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THE S I S
B O I L E R T R I A L S
ON THE
HORIZONTAL, INTERNAL FURNACE, MARLBOROUGH BOILER
A
H
D
HORIZONTAL, RETURN TUBULAR
BOILER AT THE POWER PLANT
OF THE
MICHIGAN AGRICULTURAL COLLEGE.

BY

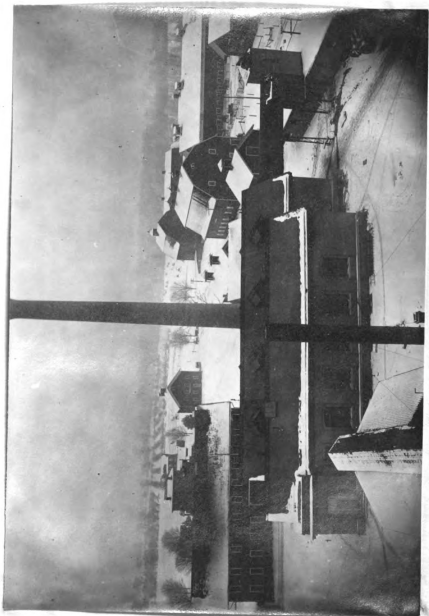
/ I. D. CHARLTON

I. C. FOMMER

F. H. TAYLOR

1907

THESIS



264802

DESCRIPTION OF TESTS.

These tests were made at the Power Plant at the Michigan Agricultural College. The first and third tests were made on the Springfield Horizontal Tubular, Internally Fired Boiler No. 3, manufactured by the Springfield Boiler & Mfg. Co., Springfield, Ill. The second test was made on the Horizontal Return Tubular Boiler, manufactured by the Lansing Boiler & Engine Works, Lansing, Mich. The first two trials were of 24 hours and the third of 6 1/2 hours duration.

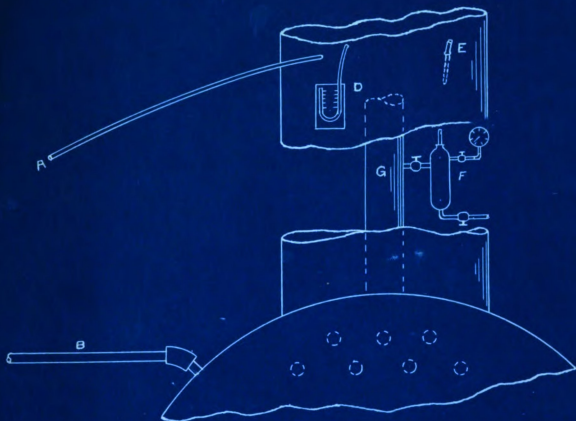
OBJECT OF TESTS.

Under the stated conditions in each case:-

- To determine the horse power developed.
- To find the amount of evaporation per pound of coal.
- To determine the thermal efficiency of boilers.
- To determine the cost of evaporation.

EQUIPMENT.

The apparatus employed in the first and last tests was as follows:- A Western Tool Co. steam gage was used for obtaining the steam pressure. A Carpenter's throttling calorimeter was used for determining the quality of the steam and was attached by means of a perforated nipple to the steam main just above the boiler. The water was fed into the boiler by a Penborthy injector, which operated by steam direct from the boiler. This water was taken directly from the water mains. Forced draught was employed, which was produced by an American Blower Co. 110 inch three



ARRANGEMENT OF APPARATUS

A IS ATTACHED TO ORSAT GAS APAR-

B " " " INJECTOR

C DRAFT GAUGE

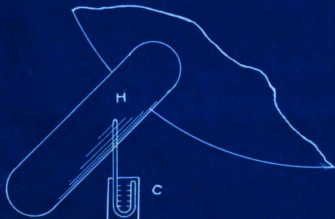
D " " "

E THERMOMETER

F CARPENTER THROTTLING CALORIMETER

G STEAM MAIN

H BLOWER PIPE



quarter housed bottom horizontal discharge fan, which is driven direct, connected by a type A.B.C. vertical engine. The air is forced through two 9 inch pipes, one entering each side of the furnace. The engine also drives, belt connected, a Cole auto regualting a Jones underfeed stoker, which was used. For taking temperatures, Farhenheit thermometers were used with the exoeption of the flue gas where a Centgrade thermometer was used. U tube draught gages were used to obtain the force and flue gas draughts. For the analysis of the flue gases an Orsat gas apparatus was used. Platform scales were used for weighing both the water and the coal.

All the aparatus was carefully tested before starting tests as shown in the figure. The aparatus used in the second test was the same as that used in the first and thirã with the exception that the furnice was hand fired and no force draught was used.

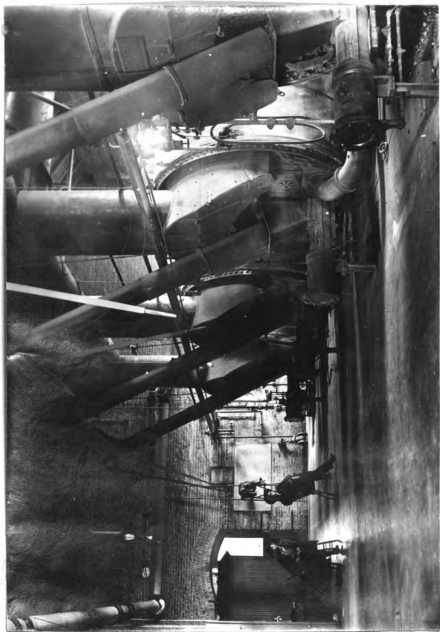
METHOD.

The first test started at 7:00 A.M. on Feb. 23 and lasted until 7:00 A.M. on Feb. 24, 1907. It was carried on under actual working conditions as nearly as possible. All connections not in use were disconnected before starting the test. The boiler was fired several hours before starting and the fires were cleaned an hour an hour before starting and stopping the test. The hight of the water in the boiler was marked on the water glass at the beginning and kept very near at the same hight during the whole test. The coal was weighed in varialbe quantities as needed every half hour. The water was weighed in a barrel and emptied into a tank, the amount being recorded every fifteen minutes.

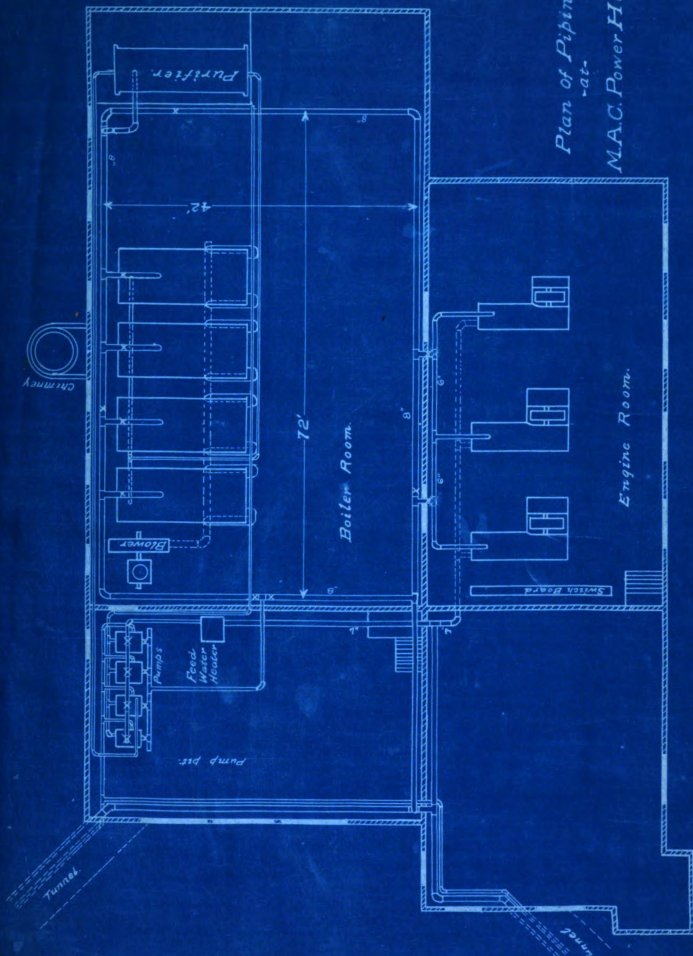
The scales being ballanced before each weighing. Readings were taken every fifteen minutes of the steam gage, draught gage in blower pipe, draught gage in uptake, also temperatures of feed water, flue gases, boiler room, external air and temperature and pressure in calorimeter.

The second test started at 7:00 A.M. on Mar. 2nd and lasted until 7:00 A.M. on Mar. 3rd 1907. This test was carried on under a load a little above that rated by the builders. The coal was weighed in variable quantities as required every half hour and deposited on the boiler floor and hand fired as required. The method was the same as in the first case except taat there were no forced draught readings to be taken.

The third test was started at 8:30 A.M. on Mar. 16, 1907 and ended at 3:00 P.M. of the same day. The test was identical with the first one only the load was a great deal heavier as the boiler furnished steam to run a 125 K W engine and generator which was run with an over load. Small samples of coal were taken out at each weighing in all the 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. All these tests were started and stop-
ped by the alternate method. The results of the tests were recorded in accordance with the standard short form advised by the Boiler Testing Committee of the A.S.M.E.



Plan of Piping
-at-
M.A.C. Power House



LOG OF READINGS

BOILER NO 5

MAR. 2 AND 3, 1907.

TIME	WEIGHT OF WATER	WEIGHT OF COAL	GAGE	PRESSURE IN CHL	CHIM DRAFT	TEMPERATURES (Far)					ASH
						BOILER ROOM	EXT AIR	FLUE GAS-C	FEED WATER	CHL.	
7:00	392	306	101	test.	.35	75	28	265	53°	276	
7:15	371	304	96		.4	74	27	242	53	278	
7:30	1131	273	102	the test.	.4	73	27	252	53	275	
7:45	745	318	102		.4	76	27	267	52	272	
8:00	1828	284	101		.5	71	27	242	52	274	
8:15	1469	290	100		.5	70	26.5	254	52	273	
8:30	1914	312	95		.5	69	26	278	52	274	
8:45	1015		102		.5	71	26	259	52	269	
9:00	1105		100		.5	68	26	278	51	268	
9:15	1463	314	97		.45	68	26	259	51	267	
9:30	1464		100		.5	67	26	245	52	265	
9:45	1108	284	97		.5	68	25.5	258	52	266	
10:00	1478		100		.45	67	26	252	52	268	
10:15	1470	312	95		.5	67	26	245	52	269	
10:30	1131	317	95	(13.87)	.6	67	25	221	52	270	
10:45	1491	308	95		.6	67	25	221	52	268	
11:00	1464	275	98		.5	68	25	229	52	267	
11:15	1091		98		.48	67	25	253	52	268	
11:30	1470	208	95		.45	69	26	248	52	265	
11:45	1096	297	96		.5	68	26	245	52	264	
12:00	1832		100		.5	68	26	239	52	266	
12:15	725		97		.45	71	26	245	52	270	
12:30	1133	296	100		.5	70	25	264	52	268	
12:45	1431		99		.5	68	25	235	52	266	
1:00	1817	305	100		.5	62	25	257	52	266	

MEAN BAROMETER READING = 29.42"

LOG OF READINGS

BOILER NO. 5

MAR. 2 AND 3, 1907.

TIME	WEIGHT of WATER	WEIGHT of COAL	GAGE	PRESSURE IN CAL.	CHIMNEY DRAFT	TEMPERATURES (Far)					ASH
						BOILER ROOM	EXTL AIR	FLUE GAS-C	FEED WATER	CAL.	
1:15	1425	292	98		.55	64	25	255	52	266	
1:30	2147	309	100		.55	64	25	258	52	265	
1:45	1834	297	102		.56	62	25	265	52	275	
2:00	1443		97		.55	65	25	255	52	265	
2:15	1534	311	98		.6	62	25	265	52	264	
2:30	1484		99		.58	46	25.5	247	52	266	
2:45	1442	310	105		.6	65	26	261	52	265	
3:00	1447		106		.55	65	26	255	52	264	415
3:15	1423		97		.6	49	26	264	52	265	
3:30	1775	288	98		.6	66	26	264	52	263	
3:45	1445	305	97		.6	54	26.5	263	52	250	
4:00	1446		97		.6	48	27	243	52	252	
4:15	1468	311	96		.65	50	27	265	52	256	
4:30	1454	315	95		.6	57	27	226	52	264	
4:45	1101		98		.55	66	27	225	52	270	
5:00	728		98		.6	67	27	223	52	266	
5:15	1090		95		.6	70	27	233	52	265	
5:30	1083		97		.55	69	27	225	52	267	
5:45	1091		95		.45	70	27	245	52	265	
6:00	740		99		.5	70	27	224	52	265	
6:15	1418	314	93		.45	71	28	220	52	266	
6:30	370		94		.4	69	27	206	52	266	
6:45	1838		93		.5	71	27	224	52	265	
7:00	781		93		.5	69	28	242	52	265	
7:15	1098		98		.5	65	28	252	52	267	

LOG OF READINGS

BOILER No 5

MAR 2 AND 3 1907.

TIME	WEIGHT of WATER	WEIGHT of COAL	GAGE	PRESSURE IN CHL.	CHIMNEY DRAFT	TEMPERATURES (Far.)					ASH
						BOILER ROOM	EXTL AIR	FLUE GAS	FEED WATER	CHL.	
7:30	1066	320	94		.45	66	27	263	52	266	
7:45	1086	313	95		.5	66	27	258	52	268	
8:00	1084	313	97		.5	64	25	251	52	267	
8:15	1443		94		.45	70	25	248	52	267	
8:30	1106	307	98		.4	70	24.5	261	52	268	
8:45	1474	297	98		.45	70	24	236	52	267	
9:00	1499		98		.4	70	24	241	52	268	
9:15	1119	312	98		.4	71	24	255	52	268	
9:30	1854	368	93		.4	68	23	248	52	267	
9:45	1119	311	100		.4	67	23	222	52	268	
10:00	1466	304	100		.4	66	22	206	52	265	
10:15	739		99		.45	68	21	225	52	267	
10:30	1111		96		.5	66	22	251	52	267	
10:45	747	304	97		.4	68	22	209	52	267	
11:00	1104		95		.4	67	23	190	52	266	
11:15	1105		94		.4	66	23	194	52	266	
11:30	360		93		.4	67	23	240	52	267	
11:45	368		92		.4	68	23	224	52	267	
12:00	1466	316	97		.4	69	23	260	52	267	
12:15	1100	316	94		.4	68	22	245	52	267	
12:30	1474		97		.4	69	22	259	52	268	
12:45	1112		92		.5	68	22	265	52	264	
1:00	1455		102		.4	69	22	255	52	265	
1:15	1135		95		.5	68	21	261	52	265	
1:30	1091		99		.4	71	20	236	52	265	

LOG OF READINGS

BOILER NO 5

MAR. 16, 1907.

TIME	WEIGHT OF COAL	WEIGHT OF WATER	GAGE	PRESSURE IN CAL -	DRAFT		TEMPERATURES						ASH
					CHIM- NEY	FORCE	BOILER ROOM	EXT- AIR	FLUE GAS	FEED WATER	IN CAL -		
8:30	540 ⁺	0 ⁺	95 ⁺	5 ⁺ #	.5"	1 ⁺ / ₄ "	84 ⁺ F	47 ⁺ F	267 ⁺	52 ⁺ F	273 ⁺ F		
8:45		1515	70	"	.7	4	92	48	307		265		
9:00	595	2285	85	"	.5	4	90	48	284	52 ⁺	272		
9:15		1905	97	"	.5	4	91		285		278		
9:30	411	1900	85	"	.55	5	91	48	287	52	273		
9:45		1900	92	"	.55	5 ¹ / ₄	90		282		277		
10:00	432	1525	85	"	.5	2	90	49	283	52	276		
10:15		1900	84	"	.5	5	92		287		273	123	
10:30	564	1900	95	"	.5	5	94	51	286	52	276	355	
10:45		2280	98	"	.45	4 ¹ / ₄	93		287		278		
11:00	515	1520	90	"	.55	5	91	52	279	52	277		
11:15		1900	90	"	.6	5	89		283		277		
11:30	551	1900	88	"	.65	5 ¹ / ₄	94	54	285	52	274		
11:45		1900	94	"	.65	3 ¹ / ₄	94		278		277		
12:00	644	1520	70	"	.5	5	94	56	281	52	272		
12:15		1520	60	"	.6	4 ¹ / ₄	95		283		265		
12:30	300	1520	64	"	.65	4	95	57	286	52	263		
12:45		1520	75	"	.6	4 ¹ / ₄	98		282		270		
1:00	541	1520	76	"	.65	3 ¹ / ₄	101	59	278	52	270		
1:15		1520	84	"	.7	5	94		293		271		
1:30	285	1520	90	"	.65	3 ¹ / ₄	97	59	277	52	278		
1:45		1900	91	"	.65	4 ¹ / ₂	99		285		277		
2:00	467	1900	96	"	.65	3	94	59	277	52	279		
2:15		1900	94	"	.65	4	95		279		278		
2:30	251	1900	90	"	.6	4	94	59	280	52	275		
2:45		1520	90	"	.6	4	96		281		275		
3:00		1520	91	"	.65	4	101	59	276	52	277	540	
AVG-			85.9	5 ⁺ #	.58	4.11	94	54.07	282.2	52	274.4		
TOTAL	6096	45610										1018.	
AVERAGE BAROMETER READING = 29.53"													

AVERAGE BAROMETER READING = 29.53"

FLUE GAS ANALYSIS

BOILER NO. 3

MAR. 16, 1907.

TIME	% of CO ₂	% of CO	% of O	% of N	REMARKS
8:30	9.9%	8.5%	0.7%	81.6%	
9:00	13.6	5.2	0.	81.2%	
10:00	9.8	9.3	0.	80.9	
11:00	11.6	7.1	0.	81.3	
12:00	10.4	9.0	0.	80.6	
1:00	12.3	4.7	0.	83.0	Fires Being Cleaned
2:00	9.4	10.6	0.	80.0	
3:00	11.8	7.2	0.	81.0	
Total	11.1	7.7	0.	81.2	

DATA AND RESULTS OF EVAPORATIVE TEST ARRANGED
ACCORDING TO A.S.M.E. STANDARD SHORT FORM.

Made by Charlton, Koehler, and Taylor on a Springfield boiler,
at E.A.C. to determine the evaporation, cost of evaporation and
thermal efficiency, when running above rated horse power.

Water heating surface	1309 sq.ft.
Kind of fuel	Fairmount Slack
Kind of furnace	Internal
Grate surface	-----
Superheating surface	-----

TOTAL QUANTITIES.

Date of trial	Mar. 16th 1907
Duration of trial	6 1/2 hours
Weight of coal as fired	6,097#
Moisture in coal	3.05%
Total weight of dry coal consumed	5,910.2#
Total weight of refuse	1,018#
Percent of ash and refuse in dry coal	16.88%
Total weight of water fed to boiler	45,610#
Moisture in steam	.5%
Water actually evaporated corrected for moisture	45,382#
Equivalent water evaporated into dry steam from and at 212 degrees	54,544.6#

HOURLY QUANTITIES.

Dry coal consumed per hour	909.26#
Water fed per hour	7,016.9#
Equivalent water evaporated per hour from and at 212 degrees, corrected for quality of steam	8,391.5#
Equivalent water evaporated per sq. ft. of water heating surface per hour	6.41#

AVERAGE PRESSURES, TEMPERATURES, ETC.

Average boiler pressure	85.9#
" temperature of feed water	52°
" " " escaping gas	510°
" " " fire room	94°
" " " outside air	54°
" " " calorimeter	274.4°
" force of draught between damper and boiler	.58"
" " " at furnace	4.11"
" barometer pressure in inches	29.53"

HORSE POWER.

Horse power developed	240.33
Builders' rated horse power	150
Percent of builders' rated horse power	160.2%

ECONOMIC RESULTS.

Water apparently evaporated per pound of coal under actual conditions	7.485
Equivalent water evaporated from and at 212 degrees per pound of coal as fired	8.831
Equivalent water evaporated from and at 212 degrees per pound of dry coal	9.23
Equivalent water evaporated from and at 212 degrees per pound of combustible	11.104

EFFICIENCY.

Calorific value of the coal	13,519 B.T.U.
Efficiency of boiler (based on coal)	66.0

COST OF EVAPORATION.

Cost of coal per ton of 2000# delivered in boiler room	\$2.60
Cost of coal required for evaporation 1000# of water from and at 212 degrees	\$0.147

PRINCIPAL DIMENTIONS OF BOILERS.

SPRINGFIELD BOILER

Inside diameter	8'
Length between heads	14'-11 5/8"
Number of three inch tubes	94
Diam. of corrugated flue box inside of corrugation	50"
Diam. of corrugated flue box outside of corrugation	58 3/4"
Total water heating surface	1,309 sq.ft.
Hight of chimney	127'
Area of chimney	28.27 sq.ft.

RETURN TUBULAR BOILER

Inside diameter	6'
Length between heads	17' 10"
Number of four inch tubes	74
Length of grate	68"
Width of grate	68"
Total grate area	
Total water heating surface	1,500 sq.ft.
Hight of chimney	127'
Area of chimney	28.27 sq.ft.

CONCLUSION.

In the tests on the Springfield boiler the pounds of water evaporated from and at 212 degrees was a little low in the first test but was fairly good in the second as compared with the tests on other boilers of this type. In tests on boilers of this kind, fed with the same kind of stoker have given an equivalent evaporation from and at 212 degrees per pound of combustible about 11.5; while the value of our tests were 10.796 and 11.104, making a difference of about .504 and .196.

The evaporative results obtained from the Horizontal Return Tubular boiler compare very favorably with the data we have been able to obtain from tests made on other boilers of similar make and the same horse power.

It is almost impossible to take into account the grate area when the mechanical stoker is used, as when hand firing is employed. The stoker working intermittently deposits the coal in a pile in the center so it is not spread evenly over the grate surface as when hand firing is employed. Hence it would be a wrong assumption to consider it the same as in the hand fired boilers.

The flue gas analysis shows about a perfect combustion; thus giving very little smoke.

By making a comparison of the three tests, we find that the Springfield boiler can be crowded or over loaded to better advantage than the Tubular boiler can.

They also show that there is very little loss in efficiency when it is working under a very large overload

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