Donigan and Luney

Tests of Different Coals In a Mercer Residence-Heating Boiler (Steam)

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TESTS OF DIFFERENT COALS IN A MERCER RESIDENCE-HEATING BOILER (STEAM)

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

FRANK LYLE DONIGAN and FRANCIS SOLON LUNEY

ENTITLED TESTS OF DIFFERENT COALS IN A MERCER

RESIDENCE HEATING BOILER (STEAM)

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering

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TESTS WITH VARIOUS COALS
in a
MERCER RESIDENCE HEATING BOILER
(steam)

Introduction.- In the fall of the year 1906 the H. B. Smith Company of Westfield Massachusetts loaned to the Mechanical Engineering Department one of their "Mercer" sectional house heating boilers for experimental work. The following spring the boiler was erected in the Mechanical Engineering Laboratory and fitted with apparatus preparatory to a series of tests by the Engineering Experiment Station. The first trials of this series were taken as the subject of this thesis, the object in view being to determine the adaptability of various coals for use as fuel in this type of boiler and furnace.

DESCRIPTION OF APPARATUS

Boiler:- The boiler is best described by referring to figures No. 1, 2 and 3. The boiler sections are of cast iron and are joined consecutively through the connections in the lower feed drum and the upper steam drum. The dimensions are shown in Figure 6. The extreme length is sixty-five inches.

Heating Surface:- The water heating surface of the boiler is given in table I. All surface in direct contact with the fire was called "direct" and all other heating surface "indirect".

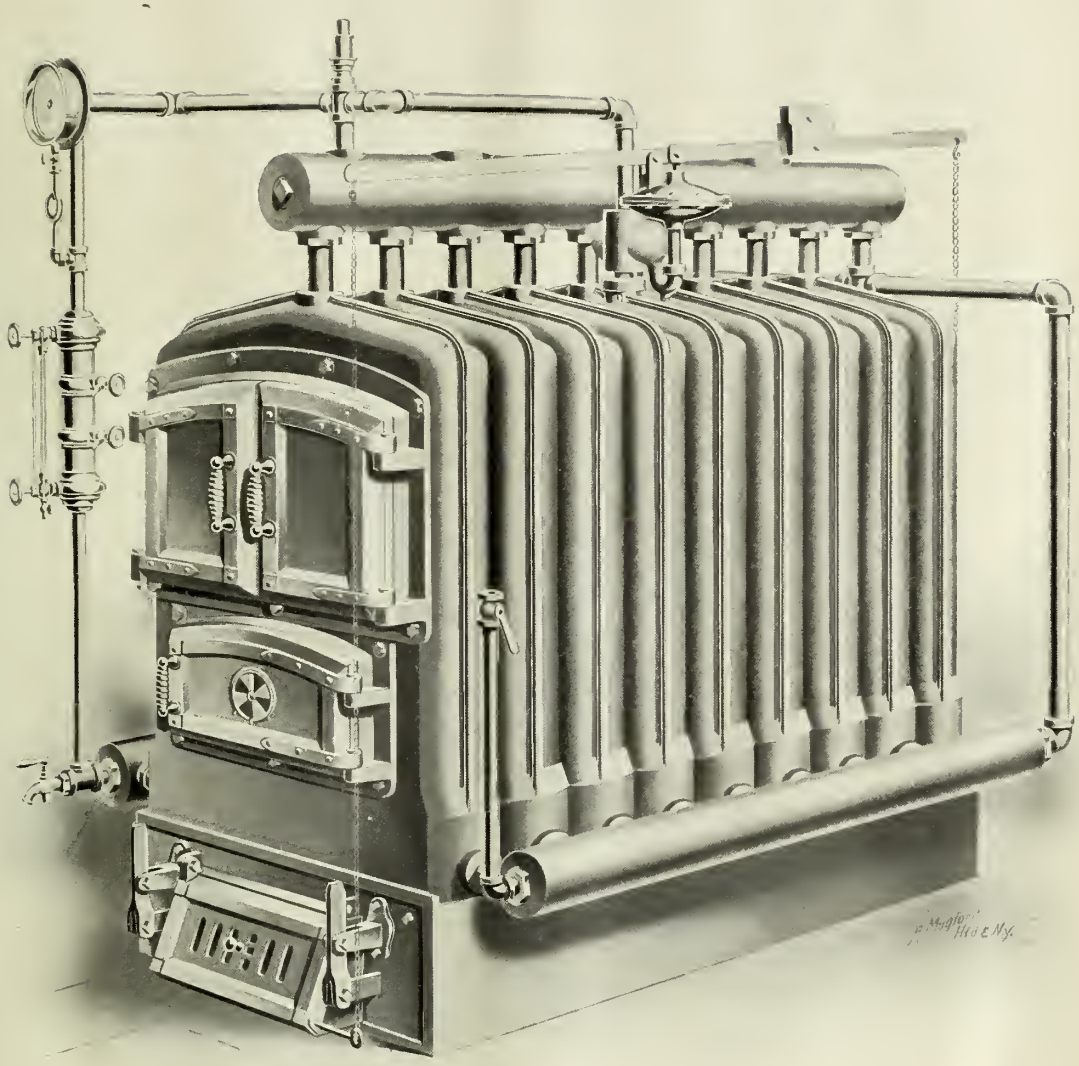


Fig. 1

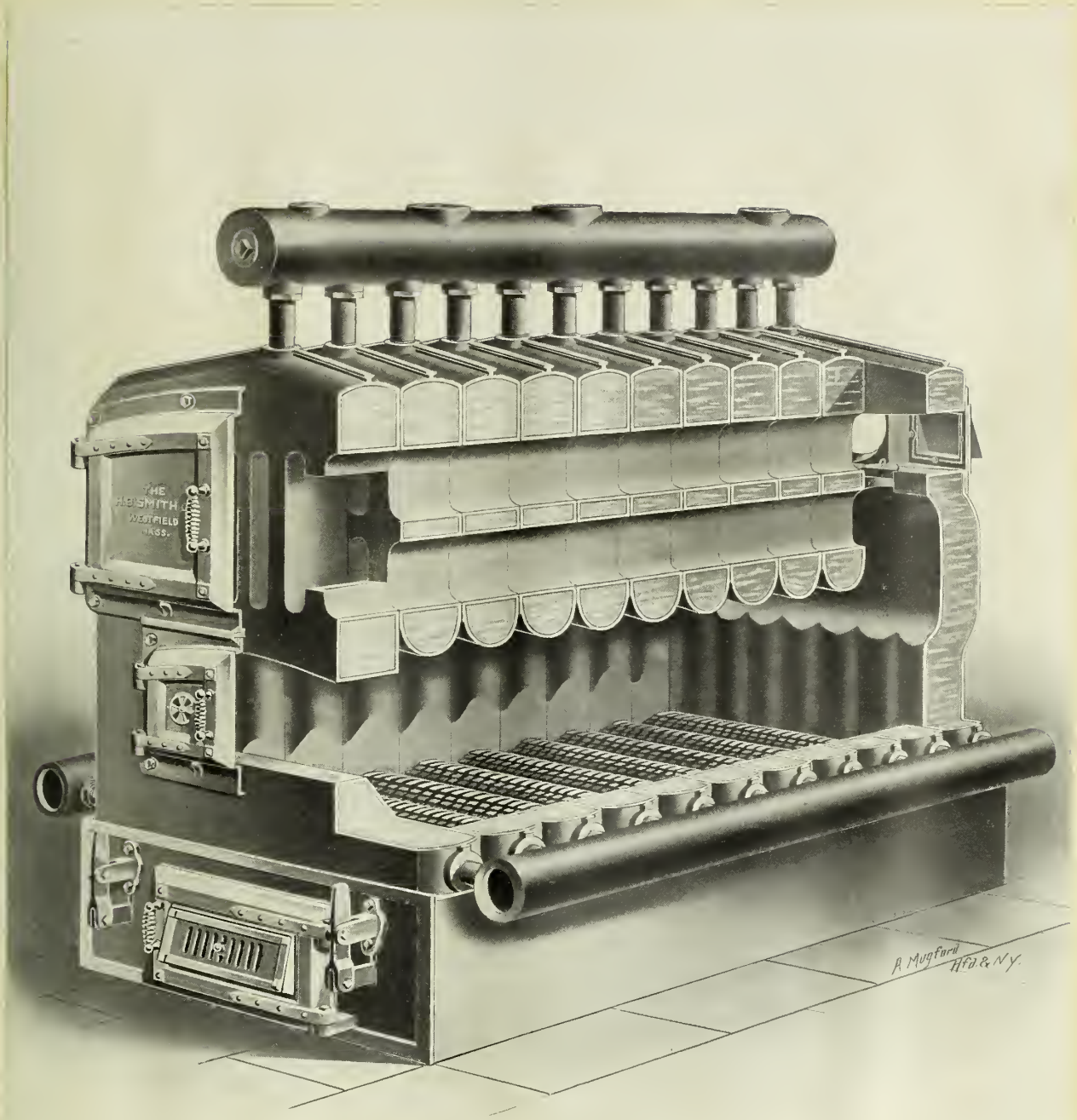


Fig. 2

TABLE I

WATER HEATING SURFACE OF 9 SECT. "MERCER" BOILER

Section No.	Direct		Indirect	
	per Sect.	Total	per Sect.	Total
#1 (Front)	2.7	2.7	6.6	6.6
#2,3,4,5,6,7 Central	2.3	13.8	5.97	35.8
#8	2.3	2.3	7.1	7.1
#9 (Back)	3.0	3.0	4.1	4.1
		21.8		53.6

Grand total 75.4

Furnace:- The boiler is internally fired, the furnace being formed by the water legs of the boiler sections. See Fig. 2, 3 and 6. The chamber thus formed is forty-eight inches long, by nineteen inches high, by eighteen inches wide. The travel of the burned gases is well shown in Fig. 2.

Grate:- The grate is of the rocker type with alternate sections connected together operated by levers shown at either side of the ash pit door. Grate sections are shown in Fig. 5. The grate had an area of six and one-fourth square feet, it being eighteen by forty-eight inches. Approximately fifty per cent was air space.

The ash pit is made of cast iron sections bolted together forming the foundation of the boiler sections and grate.

Breeching and Stack:- The breeching used in the first five tests was a ten inch circular sheet iron pipe thirty-four feet

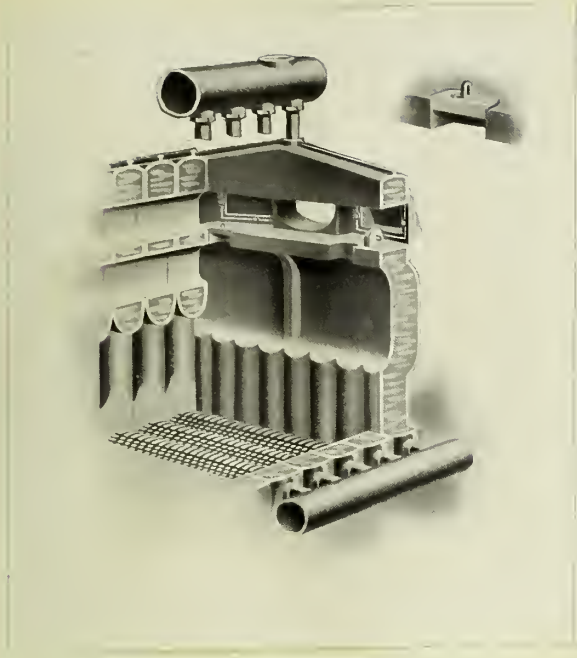


Fig. 3

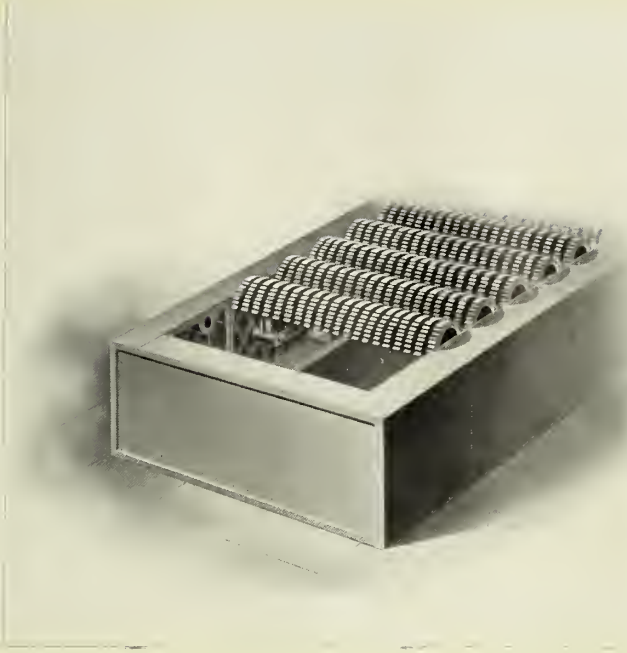


Fig. 4

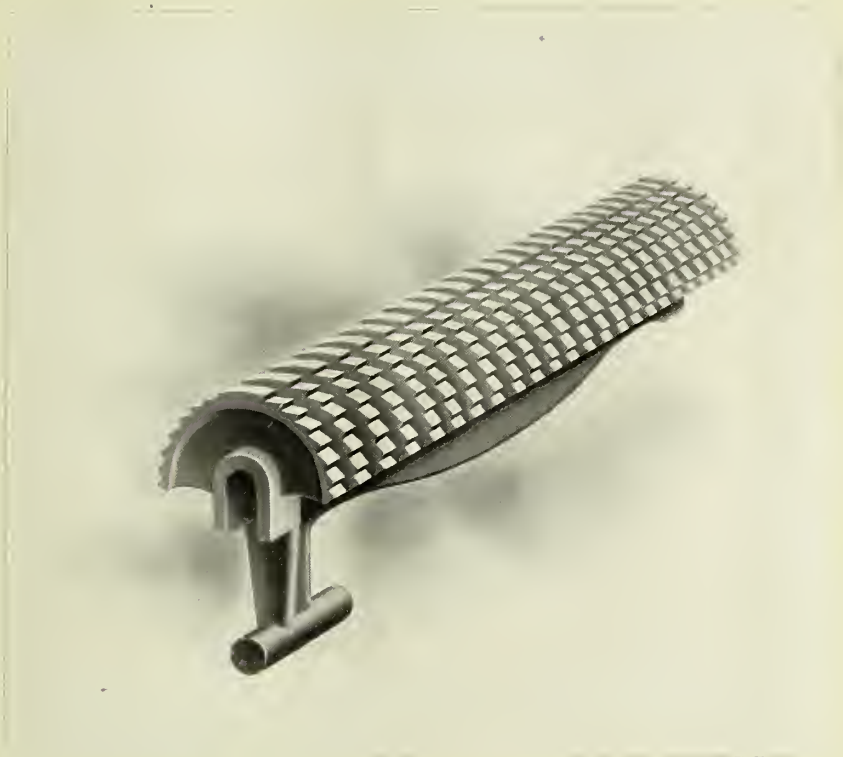


Fig. 5

long containing three bends. See Plate I. It connected the boiler with a brick smoke stack eight by twelve inches, cross section, and forty-five feet high, including a seven foot galvanized iron extension. The stack proved to be too small for the boiler so a separate fourteen inch circular sheet iron stack forty feet high was erected just back of the boiler and connected to the boiler by a ten inch breeching eleven feet long containing two bends.

Automatic Draft Regulator:- The draft, and hence the steam pressure, was automatically regulated by the apparatus shown in Fig. 1 placed above and to the right of the boiler. Steam pressure acting upon a diaphragm moved the lever and closed the ash pit door at the same time opening the back check damper.

Steam Connections:- The steam connections are well shown in Plate I. The steam was passed through a reducing valve (see Plate I) into a separator and hence through an orifice .906 inches in diameter and hence into the atmosphere. The orifice was intended to pass an amount of steam per hour which would take care of the rated heating surface of the boiler.

The water of condensation from the heating system of the building was used for feed water to prevent scale formation in the boiler. It was collected in two feed tanks of 230 pounds capacity each, and fed to the boilers under air pressure. The height of water in the tank was obtained from a water glass scale calibrated to read in pounds of water at 75° F. The temperature of the feed water was taken at entrance to boiler.

Steam Pressure:- A "Bristol" continuous recording pressure gage was connected to the steam drum and the pressure for each

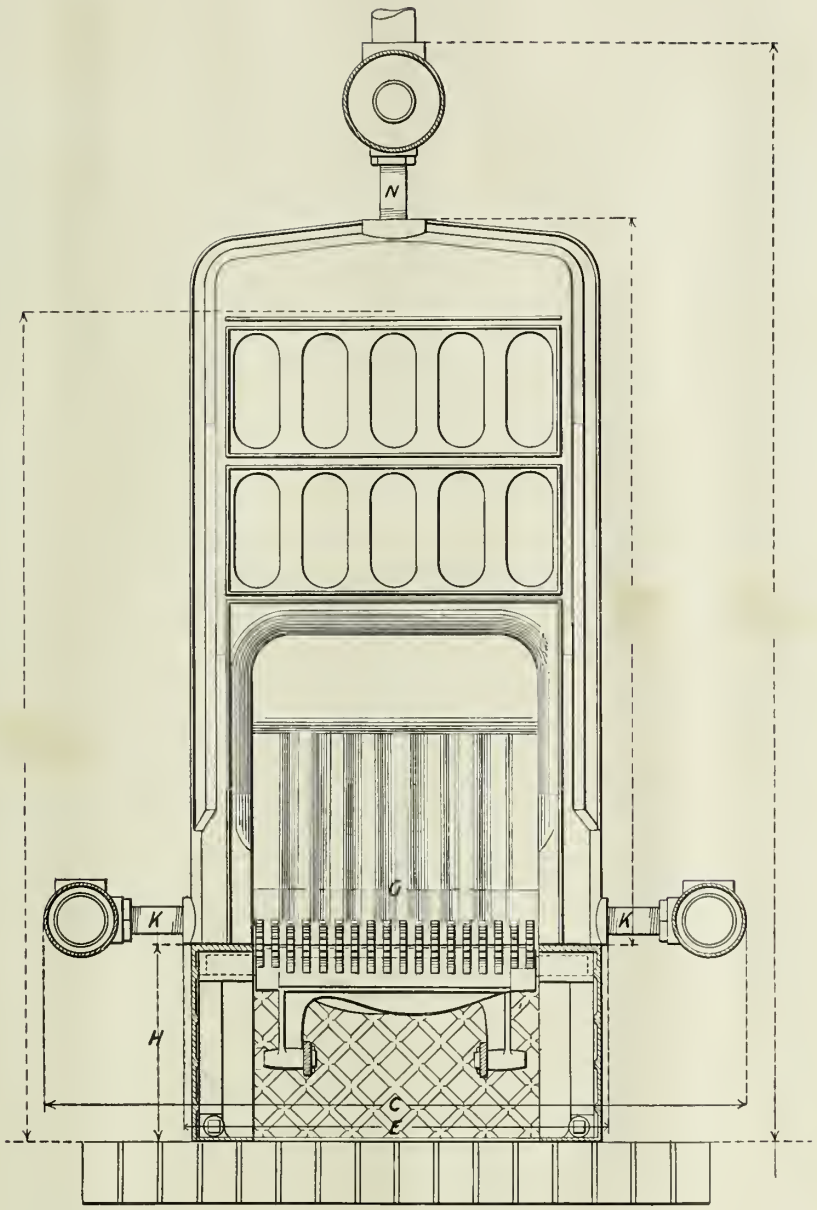


Fig. 6

test was calculated from the chart taken from this gage.

Steam Quality:- The quality of the steam was obtained from a separating calorimeter in the vertical steam line over the main steam valve.

METHOD OF TESTING

Conditions:- The conditions under which the boiler was operated were kept as constant as possible in all the tests, at the same time keeping them similar to those obtained in a house heating boiler. The load was kept fairly constant by passing the steam through an orifice and maintaining two pounds pressure on the separator side and atmosphere on the exhaust.

Before a test was started the boiler was fired and operated for an hour or more to get it warmed up.

Starting Test:- In starting a test the fire was dumped and the ash pit cleaned out. The fire was started with wood and coal thrown in upon this. Observations were started and readings made every ten munutes.

Observations:- The following observations were made:

1. Weight of feed water
2. Temperature of feed water
3. Steam pressure
4. Quality of steam
5. Draft over fire
6. Draft in breeching
7. Outside temperature

8. Inside temperature

The following were taken as general information but not used in computations:

1. Separator pressure
2. Back pressure on orifice
3. Condensation from separator

Firing:- The system of firing adopted after the first test, and used for all soft coals, was to fire seventy-five pounds of coal at a time and let the boiler regulate itself. Before each firing the steam pressure was allowed to drop to a point which showed that all the heat to be obtained from the coal had been absorbed by the boiler. In the first six tests the coal used was bituminous and was fired as follows: Test number one the coal was fired at frequent intervals and in amounts of from ten to fifteen pounds; test number two, fifty pounds was fired at one firing; test number three, five, and six, seventy-five pounds was fired at a time. In test number four, a slight variation was made and the first three firings were in amounts of seventy-five pounds and the last two firings in amounts of fifty pounds. The last two tests, seven and eight, were run on anthracite coal and in the first one the amount fired each time was seventy-five pounds, the same as was fired in tests numbers three, five and six. In the last test a decided variation was made, the first firing being one hundred and twenty-five pounds and the last firing one hundred and fifty pounds, there being only two firings during this trial.

Stopping Test:- The test was run for about eight hours, after which the fire was allowed to burn out. The readings were continued until the steam pressure dropped, showing that the heat was all out of the coal. The ashes were weighed and then the fire dumped and weighed. A sample of the coal, ash, and refuse fire was taken for analysis.

METHOD OF CALCULATION

An average was made of all the observations taken during a test and these made a basis of the calculations. A sample calculation given below will best illustrate the method employed.

TEST # 7

Duration 6.42 hrs.

Correction for ht. of water in boiler at start and finish

A.M. 10:05 --- 3.25" 22# from calibration curve.
P.M. 4:30 --- 4.50"

Total feed water @ 119° F as read from tanks = 1157#

Total feed water corrected = 1147#

Average quality from calorimeter 95.8%

Average steam pressure = 1.98#

Temperature of steam from tables = 219° F

Water evaporated = 1147 X 95.8 = 1098#

Water raised from 119° to 219° = 1147-1098+22 = 73#

$$\text{Factor of evaporation} = \frac{960.9 + (187.8 - 87)}{966} = \frac{1062}{966} = 1.10$$

Water evaporated from and at 212° F

$$= 1098 \times 1.1 + \frac{73 \times 100.8}{966} = 1283\#$$

Assuming the temperature of the feed water as that of the return water from an actual heating system, the available B. t. u. per hr. for heating =

$$\frac{1283 \times 966 + 1283 (181 - 87)}{6.42} = \frac{1248050}{6.42} = 194000 \text{ B. t. u.}$$

Assuming the temperature of the room as 70° and that 1.5 B. t. u. are radiated per hour per degree difference between the temperature of steam and room =

$$\frac{194000}{1.5 \times (212 - 70)} = 913 \text{ sq. ft. of radiating surface}$$

Catalog rating of boiler = 1075 sq. ft.

Coal actually fired 225#

Coal equivalent of wood = 34.5 = $\frac{8.6}{233.6\#}$ coal

Coal burned per sq. ft. of grate area per hour =

$$\frac{233.6}{6.25 \times 6.42} = 5.8\#$$

Water evaporated per pound of coal as fired

$$\frac{1283}{233.6} = 5.5\# \text{ from and at } 212° \text{ F.}$$

Water evaporated per sq. ft. grate area per hour =

$$\frac{1283}{6.25 \times 6.42} = 32.0\#$$

Water evaporated per sq. ft. heating surface per hour =

$$\frac{1283}{6.42 \times 75.4} = 2.68\#$$

In the calculations as above no correction was made for dry coal by analysis nor for the refuse left on the grate. This latter correction would probably not make a large error because all the available heat was apparently absorbed by the boiler at

the close of the test. Hence it seemed permissible to make calculations with coal as fired.

CALIBRATIONS

Calibrations were made of all the apparatus. A discussion of the methods used will be taken up for each separate piece.

(a) Calibration of Boiler:- The boiler was filled with water up to a point which showed six inches of water in the glass. The water was drawn out in increments of ten pounds, after which a reading was taken of the height of water in the glass. This was continued until the water in the glass disappeared. A repetition was made starting from five inches of water in glass. Curves were plotted as shown Plate III.

(b) Calibration of Feed Water Tanks:- The feed water tanks were calibrated at a temperature of 75° F with all pipes and coils in their proper position. The method of calibration was to fill tanks and then draw out the water in increments of one pound, after which the height of water in gage glass was marked on a stick of wood fastened to the glass, thus forming a scale graduated to read in pounds of water at 75°

(c) Calibrations of Thermometer:- The thermometer used to measure the temperature of the feed water was calibrated by comparison with a standard thermometer. The two thermometers were placed in water, the temperature of which was increased in small increments up to 200° F. Readings on the thermometers were taken simultaneously. The curve shown in

Plate IV gives the calibration curve for the thermometer.

(d) Calibrations of Bristol Recording Pressure Gage:- The Bristol recording pressure gage was compared with a standard test gage. The pressure was increased in increments of one pound up to fourteen pounds, the limit of the gage, and then decreased in the same increments to zero. The results are shown in Plate V.

(e) Calibration of Platform Scales:- The platform scale was calibrated by means of standard weights. The load on the scale was increased from zero up to 200# and then decreased to zero. The calibration curve is shown in Plate VI.

DISCUSSION OF RESULTS

Test number one and number two were run with the same kind of bituminous coal; i. e., Herrin washed nut, and under practically the same conditions, the only variations being in the method of firing. (See "Method of Firing") The method used in the second test proved to be the better way. It showed a saving of 1.66 pounds of coal per hour per 100 sq. ft. of radiating surface.

In tests number three and four, the same kind of coal was used as in one and two, except that it was unwashed. The conditions were practically the same, although the draft in breeching was slightly greater, which probably accounts for the slightly better showing of number four over number three; i. e., a saving of 0.36 pounds of coal per 100 sq. ft. of radiating surface. The draft in the first five tests was so slight owing to the small size of chimney used that any small increase in the draft of one

test over that of another would have a very material effect. This was found conclusively after the system of stacks was changed between tests numbers five and six as already described.

Tests number five and number six run on the same kind of coal, West Virginia "Black Band", a semi bituminous coal, but the conditions were not the same in both tests. Test number six was run after the change in stacks was made and as a result the draft was doubled. Test number six showed a saving of .58 pounds of coal per 100 sq. ft. of radiating surface per hour over number five.

Tests number seven and eight were run with anthracite coal and showed a very material saving of coal over the other tests, being on the basis of average results, 0.85 pounds of coal per sq. ft. of radiating surface per hour over the best performance of the boiler on bituminous coal. However, here enters the element of better draft and must be considered. The method of firing number seven was using seventy-five pounds of coal at a time. This amount was not enough to fill the fire box to a sufficient depth to prevent holes in the fire which resulted in low steam pressure and hence the ash pit damper was open most of the time. In number eight the amount was increased to 125 pounds, then to 150 pounds and since the fire box was more nearly full no trouble was experienced with holes in the fire. No wood was used to start number eight. Instead the coal left on the grate from number seven was used after apparently all the available heat had been absorbed by the boiler. Of course, test number eight is open to the objection that some heat was left in the refuse of number seven, but hardly enough to make the difference in showing

namely 1.9 pounds of coal per 100 sq. ft. of radiating surface per hour. It is more likely due to better management of fires.

Conclusion:- As a result of this series of tests it has been shown that this style of boiler and grate will operate on either hard or soft coal for from two hours to five hours with no attention and keep the steam pressure regulated to any desired pressure by adjusting the automatic draft regulator. The furnace regulates better with the fire box full, at least to a level with the fire door.

It was also shown that to burn the coal to the best advantage a draft of at least .15 inches of water in the breeching is necessary. It is thought that the boiler would operate more efficiently if the top and steam drum were covered with asbestos. A better quality of the steam would result.

STS

1	Test numbe	4	5	6	7	8
2	Duration of	8.7	8.83	7.67	6.42	9.16
3	Inside temp	80	79	77	78	75
4	Outside	36	44	69	59	52
5	Kind of coa	ame	same	same	Anthracite	do
6	Commercia	ame	Black Band	same.	Egg	same.
7	Draft over fi	.010	.010	.025	.030	.040
8	" in bre	.067	.070	.160	.163	.145
9	Weight of f	1857	1605	1734	1147	1835
10	Temperature	170	165	156	119	149
12	Steam pres	2.88	2.0	4.25	1.98	3.53
12	" tem	219	225	225	219	223
13	" qua	89.7	89.1	95.0	95.8	91.8
14	Factor of ev	048	1.05	1.062	1.10	1.07
15	Water evapor	775	1523	1755	1283	1820
16	Available B	,500	175,000	234,000	194,000	193300
17	Equivalent of	955	822	1100	913	909
18	Sq. ft. of rad. s	—	—	25	—	—
19	" " " "	120	253	—	162	166
20	Total coal b	329	304	304	234	175
21	Coal burned	6.05	5.5	6.35	5.8	3.06
22	" "	3.96	4.20	3.61	4.0	2.10
23	" "		3.90		3.05	
24	Water evapo	5.33	5.03	5.8	5.5	104
25	"	2.30	27.60	36.70	32.00	31.70
26	Water evapor	2.68	2.29	3.04	2.68	2.75
27	" "	1.10	21.05	20.80	22.00	21.05

Table of Results for Merger Tests

1	Test number.	1	2	3	4	5	6	7	8
2	Duration of trial–hours.	8	8.65	7.7	8.7	8.83	7.67	6.42	9.16
3	Inside temperature.	77	75	82	80	79	77	78	75
4	Outside "	61	39	38	36	44	69	59	52
5	Kind of coal.	Bituminous	same	same	same	same	same	Anthracite	do
6	Commercial name of coal.	Herrin Wash Nut	same	Unwashed	same	Black Band	same.	Egg	same.
7	Draft over fire. in. of water.	.007	.013	.004	.010	.010	.025	.030	.040
8	" in breeching. " " "	.070	.070	.050	.067	.070	.160	.163	.145
9	Weight of feed water. pounds	1888	1876	1629	1857	1605	1734	1147	1835
10	Temperature of feed water. Fahr.	170	170	160	170	165	156	119	149
12	Steam pressure. pounds gage.	5.44	5.00	3.75	2.88	2.0	4.25	1.98	3.53
12	" temperature. degrees Fahr.	228	227	224	219	225	225	219	223
13	" quality – per cent.	95.5	94.3	82.8	89.7	89.1	95.0	95.8	91.8
14	Factor of evaporation.	1.05	1.05	1.058	1.048	1.05	1.062	1.10	1.07
15	Water evaporated from and at 212° F.	1806	1870	1479	1775	1523	1755	1283	1820
16	Available B.t.u. per hour	227,500	219,500	195,800	203,500	175,000	234,000	194,000	193300
17	Equivalent of 16 in sq. ft. of rad. surface	1070	1028	915	955	822	1100	913	909
18	Sq. ft. of rad. sur. supplied above rating.	—	—	—	—	—	25	—	—
19	" " " " " " below "	5	47	180	120	253	—	162	166
20	Total coal burned – pounds.	433.4	303.	303.8	329	304	304	234	175
21	Coal burned per sq. ft. grate area per hour	8.65	5.6	6.32	6.05	5.5	6.35	5.8	3.06
22	" " " 100 sq. ft. rad. sur " "	5.07	3.41	4.32	3.96	4.20	3.61	4.0	2.10
23	" " " " " " " " " " average	4.24		4.69		3.90		3.05	
24	Water evaporated per lb. coal as fired.	4.10	6.17	4.86	5.33	5.03	5.8	5.5	10.4
25	" " " sq. ft. grate area/hr.	36.10	34.16	30.80	32.30	27.60	36.70	32.00	31.70
26	Water evaporated per sq. ft. heat. sur per. hr.	3.0	2.87	2.56	2.68	2.29	3.04	2.68	2.75
27	" " " 100 " rad. " " "	21.1	21.05	21.05	21.10	21.05	20.80	22.00	21.05

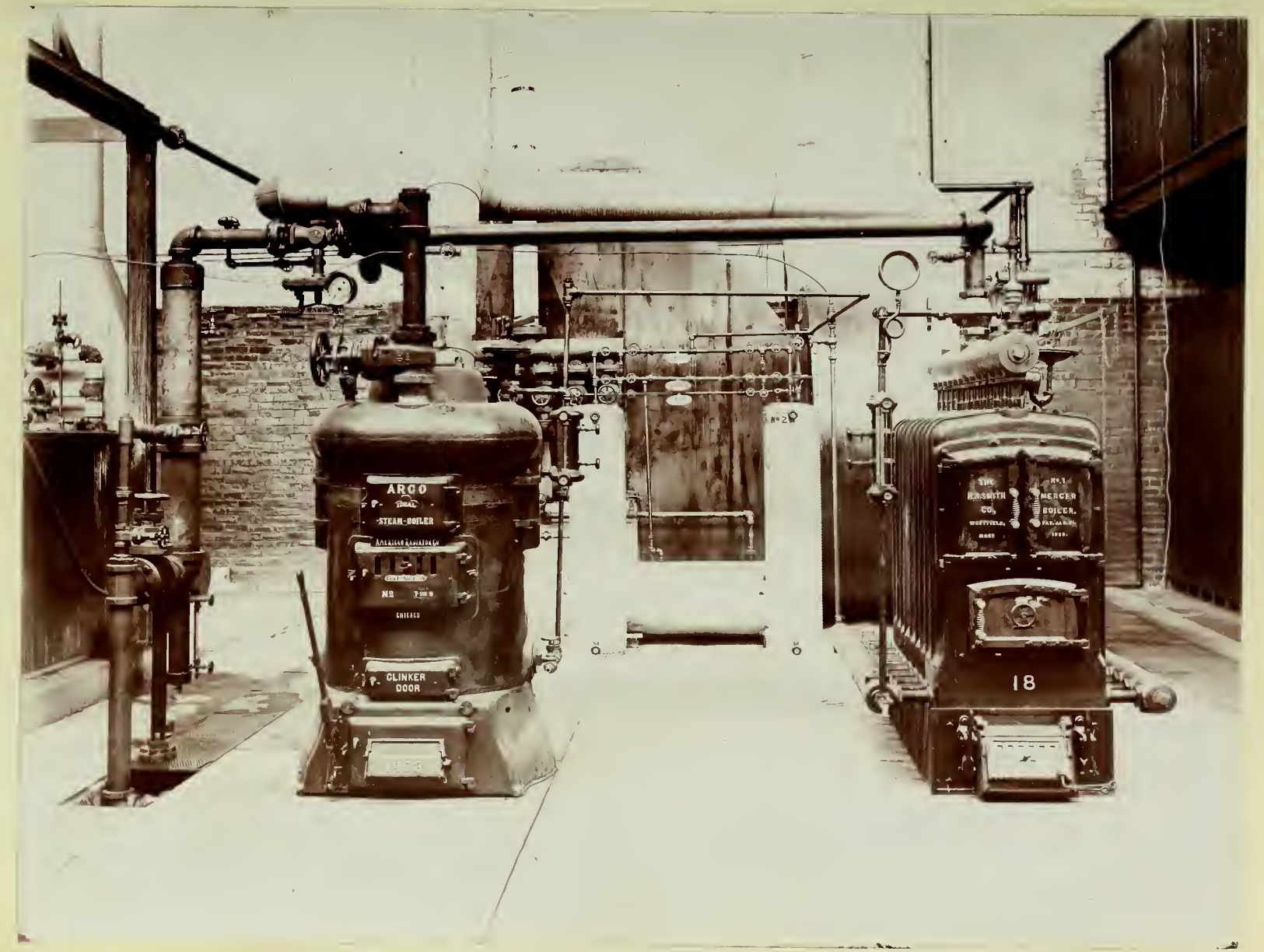

ARCO
STEAM-BOILER
AMERICAN RADIATOR CO
CHICAGO
CLINKER
DOOR
THE
H.B.SMITH
CO.
No.1
MERCER
BOILER.
18

Plate I

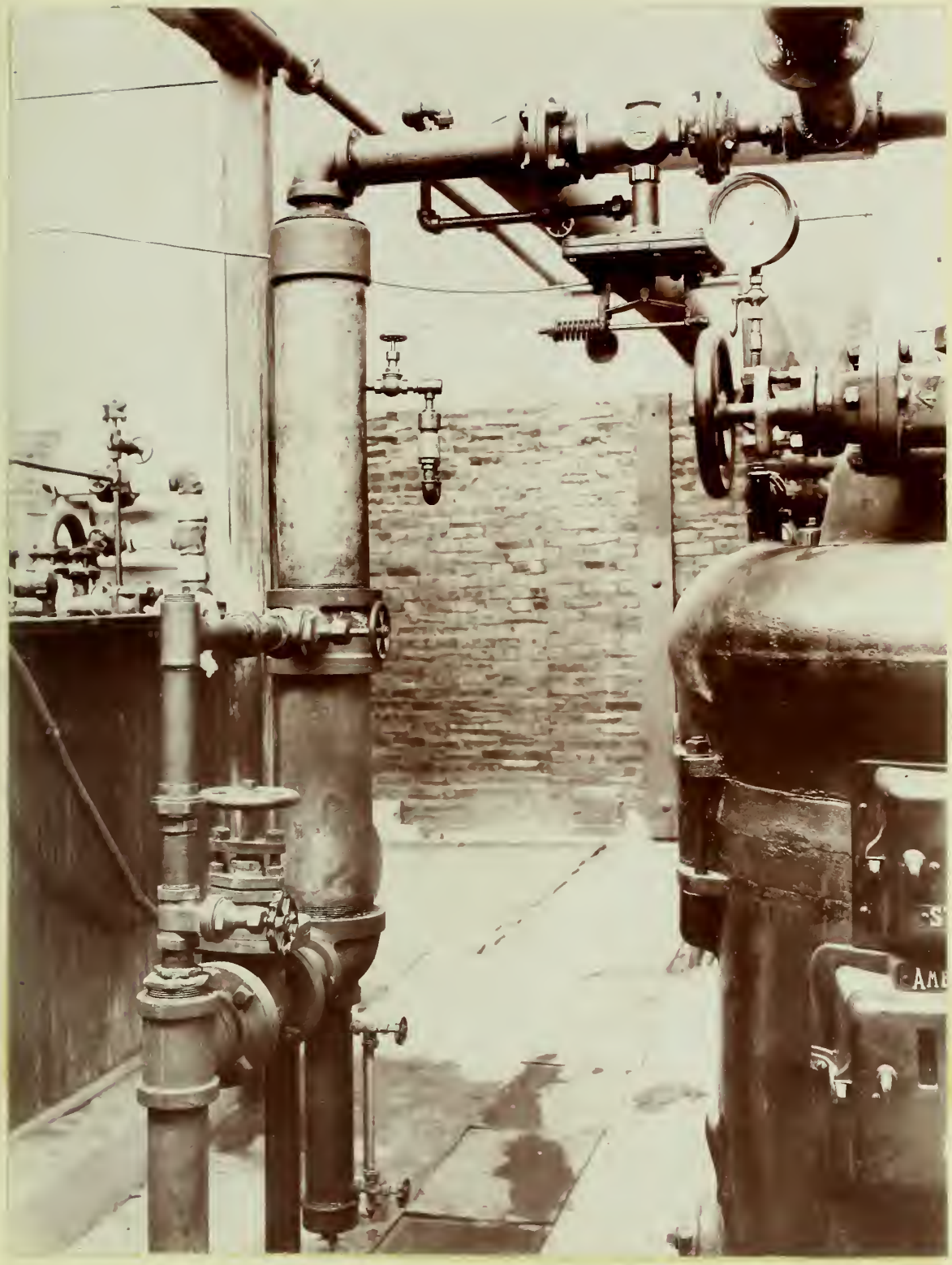
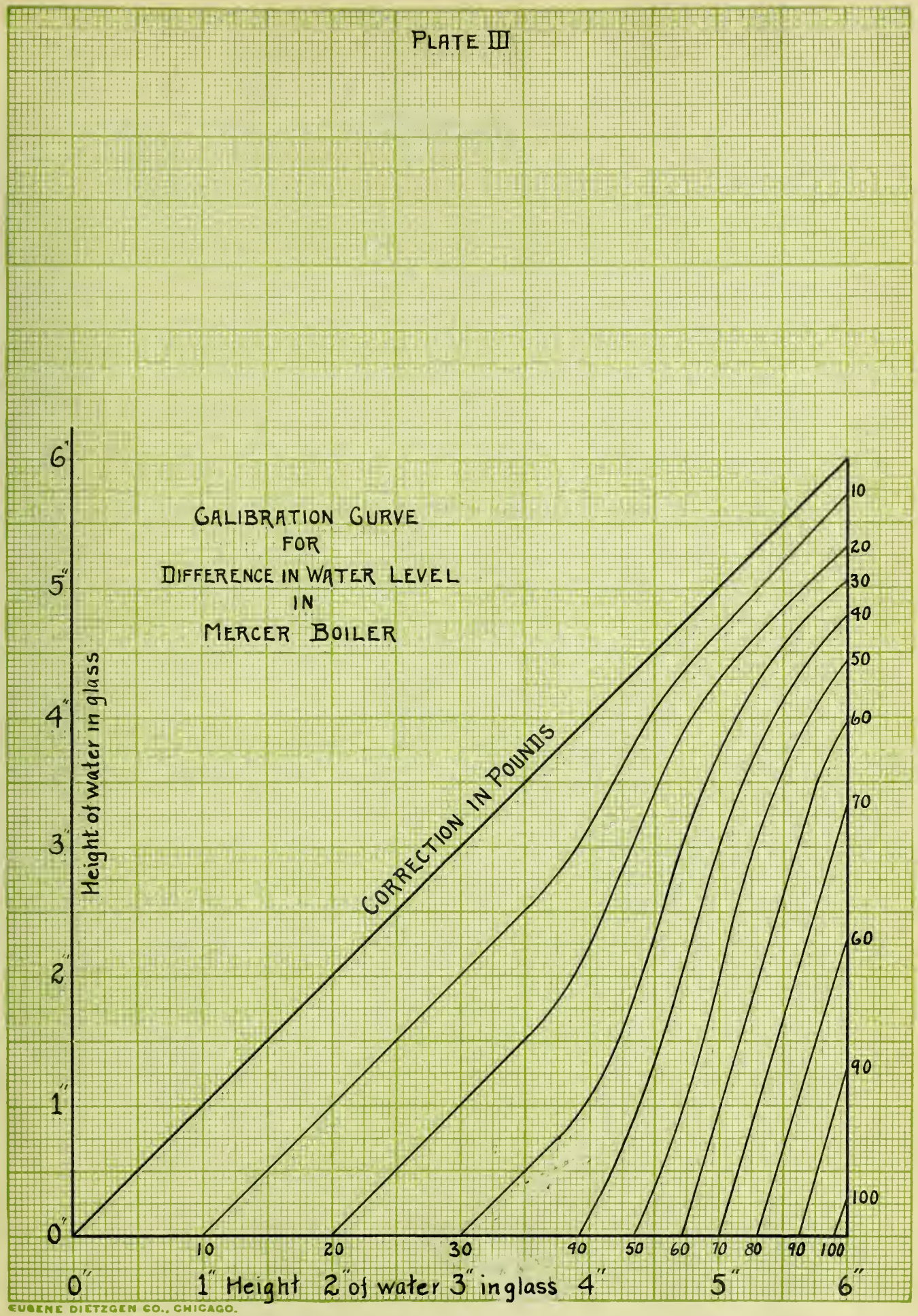


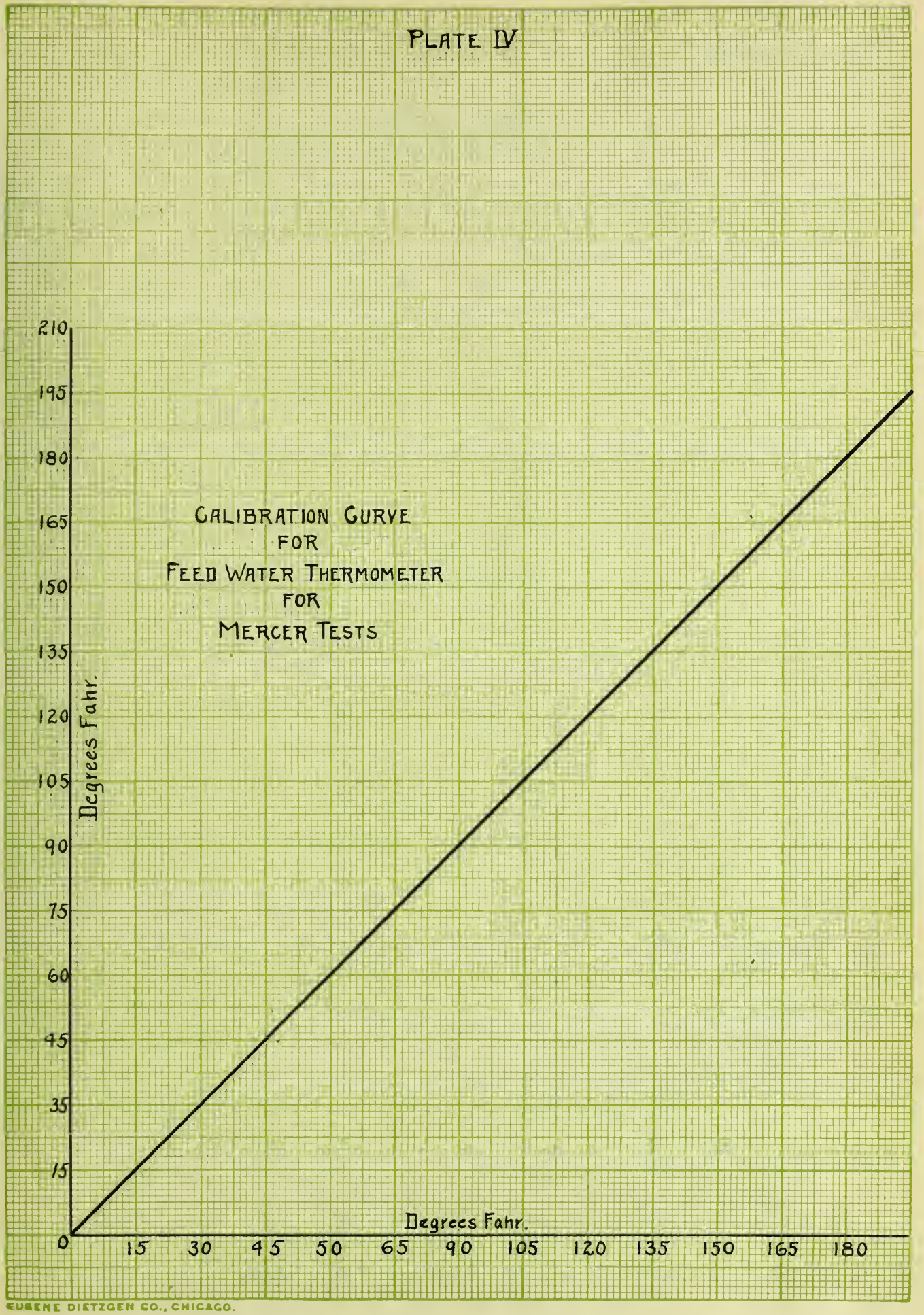
Plate II

PLATE III



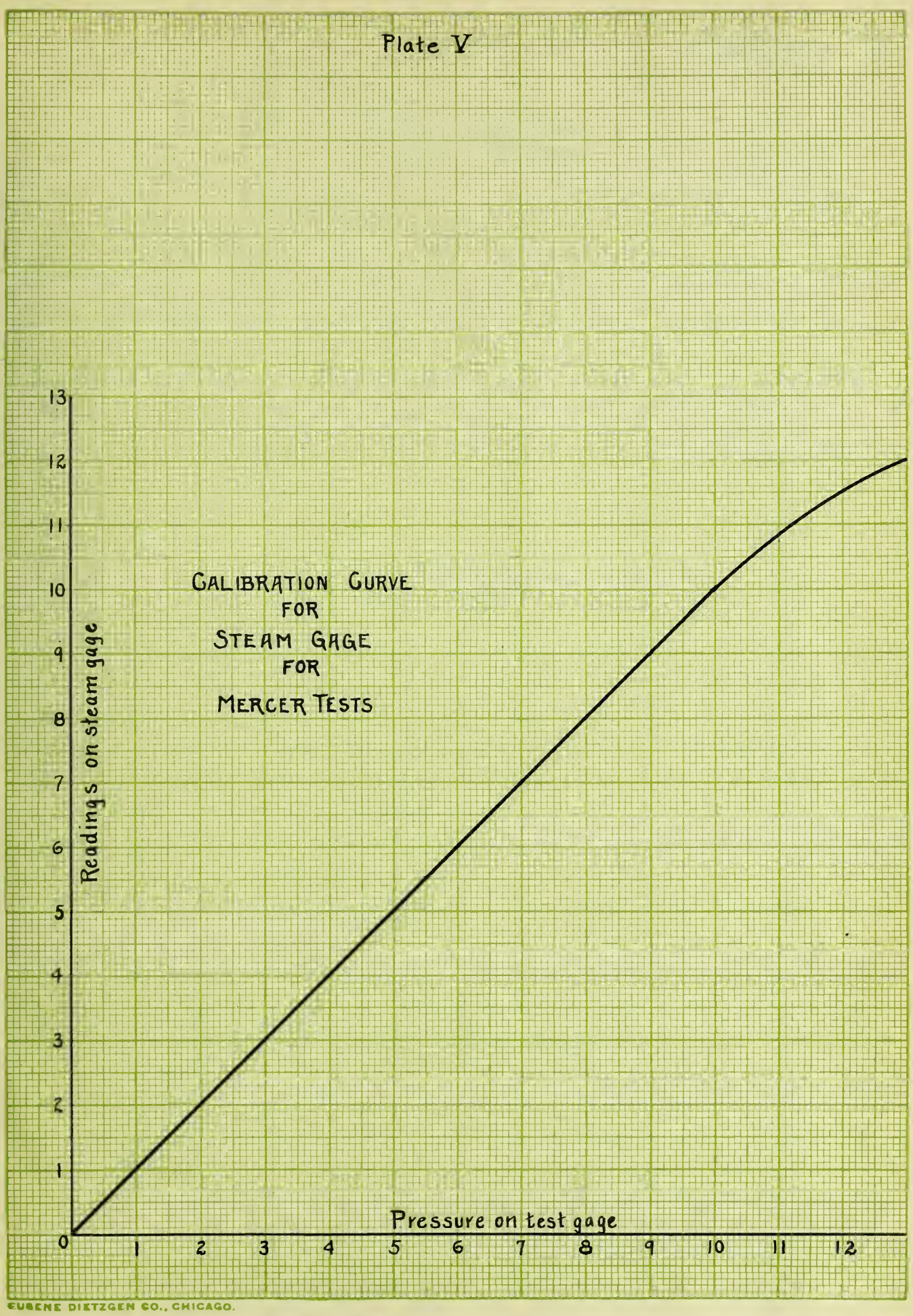
EUGENE DIETZGEN CO., CHICAGO.

PLATE IV



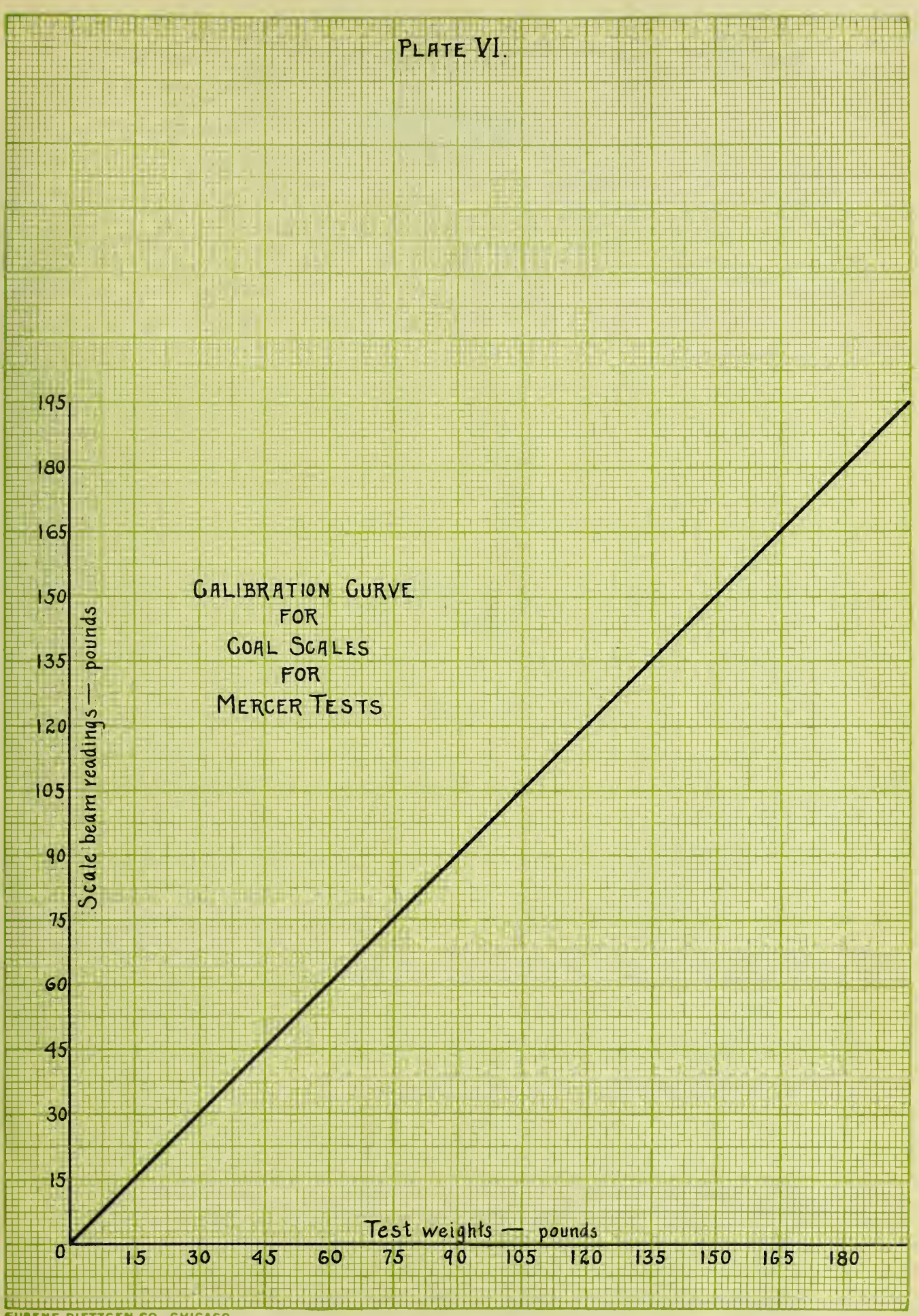
EUGENE DIETZGEN CO., CHICAGO.

Plate V



EUGENE DIETZGEN CO., CHICAGO.

PLATE VI.



EUGENE DIETZGEN CO., CHICAGO.