke[illegible]
Test Conducted by-	Mechanical Departmen[illegible]
Object of Test-	Performance
Boiler Heating Surface-	6074 Sq. ft.
Total Steam Gen Surface-	6074 Sq ft.
Grate Surface-	152.5 Sq. ft
Fuel burning Equipment-	B&W. Stoker
Method of Producing Draft-	Forced Draf[illegible]
Fuel -	1¼" Milled Coal From Cornell, Kansa[illegible]
Volume Of Combustion Space-	1170 Cu.Ft
Furnace, Nearest Dist. from Grate to H.S.:	6[illegible]
Furnace Vol/Boiler H.S. -	.193 Sq. ft
Ash -	14.[illegible]
Moisture-(as fired)-	4.6%
Heating Value (as fired)-	11790 B.t.u.
Heating Value (dry) -	12370 B.t.u.
Sulphur -	2.9%
Size Of Coal (as fired)	1¼"
Moisture In Air	20 grains /# Air
Refuse Per Hour	819.3#
Heat Abs. By H_2O in Boiler	82.71 Million B.t.u.
Rate Of Abs. In Boiler H_2O	6.89 Million B.t.u. Per Hr.
Total Rate Of Heat Abs.	40.2 Million B.t.u. per Hr
Refuse % Of Fuel	18.5%
% Of Carbon In Refuse	24.8%
Carbon Burned Per # Fuel	69.9%
Heat Abs. □' Boiler/Hr.	6615 B.t.u.
Efficiency Of Unit	77.8%
Grate Eff.	89.6%
Boiler Eff.	87.0%

FIGURE VII

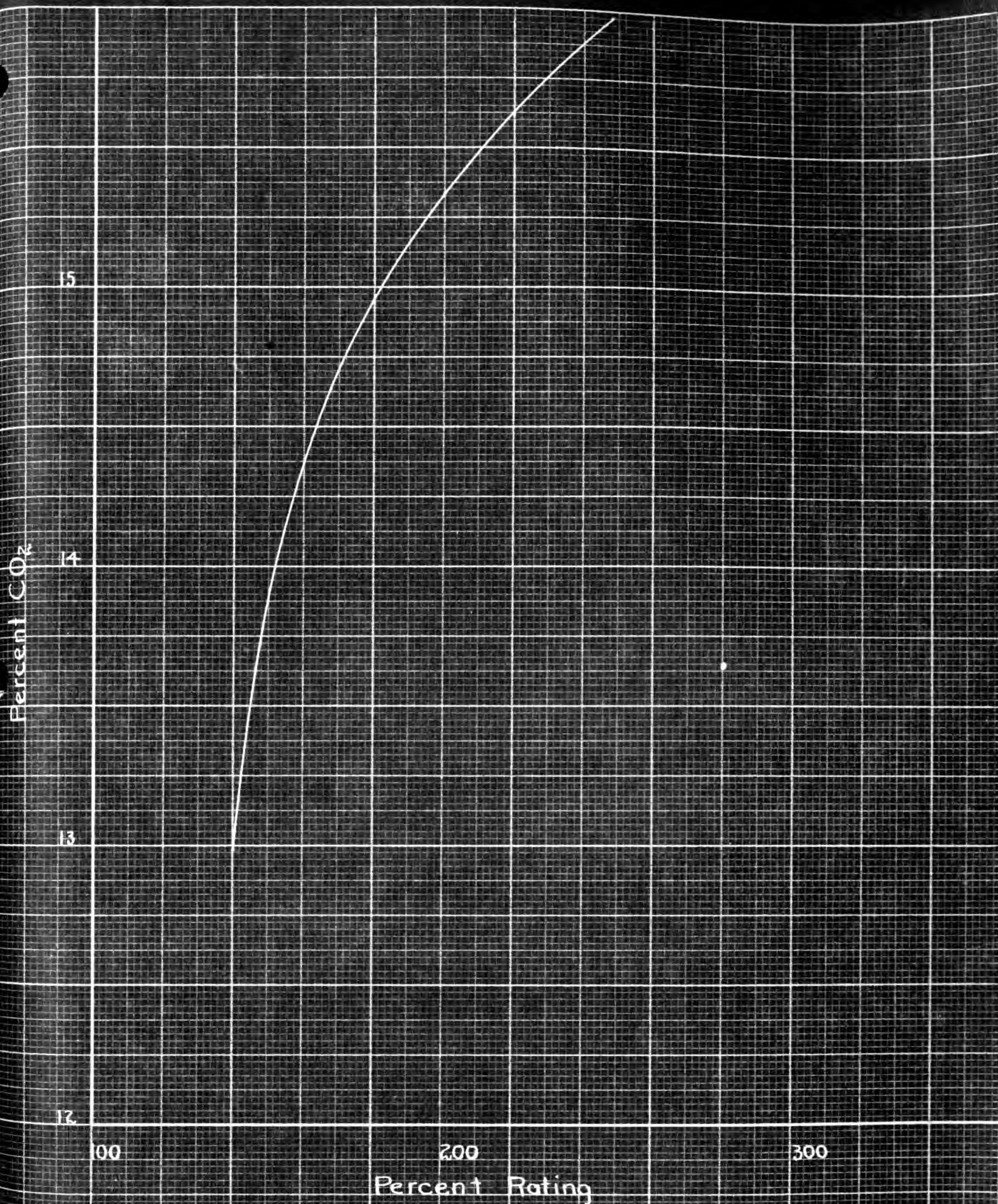
BOILER TEST

In order to determine the efficiencies and to check the Boiler Guarantee, a 12-hour Performance Test was run on one of these boilers (Boiler No. 5).

All feed water, coal, and ash were weighed during the test. The feed water temperature was obtained at the point at which the water line enters the boiler, and the steam pressure was obtained by means of a gauge on the rear steam drum. The steam quality was determined by means of a B. & W. standard throttling test calorimeter. The complete test data, as taken during the test, is shown in Figure VII.

In order that a representative day's operation might be obtained, the Boiler rating was not "crowded up" but was allowed to follow the regular Boiler Room operation. The boiler was not "blown down" during the test, but the water concentration in grains per gallon was obtained hourly during the test and was found to have increased from 32 grains at the start to 60 at the finish. At this higher concentration no priming was evident.

The highest rating obtainable was 248% from the Bailey Meter reading, but this was obtained at the cost of efficiency due to lack of stack draft. At this higher rating the lack of stack draft produced a "bottling effect" in the furnace with the result that the CO_2 content of the flue gasses went up and the furnace refractory started to



Percent CO_2 vs Percent Boiler Rating
For 607 H.P. Stirling Boiler

FIGURE VIII

Date 3-25-31

melt. Figure VIII shows the curve, Percent CO_2 vs. Percent Boiler rating, obtained during this test.

The Test results as calculated from the Test Data (Figure VII) are as follows:

B. T. U. added per lb. steam	1,035.6
B. T. U. added per lb. coal	9,175.4
Water apparently evaporated per lb. coal	8.86
Factor of evaporation	1.067
Equivalent evaporation per lb. coal	9.44
Combined efficiency %	77.8

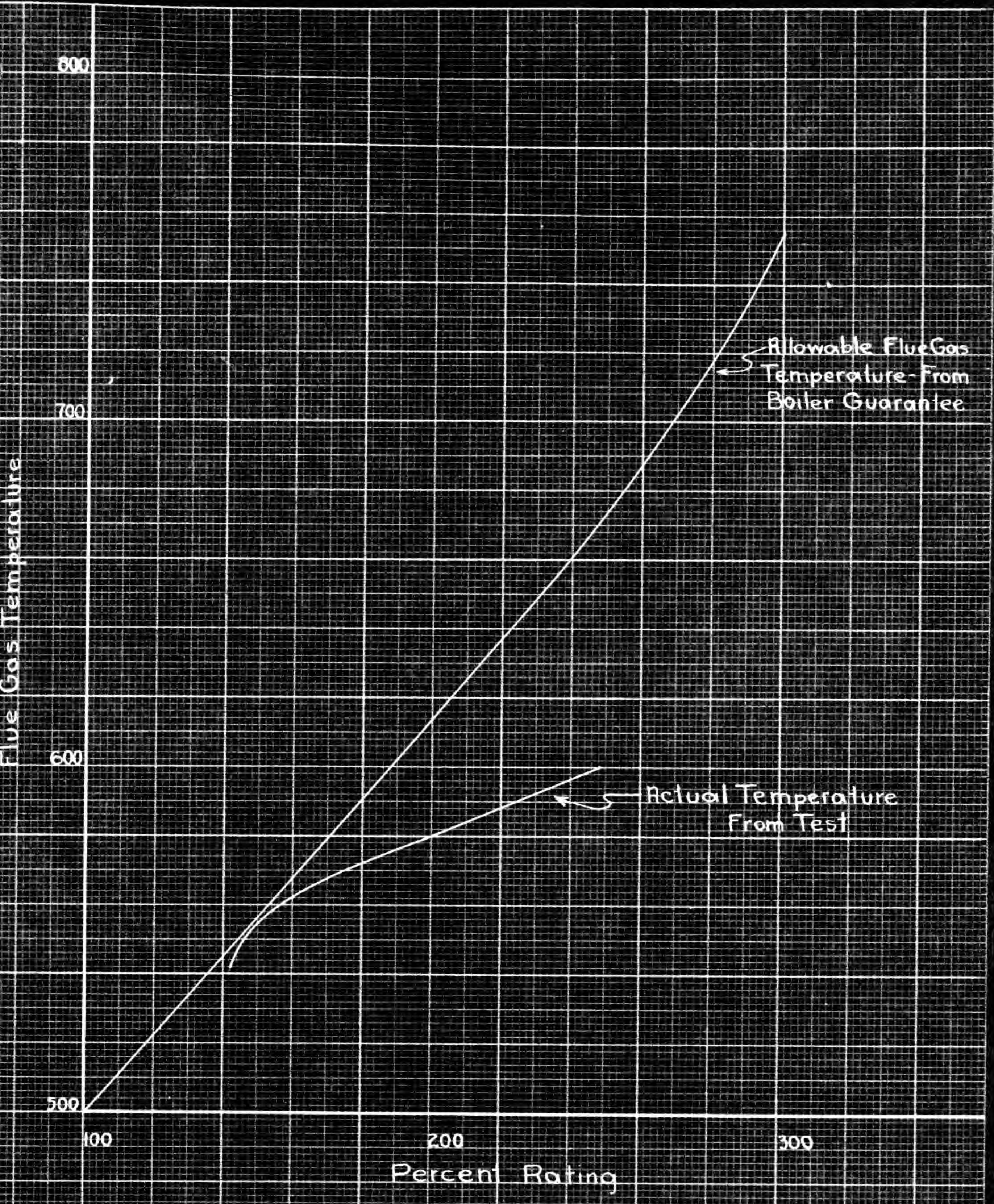
The average rating for the 12-hour period was found to be 170% from the Bailey Meter readings, while the efficiency of the unit was 77.8%.

In order to check the Guaranteed Boiler performance against the Actual, the following data is presented:

	Guaranteed	Actual
Rating in %	200	200
Steam pressure in lbs. per sq. in.	160	155
Temperature flue gas °F	615	580
Efficiency of boiler and furnace %	72.7	77.8 *
Draft loss through furnace in inches of water	.82	.49

* At 170% rating from the Bailey Meter readings.

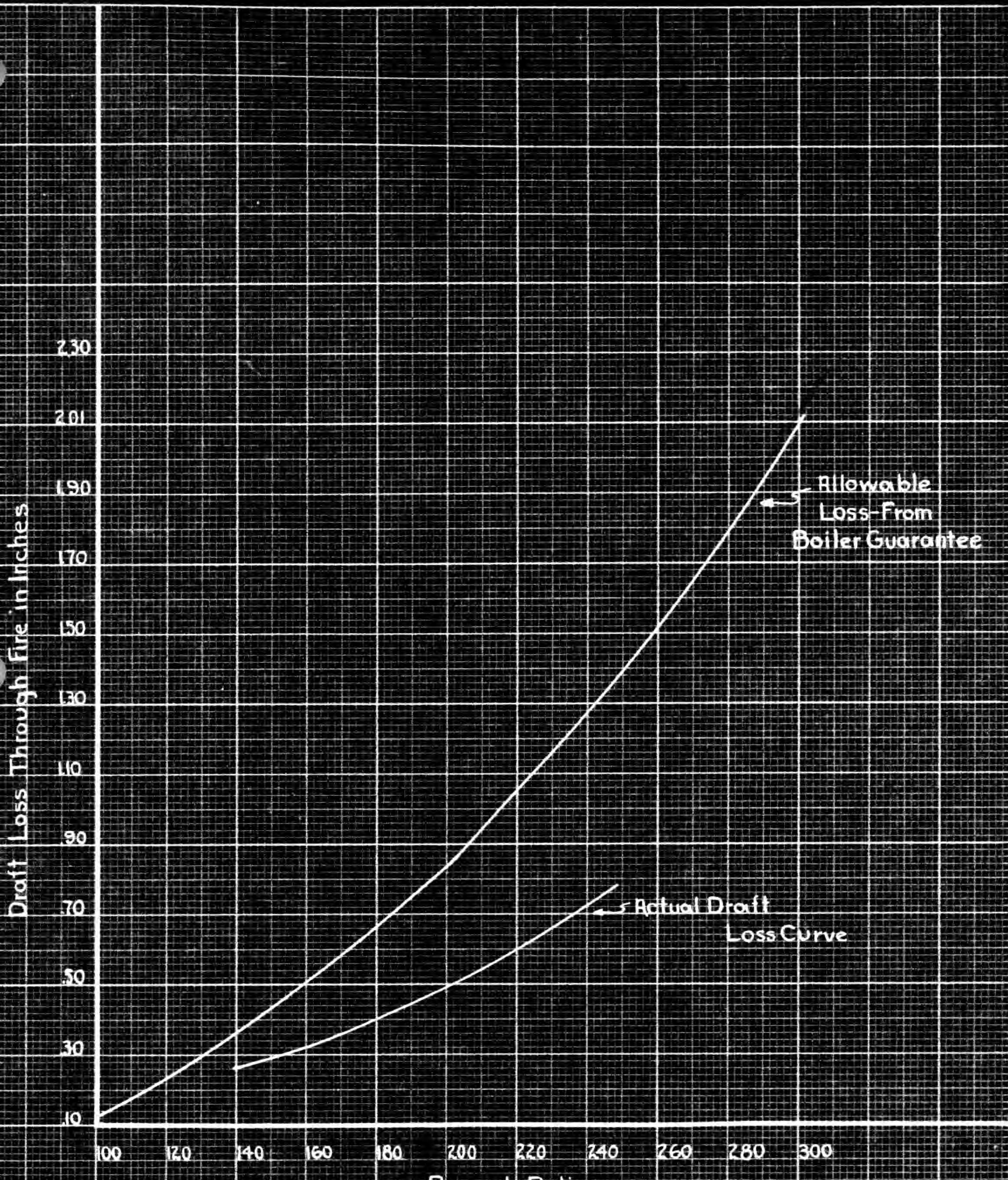
From this comparison it will be noted that the Actual performance bettered the Guaranteed performance.



Flue Gas Temperature vs Boiler Rating
For 607 H.P. Stirling Boiler

FIGURE IX

Date 3-25-31



Draft Loss Through Boiler VS Percent Boiler Rating For 607 H.P. Stirling Boiler

FIGURE X

Date 3-25-31

Figure IX shows the comparison of the Actual Flue Gas Temperatures with the Guaranteed Flue Gas Temperatures. Figure X compares the Actual Draft Losses with the Guaranteed Draft Losses.

CONCLUSION

These new boilers have been in operation approximately two years, and the problems outlined above have been encountered during that time. New equipment when installed is far from perfect and especially such equipment as boilers. Each installation has its own particular problems, which the builders cannot foresee at the time the equipment is manufactured and which fall upon the purchaser after the installation is completed. The same is true of boiler operation. The operation of a set of boilers in one plant may be entirely different from the operation of a set of similar boilers in another plant due to local problems such as draft, fuel, and feed-water conditions, even though the general characteristics of boiler operation in all plants are similar.