FRANK JOSEPH KRATZ

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THS

THESIS

This thesis was contributed by

Mr. C. A. Stimpson

under the date indicated by the department stamp, to replace the original which was destroyed in the fire of March 5, 1916.

RECEIVED
OCT 8 1918
DEPARTMENT OF
CIVIL ENGINEERING.

T H E S I S

B O I L E R T E S T S

O N

[illegible] TUBE, VERTICAL WATER TUBE

A

A N D

HORIZONTAL, INTERNAL FURNACE

[illegible] WATER BACKED GRATE

B Y

E. J. [illegible] E A T E. C. A. [illegible] E D S O N.

1 9 0 5.

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[illegible]

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THESIS

BOILER TRIALS

ON

HAND FIRED, VERTICAL WATER TUBE

AND

HORIZONTAL, INTERNAL FURNACE

WITH [illegible]

BY

[illegible]. [illegible]. [illegible]RATT.   C. A. [illegible].

1 9 0 8.

THESIS

2-4-51
9

DESCRIPTION OF TESTS.

The first test was made at the new Power Plant at the Michigan Agricultural College, on the Springfield Horizontal Tubular Internally Fired Boiler #1, manufactured by the Springfield Boiler & Mfg. Co., Springfield, Ill., which was installed in the plant in the Fall of 1904. The last test was made at Platt's Steam Power Plant at Lansing, Mich., on a Wickes Vertical Water Tube Boiler #4, manufactured by Wickes Bros., Saginaw, Mich. and installed in the plant in Jan. 1902. The first trial was of 10 hours and the latter of 12 hours duration.

OBJECTS OF TESTS.

Under the existing conditions:

To determine the horse power developed.

To find the amount of water evaporated per pound of coal.

To determine the thermal efficiency of the boilers.

To determine the cost of evaporation.

EQUIPMENT.

The apparatus employed in the first test was as follows:

A Crosby steam gauge was used for determining steam pressure.

A Carpenter's separating calorimeter for determining the quality of the steam was attached, by means of a perforated nipple, to the steam main just above the boiler.

Water was fed to the boiler by means of a Laidlow, Dunn, Gordon & Co's. pump. This water was principally return water, mixed at times with cold water from the well. The meter used was a Hersey hot water meter which was piped in for the test, with a

264830

by pass, near the pump.

Forced draft was employed, generated by an A.M.C. blower which was run by an A.M.C. vertical engine. The blower pipe being tapped between damper and boiler and draft gauge attached. A draft gauge was also connected with the uptake at a point just above the damper.

For taking temperatures, Fahrenheit thermometers were used.

For analyzing the flue gases, an Orsat's gas apparatus was used, samples being taken through a hole tapped in the uptake a short distance above the damper.

The only essential difference between the apparatus used in the first and second test was that a tank was used in the second test for measuring the feed water instead of a meter. Also, since an analysis was not made of the flue gases, no gas apparatus was used, and owing to the boiler being hand-fired there was no forced draft to be measured.

METHOD.

The first test was started at 11:30 A. M. on May 9, 1905 and lasted until 9:30 P. M. of the same day. As the load on the boiler was not a maximum, the maximum rated horse power was not being developed, the load being a high pressure main leading to the Dairy Building and Woman's Building, also the feed water pump and the blower engine. The water was fed through the meter at an average temperature of 135°F. The meter was carefully calibrated by weighing the water which passed through the meter for several hours and correcting the different weights for temperature. It was found that the meter read .6% low. The section conveying water to the other boiler was

cut off before beginning the test.

The boiler was fired several hours before and the fire cleaned, just before the test. The height of the water in the boiler was marked on the water glass at the beginning and fortunately was at the same height when the test was finished.

The coal was weighed in quantities of 200# per weight and fired as it was required. The scales being balanced before each weighing.

Readings were taken every half hour of the steam gauge, water meter, barometer, draft gage in blower pipe, draft gage in uptake, height of water in glass, also temperature of feed water, flue gases, boiler room and external air. Readings of separating calorimeter were taken every ten minutes and samples of flue gas were analyzed on an average of every hour.

The second test was started at 6:00 A. M. on May 19, 1905 and run until 6:00 P.M. of the same day. The load on the boiler during that time was quite heavy, consisting of a 250 horse power Corliss engine, a steam main leading to the Hotel Downey, a feed water pump and an Otis tubular feed water heater and lime extractor.

The coal was weighed in quantities of 200#; deposited on the boiler room floor and fired as required.

Readings were taken every half hour of the steam gauge, height of water in glass, barometer, draft gauge, also temperatures were taken every half hour of boiler room and external air. Readings of the separating calorimeter were taken every ten minutes. The feed water tank was filled as required and temperature taken at the same time, of the water in the tank and of the water in the feed water heater.

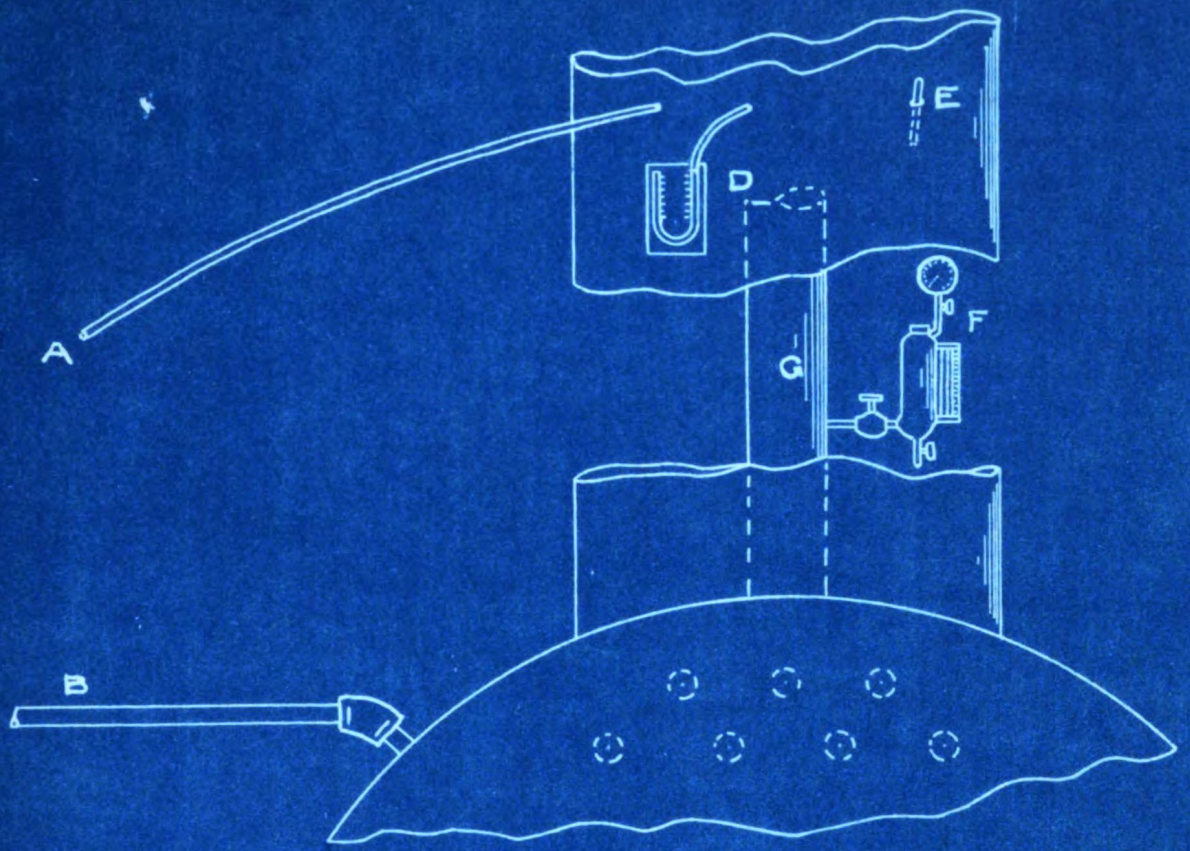
Samples of coal were taken at frequent intervals during both tests and the amount accumulated reduced by the method of quartering and crushing as recommended in the A.S.M.E. code, and these resulting samples were tested by the Chemical Department.

Both tests were started and stopped by the alternate method.

The results of the tests were recorded in accordance with the short form advised by the Boiler Test Committee of A. S. M. E. However, the flue gas analysis is not required in this form so that in the recording of the first test this analysis is in addition to the standard form.

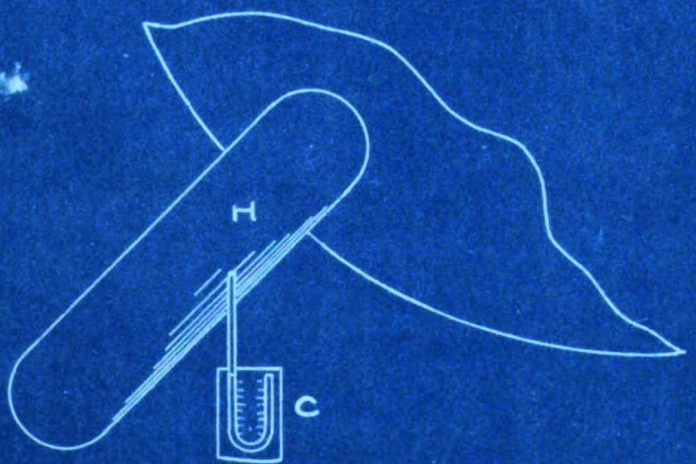
ANALYSIS OF COAL.

Kind of coal	Fairmount slack.	Hanawha splint.
Moisture	.98%	7.73%
Volatile carbon	35.43%	30.09%
Fixed carbon	49.62%	49.58%
Ash	13.99%	12.60%
Calorific power per pound of coal in British Thermal Units	12,710	11,71[illegible]



ARRANGEMENT OF APPARATUS.

A IS ATTACHED TO ORSAT GAS APAR.
B " " " WATER METER
C DRAFT GAUGE
D " "
E THERMOMETER
F CARPENTER SER CALORIMETER
G STEAM MAIN
H BLOWER PIPE



LOG OF 1st TRIAL SPRINGFIELD BOILER

TIME	NET. AM'T OF WATER IN LBS.	GAGE COR'D	CHIM. DRAFT	DRAFT IN BLOW PIPE	TEMPERATURES				COAL FIRED	ASH	QUALITY STEAM %	HEIGHT WATER IN GLASS	BAROM. READ
					BOILER ROOM	EXT. AIR	FLUE GAS	FEED WATER					
11-30 A.M		94.5	.5	2	71	62	542	101				7.5	29.56
12.00	3079.00	79.5	.5	2.25	68	62	443	129			98.	8.75	29.56
12-30	1151.78	83.5	.5	2.25	70	61	545	177			98.3	6.625	29.56
1-00	1157.48	94.5	.5	2.25	71	61	545	163			98.4	5.	29.55
1-30	4293.87	82.5	.5	2	71	61	545	80			98.4	10.5	29.56
2.00	1336.50	92.5	.5	2.5	70	59	550	171			98.5	8.5	29.55
2-30	1096.20	84.5	.5	2	72	58.5	545	164			98.5	6.25	29.56
3.00	2540.36	78.5	.5	2	69.5	58.	540	105			98.3	7.75	29.55
3.30	2662.13	84.5	.5	2	77	56	550	109			98.4	9	29.54
4.00	1094.58	96.5	.5	2.25	78	56	542	168			98.4	6.75	29.54
4-30	1732.92	91.5	.5	2.25	74.5	54	540	110			98.4	6	29.54
5.00	2952.48	81.5	.5	2	72.	54	545	133			98.5	7.625	29.54
5.30	1984.96	72.5	.5	1.75	68.5	52	540	99			98.5	8	29.55
6.00	1955.84	72.5	.5	1.75	73.	52	*	153			98.4	7.5	29.55
6.30	1031.22	94.5	.5	2.25	76	51.5		175			98.2	5.625	29.55
7.00	2461.60	94.5	.5	2.25	73	51		131			98.3	6.375	29.55
7.30	2916.35	94.5	.5	2.25	77	50		98			98.5	8.25	29.56
8.00	2342.70	96.5	.5	1.75	73	50		125			98.5	7.625	29.56
8.30	1222.80	95.5	.5	2.25	71	49		152			98.4	7	29.56
9.00	1957.76	96.5	.5	1.5	64	48.5		150			98.3	6.75	29.56
9.30	2435.18	94.5	.5	2.25	70	48		125			98.3	7.5	29.56
#	41654.1	88.38	.5	2.1	71.85	54.98	545	1345	5400#	688#	98.35		29.55

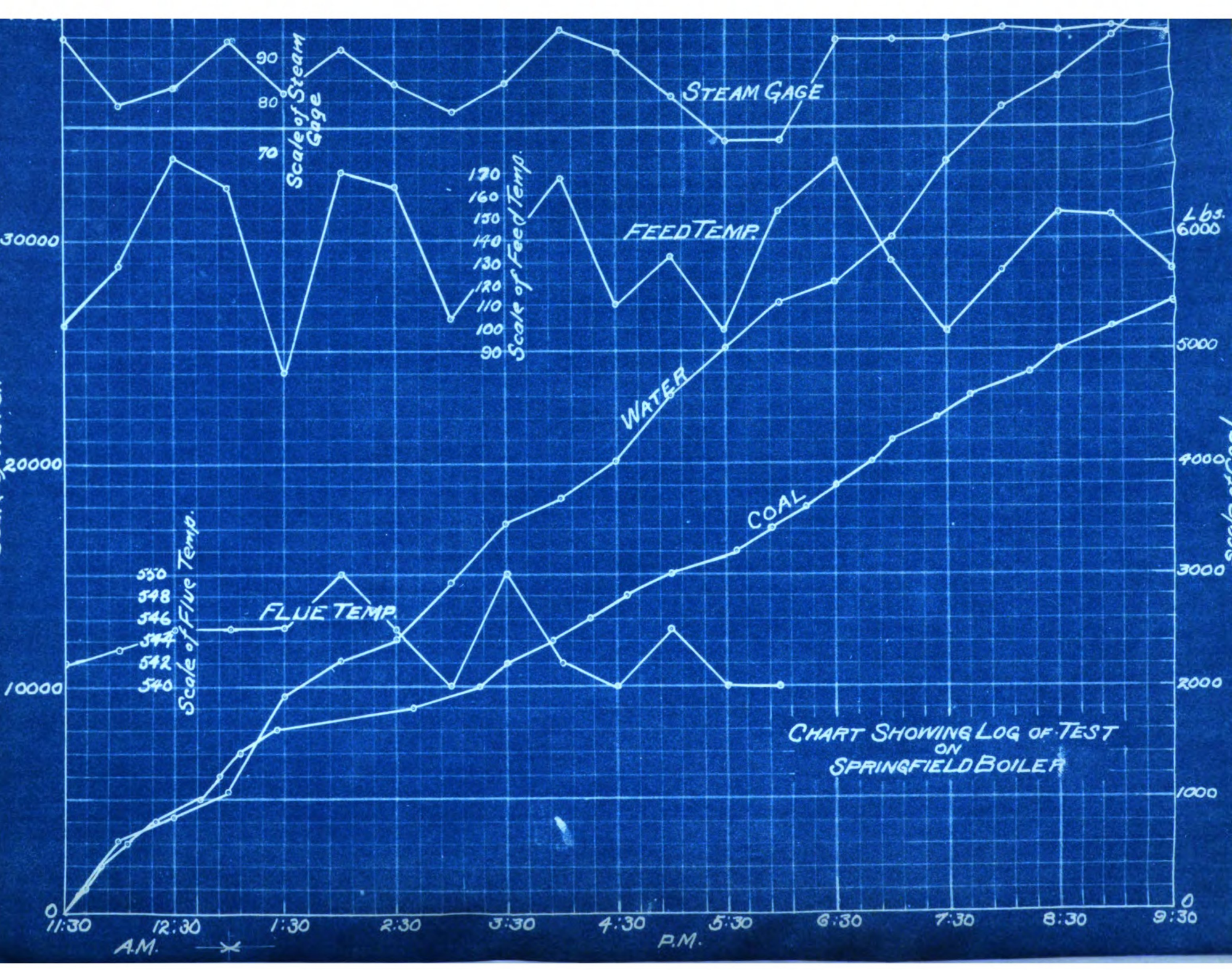
COR'D TOTAL AND AVER. * THERMOMETER BROKE

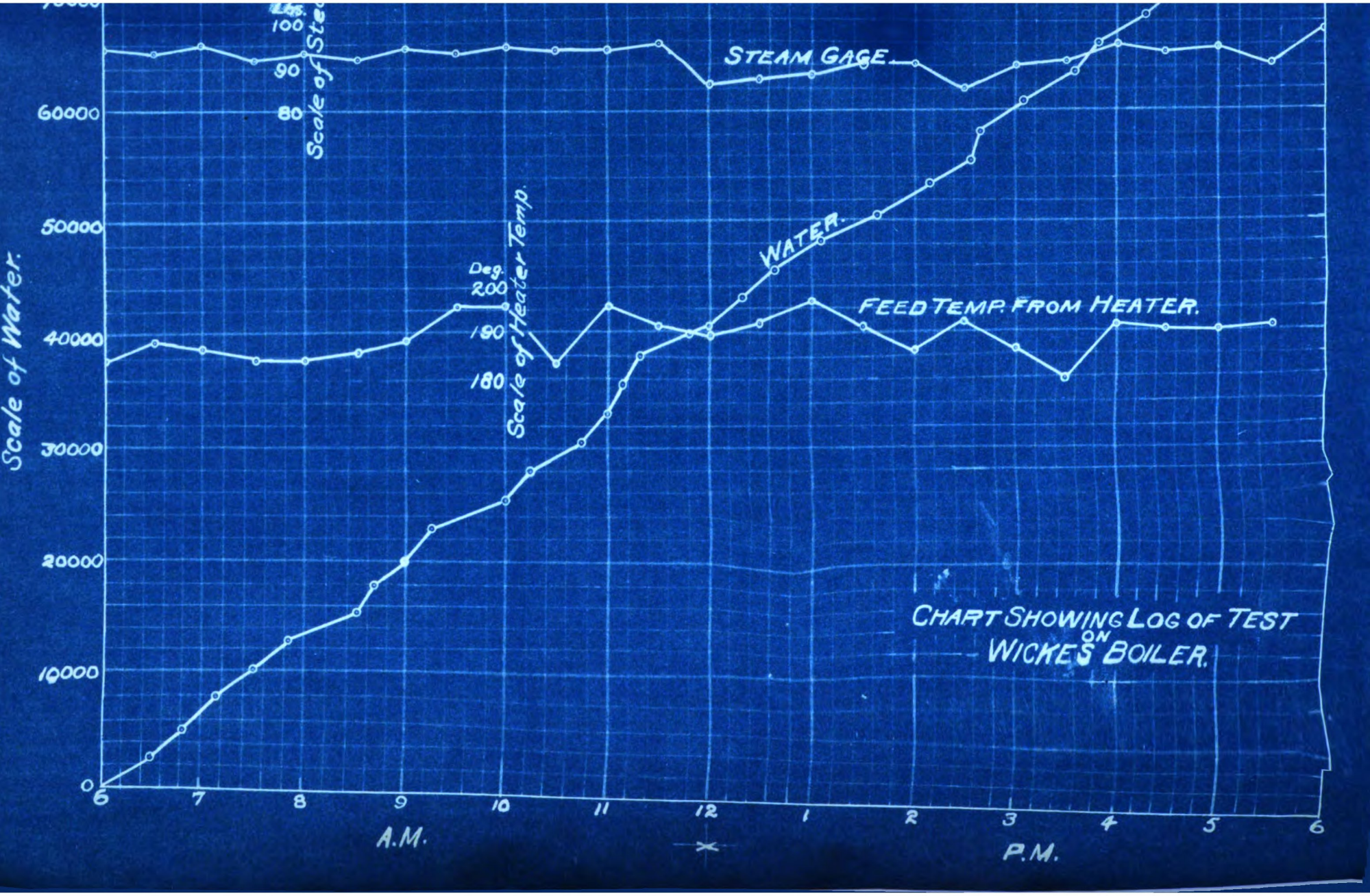
LOG OF 2ND TRIAL WICKES BOILER.

TIME	WATER TO FEED TANK IN LBS.	GAGE COR'D	CHIM. DRAFT	TEMPERATURES. BOILER ROOM	TEMPERATURES. EXT. AIR.	TEMPERATURES. FEED WATER IN TANK	TEMPERATURES. FEED WATER IN HEAT.	COAL FIRED	ASH. IN LBS.	QUAL. STEAM. %	HEIGHT IN WATER GLASS	BAROM. READ
6-00 A-M		108.3		69	57	78	184				8.25	29.14
6-30		107.3		70	57	74	188			98.25	8.5	29.14
7-00		109.3		70	60	77	187			98.4	9.25	29.13
7-30		106.3		72.5	54.5	88	184			98.5	7.75	29.125
8-00		108.3		73.5	64.5	84	184			98.7	8.25	29.125
8-30		107.3	.625	72	66.5	87	186			98.4	10	29.15
9-00		108.3	.625	73.5	65.5	80	188			98.5	10	29.1
9-30		107.3	.625	77	70	82	196			98.6	9	29.085
10-00		108.3	.625	75	69.5	86	196			98.6	8.75	29.07
10-30		107.3	.625	76.5	69.5	94	193			98.6	9.5	29.065
11-00		107.3	.625	68	54	95	196			98.7	8.5	29.085 *
11-30		108.3	.625	74	57	94	191			98.5	10.25	29.1
12-00		100.3	.625	71	55	98	194			98.5	9.25	29.1
12-30		101.3	.625	68	53	92	192			98.7	10.25	29.11
1-00		101.8	.625	73	54	84	197			98.6	9.125	29.08
1-30		104.3	.625	66	54	84	191			98.5	10.5	29.08
2-00		104.3	.625	70	56	82	186			98.5	7.625	29.08
2-30		99.3	.75	73	57	80	192			98.6	8	29.08
3-00		104.3	.75	69	56	80	186			98.4	9	29.08
3-30		105.3	.75	73	59	90	179			98.5	10.5	29.08
4-00		108.3	.75	72	60	92	191			98.3	9	29.08
4-30		107.3	.75	76	60	95	190			98.4	9.75	29.08
5-00		108.3	.75	79	61	95	190			98.4	9.5	29.08
5-30		104.3	.75	74	60	95	191			98.7	9	29.08
6-00		112.3	.75	71	59					98.4	7	29.09
#	78326					86.9	189.7	10900	1058			

COR'D TOTAL AND AVER'S.

* HEAVY SHOWER


STEAM GAGE
Scale of Steam Gage
90
80
70
FEED TEMP.
Scale of Feed Temp.
170
160
150
140
130
120
110
100
90
WATER
COAL
FLUE TEMP.
Scale of Flue Temp.
550
548
546
544
542
540
30000
20000
10000
0
Lbs.
6000
5000
4000
3000
2000
1000
0
11:30
12:30
1:30
2:30
3:30
4:30
5:30
6:30
7:30
8:30
9:30
A.M.
P.M.
CHART SHOWING LOG OF TEST
ON
SPRINGFIELD BOILER


Scale of Water.
60000
50000
40000
30000
20000
10000
0
Scale of Steam Gage.
100
90
80
Scale of Heater Temp.
Deg.
200
190
180
STEAM GAGE.
WATER.
FEED TEMP. FROM HEATER.
6
7
8
9
10
11
12
1
2
3
4
5
6
A.M.
P.M.
CHART SHOWING LOG OF TEST ON WICKES BOILER.

ON 1ST TRIAL SPRINGFIELD BOILER.

FLUE GAS ANALYSIS			
TIME	CO_2 %	O%	CO%
11:35 A.M	10.2	9.8	.2
12:40 PM	9.8	9.6	.2
1:40 "	12.0	7.7	.0
2:40 "	7.6	13.0	.2 *
3:40 "	11.0	8.8	.0
4:40 "	9.4	10.6	.0
5:35 "	9.0	11.0	.0
6:40 "	10.8	8.2	.2
7:35 "	10.6	8.6	.0
8:35 "	10.2	10.0	.0
9:30 "	12.2	7.6	.0

FLUE WAS TAPPED JUST ABOVE THE DAMPER * FIRE WAS SLASHED
ANALYSIS MADE WITH ORSAT APAR.

PRINCIPAL DIMENSIONS OF BOILERS.

SPRINGFIELD BOILER:

Inside diameter	[illegible]
Length between heads	14'-11-5/8"
Number of 3" tubes	94
Diam. of corrugated flue box inside of corrugation	50"
Diam. of corrugated flue box outside of corrugation	5[illegible]-3/4"
Total water heating surface	1[illegible] sq. ft.
Height of chimney	127'
Area of chimney	[illegible].27 sq. ft.

WICKES BOILER:

Diam. of steam drum	78"
Length of shell	22"
No. of 4" tubes	10[illegible]
Total heating surface	2075 sq. ft.
Grate surface	35.75 sq.ft.
Ratio of heating surface to grate surface	58 to 1
Height of chimney	100'
Area of chimney	6.5 sq.ft.

DATA AND RESULTS OF EVAPORATIVE TEST OF A SPRINGFIELD BOILER

ARRANGED ACCORDING TO THE A. S. M. E. STANDARD SHEET FORM.

Kind of boiler	Springfield.
Kind of fuel	Fairmount slack
Kind of furnace	Internal
Method of starting and stopping test	Alternate
Water heating surface	1300 sq. ft.
Grate surface	————

TOTAL QUANTITIES.

1.	Date of trial	May 9,1905
2.	Duration of trial	10 hours
3.	Weight of coal as fired	5400#
4.	Percentage of moisture in coal	.92%
5.	Total weight of dry coal consumed	5350#
6.	Total weight of ash and refuse	688#
7.	Percentage of ash and refuse in dry coal	12.86%
8.	Total weight of water fed to boiler	41654.1#
9.	Water actually evaporated corrected for moisture	40966.8#
9a.	Factor of evaporation	1.1148
10.	Equivalent water evaporated into dry steam from and at 212°	45662.8#

[illegible]

11.	Dry coal consumed per hour	555 #
12.	Dry coal per sq. ft. of grate surface per hour	———
13.	Water evaporated per hour corrected for quality of steam	4096.60 #
14.	Equivalent evaporation per hour from and at 212°	4566.90 #
15.	Equivalent evaporation per hour from and at 212° per sq. ft. of water heating surface	3.40 #

[illegible]

16.	Steam pressure by gage	73.96# /sq. in.
17.	Temperature of feed water entering boiler	134.5°F.
18.	Temperature of escaping gases from boiler	545°F.
19.	Force of draft between damper and boiler	.5 in.
19 a.	Force of draft entering boiler	2.1 in.
20.	Percentage of moisture in steam	1.65%

HORSE POWER.

21.	Horse power developed	132.35 H.P.
22.	Builder's rated horse power	150 H.P.
23.	Percentage of builder's rated horse power developed	88.23%

[illegible].

24.	Water apparently evaporated under actual conditions per pound of coal	7.71"
25.	Equivalent evaporation from and at 212° per pound of coal as fired	8.46#
26.	Equivalent evaporation from and at 212° per pound of dry coal	8.54#
27.	Equivalent evaporation from and at 212° per pound of combustible	9.00#

EFFICIENCY.

28.	Calorific value of the dry coal per pound	12,710 B.T.U.
29.	Calorific value of the combustible per pound	14,174 B.T.U.
30.	Efficiency of boiler (based on combustible)	66.77%
31.	Efficiency of boiler (including grate) based on dry coal	_____

COST OF EVAPORATION.

32.	Cost of coal per ton of 2000# delivered in boiler room	$2.80
33.	Cost of coal required for evaporating 1000# of water from and at 212°	$ .165

[illegible]

Kind of boiler	Heine.
Kind of fuel	Kanawha Splint
Kind of furnace	External
Method of starting and stopping test	Alternate
Water heating surface	2075 Sq. ft.
Grate surface	35.75 Sq. ft.

TOTAL QUANTITIES.

1.	Date of trial	May 10,1910
2.	Duration of trial	12 hours
3.	Weight of coal as fired	10,900#
4.	Percentage of moisture in coal	7.75%
5.	Total weight of dry coal consumed	10,057.4#
6.	Total ash and refuse	1058#
7.	Percentage of ash and refuse in dry coal	10.52%
8.	Total weight of water fed to boiler	78,326#
9.	Water actually evaporated corrected for moisture	77,151.1#
9a.	Factor of evaporation	1.0612
10.	Equivalent water evaporated into dry steam from and at 212°	81,772.7#

HOURLY QUANTITIES.

11.	Dry coal consumed per hour	8[illegible].1
12.	Dry coal per sq. ft. of grate surface per hour	35.4[illegible]
13.	Water evaporated per hour corrected for quality of steam	6429.5#
14.	Equivalent evaporation per hour from and at 212°	6814.4
15.	Equivalent evaporation per hour from and at 212° per sq. ft. of water heating surface	3.38#

AVERAGE PRESSURES, TEMPERATURES, ETC.

16.	Steam pressure by gage	91.32#/sq.in.
17.	Temperature of feed water entering boiler	189.7°
18.	Temperature of escaping gases from boiler	_____
19.	Force of draft between damper and boiler	.67 ins.
20.	Percentage of moisture in steam	1.50%

HORSE POWER

21.	Horse power developed	197.52 H.P.
22.	Builders rated horse power	200 H. P.
23.	Percentage of builders rated horse power developed	98.76%

24.	Water apparently evaporated under actual conditions per pound of coal	7.[illegible]
25.	Equivalent evaporation from and at 212° per pound of coal as fired	7.50
26.	Equivalent evaporation from and at 212° per pound of dry coal	8.13
27.	Equivalent evaporation from and at 212° per pound of combustible	9.09

EFFICIENCY.

28.	Calorific value of the dry coal per pound	11,710 B.T.U.
29.	Calorific value of combustible per pound	14,350 B.T.U.
30.	Efficiency of the boiler(based on combustible)	59.11%
31.	Efficiency of the boiler, including grate (based on dry coal)	67%

COST OF EVAPORATION.

32.	Cost of coal per ton of 2000# delivered in boiler room	$3.20
33.	Cost of coal required for evaporating 1000# of water from and at 212°	$ .146

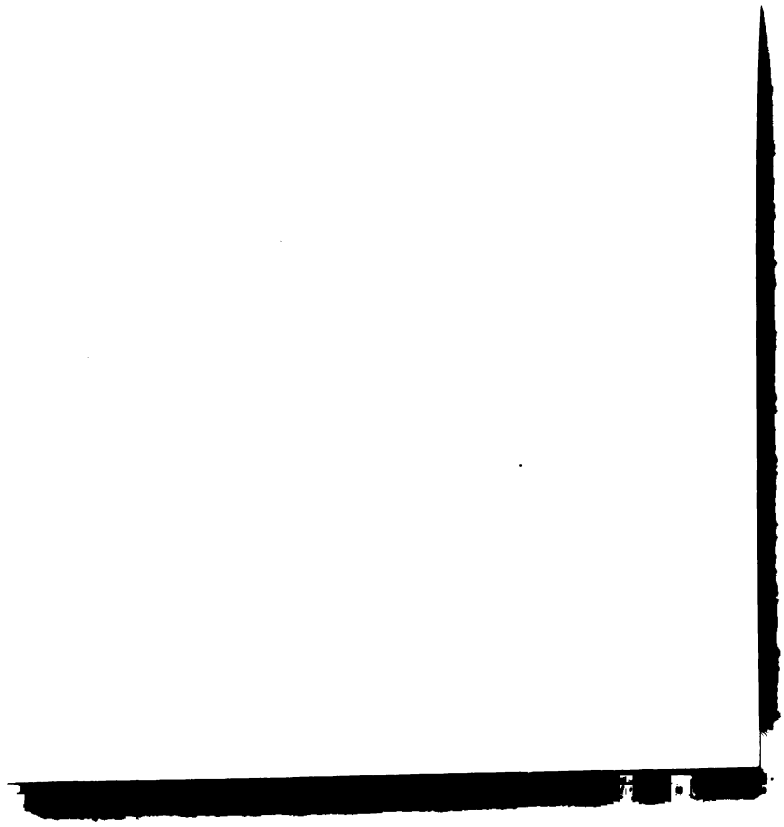
REMARKS AND CONCLUSIONS.

In the test on the Springfield boiler the pounds of water evaporated per pound of combustible from and at 212° was rather low as compared with other tests on boilers of this type. In tests on a boiler of the same kind, fed with the same kind of stoker, in the spring of 1904, the equivalent evaporation from and at 212° per pound of combustible was 11.51 and 11.53, while the value in our test was 9.93, making a difference of 1.51 and 1.40. This difference may be due, to some extent, to the boiler in our test ~~did~~ not having any kind of covering. Also the very wide range of feed water temperatures, no doubt affected the evaporative results. The evaporative results obtained from the Hickes boiler compare quite favorably with other boilers of this make and of same horse power. However, a test made by H. C. Carpenter on a Hickes vertical water tube boiler in Nov. 1903 at the Michigan Alkali Works, Wyandotte, Mich., gave an equivalent evaporation from and at 212° of 10.63 lbs. per pound of combustible. However, this was practically a new boiler, also the coal used in our test had a very large percentage of moisture.

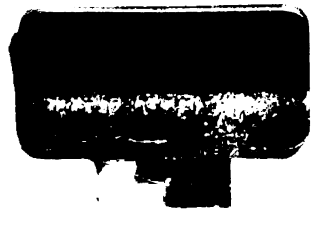
On account of the manner of working of the mechanical stoker, the grate area is not taken into account as when hand-firing is employed. The stoker, working intermittently, merely deposits the fuel in a sort of pile, rather than spreading it evenly over the grate surface as it is when hand-firing is used. Hence, it would be unfair to consider the grate surface as it is considered in a hand-fired boiler.

The flue gas analysis shows very good combustion; all of the CO in a majority of the trials having combined with the oxygen, thus giving very little black smoke.

ROOM USE ONLY



ROOM USE ONLY



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