T H E S I S

BOILER TEST AT SOUTHERN RAILWAY POWER HOUSE.

For the Degree of

BACHELOR OF SCIENCE

in

MECHANICAL ENGINEERING

by

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Under

Prof. J. A. Switzer.

1909

The plant of the Southern Railway Shops, at Knoxville, Tennessee, was tested on March 31st, and April 1st, 1909 by B. L. Thomas, Bruce Helm and J. C. Mayes, with the aid of the Junior and Senior engineers.

B. L. Thomas was in charge of the turbine test, Bruce Helm had charge of the air compressor test and J.C. Mayes was in charge of the boiler and furnace test.

The plant consists of battery of four 300 H.P. Sterling boilers fed with Roney stokers, run by an 8 H.P. Edison engine, an Ingersoll-Rand, two-stage compressor with twin engines, a Cochrane open feed-water heater, one 750 K.W. and one 350 K.W. Parsons steam turbine, with a 25 and 17½ K.W. exciter respectively.

Commencing with the boilers, I will say that they were in fairly good condition. They all were cleaned out between four and six weeks of the time the test was made. The feed-water was good being clear and containing very little solid matter.

The shell of the boilers was completely covered over the top by a double layer of brick and cement, which serves as a good non-conductor of heat.

The steam line from each boiler was covered with asbestos and immediately led into one main line from which it was carried to the various departments of the plant by means of smaller pipes.

In the operation of the plant the water that fed the boiler was taken from the city supply, passed through the open heater,

and raised to the temperature of about 180° F by the exhaust steam which came from the compressor and turbines. From the heater it was taken into a hot water pump by means of gravity and fed into the different boilers.

The coal used by the plant is dumped on the outside of the boiler room and passed through a crusher, and by means of a conveyor is carried to the top of the boiler room and automatically dumped into bins over each boiler and then carried by means of chutes to small hoppers in front of each boiler and the coal's own weight fed itself onto the rocking grates.

When we started the test we put a blind flange into the exhaust line from the compressor and turbines and turned the exhaust into a feed-water heater not now in use by the plant and used the condensing water which was taken from the city main as feed-water for the boilers.

The feed-water was weighed by means of three raised tanks, each emptying into a larger tank and from there flowed by means of gravity into a hot water pump and then forced into the boilers. The temperature of the feed-water was taken in the large tank, but it was found that a correction of 2° had to be made owing to the fact that the water had to pass through 90 feet of piping before reaching the pump. Corrected readings only are recorded on the log sheet.

The boiler test was made as prescribed by the A.S.M.E. and all precautions were taken to make it reliable.

The coal for this test was weighed by the car load and par-

ticular care was taken to have all the unweighed coal out of the bin when the test was started.

In order to do this the boilers were fired by hand from coal placed on the floor until the test began. Owing to the intense heat of the furnace the grate bars had to be kept wet and this prevented us from getting the temperature of the ashes. The ashes were dropped down into a bin in the basement of the boiler room and from there were carried by the same conveyor that handled the coal into an ash bin and there allowed to accumulate during the entire test. They were then emptied into a car and weighed. several samples were taken while they were emptying into the car and brought to the University and weighed and dried to determine the amount of moisture in order to find the actual amount of ash produced during the test.

The test lasted for 23 hours and 38 minutes, beginning at 9 A.M. March 31st and ending 8:38 A.M. April 1st, 1909.

Readings were taken at 15 minute intervals except in some cases where the state of things seem to remain constant.

As I have already stated the temperature of feed-water was taken from the large receiving tank. The temperature of the flue gas was taken just outside the boiler room, before entering the chimney by means of a pyrometer, the drought measured by a U tube manometer, and flue gas analysis made at frequent intervals. The temperature of the boiler room, also of external air was also taken. The calorimeter test of the steam was taken in the power house on account of there being no place to attach the calorimeter

in the boiler room.

A string was placed around each glass tube at the level of the water, in the beginning of the test and it was found that water stood approximately 8 inches in the tubes and this was taken as the initial point, reading above being recorded as plus and below minus. The average reading of the four water gauges, also of the four pressure gauges only are recorded on the log sheet. The temperature of the steam was found from steam tables.

A small amount of coal was taken from the hopper in front of each boiler every half hour, then at the end of every five hours this amount was quartered down to a quart and afterwards brought to the University and by means of the Parr calorimeter the B.T.U.'s per pound of coal determined, also the percent of surface and total moisture.

There was a small steady leakage from the blow-off of one of the boilers and the amount lost during the test was calculated by finding the amount lost in a given time. The total amount lost was found to be 2000 pounds. This is to be taken from the total amount of water pumped into the boilers.

Mechanical Laboratory—UNIVERSITY OF TENNESSEE

LOG OF BOILER TEST

Made by J.C. Mayes Date March 31, 1909

Kind of Boiler Stirling Mfg. by B & W

No.	Time	PRESSURES			TEMPERATURES							WATER GAUGE	
		Barometer	Steam Gauge	Draft Gauge	External Air	Boiler Room	Flue	Feed-water	Calori-meter	Steam	Furnace	From Initial	Calori meter mano meter
													"Hg
1	9.00 AM	29.11	142	1.000	56	79	730	145		330		0.000	
2	9.30		124	.875	56	79	715	149		323		4.75	
3	10.00	29.13	135	.875	54	80	710	156		330		-2.50	
4	10.30		119	.820	54	81	700	159		321		7.50	
5	10.45		113	.875	55	80	710	165		317		8.25	
6	11.00	29.12	111	.875	55	80	700	167		315		4.50	
7	11.15		116	.820	55	80	700	162		318		-2.00	
8	11.30		118	.820	54	81	700	147		320		-1.25	0.9
9	11.45 PM		113	.875	54	81	700	157		317		13.00	
10	12.00	29.11	114	.875	55	82	700	168	270	318		13.75	1.1
11	12.15		140	.820	56	81	690	178		332		6.00	
12	12.30		147	.750	55	82	660	178	278	336		9.75	1.4
13	12.45		141	.820	56	81	680	170	276	332		8.25	
14	1.00	29.10	143	.820	57	84	680	141	276	333		15.25	0.7
15	1.15		135	.820	56	84	690	141		330		12.00	
16	1.30		139	.750	57	84	680	152	274	332		9.00	1.5
17	1.45		140	.875	57	84	680	168		332		-0.50	
18	2.00	29.07	135	.875	59	84	700	159	276	330		5.00	1.6
19	2.15		144	.875	57	84	680	158		334			
20	2.30		145	.820	58	84	700	151	268	335		14.25	1.6
21	2.45		140	.875	58	83	680	157		332			
22	3.00	29.06	144	.826	58	84	670	161	265	334		5.00	1.6
23	3.15		134	820	58	85	680	168		329			
24	3.30		137	.875	58	85	680	146	266	331		13.50	1.6
25	3.45		144	.875	57	85	690	157		334			
26	4.00	29.05	136	.875	57	85	690	145	266	330		14.75	1.6
27	4.15		135	820	57	85	670	151		330			
28	4.30		138	.875	57	84	660	169	274	331		0.25	1.6
29	4.45		135	.826	57	83	630	110		330			
30	5.00	29.05	136	.820	56	84	660	120	275	330		15.25	1.8
31	5.15		131	.820	56	84	640	137		328			
32	5.30		140	.820	52	83	690	170	280	332		10.50	1.8
33	5.45		148	.820	53	85	650	176		337			
34	6.00	29.06	143	.820	53	86	660	175	278	334		11.00	1.8
35	6.15		139	.826	52	85	660	173	273	332			1.8

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LOG OF BOILER TEST

Made by..... *Date*.....

Kind of Boiler..... *Mfg. by*.....

No.	Time	PRESSURES			TEMPERATURES							WATER GAUGE	
		Barometer	Steam Gauge	Draft Gauge	External Air	Boiler Room	Flue	Feed-water	Calori-meter	Steam	Furnace	From Initial	Calorimeter manometer "Hg
1	6.30		147	.820	5-2	84	630	161	278	335°		6.5-0	1.8
2	6.45°		140	.820	5-1	84	620	149		332			
3	7.00	29.07	142	.820	5-0	83	610	144	278	333		6.5-0	1.8
4	7.15°		142	.820	49	83	640	141		333			
5	7.30		143	.820	49	82	640	15-6	278	333		6.5-0	1.8
6	7.45°		139	.820	49	82	664	15-6		332			
7	8.00	29.08	142	1.000	48	79	680	147	275°	333		-1.25°	1.8
8	8.15°		142	.935°	48	80	670	134		333			
9	8.30		139	.935°	47	81	645°	134	277	332		7.75°	1.8
10	8.45°		145°	.875°	47	80	643	133		334			
11	9.00	29.09	140	.825°	47	82	660	128	277	332		4.75°	1.8
12	9.15°		141	1.250	46	84	660	138		332			
13	9.30		143	.875°	46	84	655°	148	277	334		6.5-0	1.4
14	9.45°		143	.935°	45°	88	655°	142		337			
15	10.00	29.10	140	.875°	45°	90	660	143	277	332		4.75°	
16	10.15°		15-0	.875°	45°	86	670	15-6		332			
17	10.30		141	.935°	44	83	665°	15-6		330		5.5-0	
18	10.45°		141	.935°	44	82	670	15-3		327			
19	11.00	29.10	136	.875°	44	84	685°	139		332		6.00	
20	11.15°		131	.875°	43	81	682	146		334			
21	11.30		141	.875°	43	81	685°	149		334		8.75°	
22	11.45° AM		142	.875°	42	79	670	149		335°			
23	12.00	29.11	144	.875°	42	79	680	142		333		8.5-0	
24	12.15°		142	.820	42	79	655°	145°		336			
25	12.30		148	.875°	40	79	655°	15-5°		330		4.25°	
26	12.45°		136	.935°	41	81	680	15-8		330			
27	1.00	29.12	136	.875°	39	81	65-0	15-8		329		7.5-0	
28	1.15°		134	.875°	40	80	680	15-0		332			
29	1.30		139	.875°	39	81	685°	144		334		7.5-0	
30	1.45°		143	.875°	40	80	670	138		336			
31	2.00	29.11	148	1.000	40	82	690	148		330		2.75°	
32	2.15°		136	.935°	40	81	695°	15-2		334			
33	2.30		145°	.935°	40	82	700	148		330		4.5-0	
34	2.45°		139	.935°	40	81	670	15-6		334			
35	3.00	29.10	137	.875°	39	80	640	140		331		8.00	

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LOG OF BOILER TEST

Made by ..... *Date* .....

Kind of Boiler ..... *Mfg. by* .....

No.	Time	Pressures: Barometer	Pressures: Steam Gauge	Pressures: Draft Gauge	Temperatures: External Air	Temperatures: Boiler Room	Temperatures: Flue	Temperatures: Feed-water	Temperatures: Calorimeter	Temperatures: Steam	Temperatures: Furnace	Water Gauge: From Initial
1	3.15		139	.935	38	81	650	136		332		6.00
2	3.30		146	.935	39	81	660	132		335		
3	3.45		145	.875	39	80	665	133		335		3.00
4	4.00	29.11	141	.875	39	82	650	134		333		
5	4.15		142	.875	39	76	675	144		333		5.00
6	4.30		146	.875	39	74	695	144		335		
7	4.45		149	1.000	39	75	670	144		337		7.00
8	5.00	29.12	144	.935	40	79	636	134		334		
9	5.15		141	.875	40	78	630	128		333		6.00
10	5.30		141	.875	40	80	630	130		333		
11	5.45		136	.875	40	80	600	124		330		2.75
12	6.00	29.12	133	.875	40	79	630	109		328		
13	6.15		124	.875	41	75	642	123		324		-1.25
14	6.30		129	.935	41	76	690	117		326		
15	6.45		121	.875	41	76	705	118		321		5.50
16	7.00	29.10	139	1.000	41	76	705	103		332		
17	7.15		140	1.000	42	76	720	109		332		0.50
18	7.30				42	75	660	127				
19	7.45				42	76						
20	8.00	29.05	139		42	77				332		
21	8.15				46	75	720	168				2.00
22	8.30				47	76						
23	8.38		128	.897	48	78	735	168		326		6.50
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34												
35	ave.	29.09	137	.871	46	80	673	149	274	330		

Mechanical Laboratory—UNIVERSITY OF TENNESSEE

REPORT OF BOILER TEST

Made by J. C. Mayes

Date March 31, 1909.

Kind of Boiler Stirling, Battery of Four *Manufactured by* B & W.

Duration of trial	Hours.	23.5
DIMENSIONS. *of Each*		
Grate surface: length 7.3 ft., width 10 ft.	Sq. ft.	73.4
Water heating surface	"	3028
Superheating surface	"	
Height, chimney	Ft.	125
Ratio of draught area to grate		
Area, chimney	Sq. ft.	26.7
Tubes: Diameter	No. 311	3.25
Ratio heating to grate surface		41
PRESSURE.		
Barometer	Inches mercury	29.09
Steam gauge	Pounds	137
Absolute steam pressure	Pounds	151.2
Draught gauge, near damper	Inches water	0.871
" " in ash pit	" "	
TEMPERATURE.		
External air	Degrees F.	46
Boiler room	"	80
Escaping gases	"	673
Furnace	"	
Feed water	"	149
Steam	"	330
FUEL.		
Kind of coal	Sazamore Black	
Locality	Irogmouth Ky.	
Size of coal	Crushed.	
Fixed carbon	Per cent.	
Volatile matter	"	
Moisture Surface	"	1.73
Ash	"	39200
B. T. U. per pound coal		10771
" " combustible		10370
Carbon in ash	Per cent.	
Total coal consumed	Pounds.	137400
Total wood	"	
Moisture in coal Total	Per cent.	1.88
Dry coal consumed	Pounds.	134817
Total refuse, dry	"	31085
Total refuse, dry	Per cent.	23
(c) Total combustible	Pounds.	103632
COMBUSTION—PER HOUR.		
Dry coal		5694
(c) Combustible		4409
Dry coal per square foot of grate		19.4
Combustible per " " "		15.01
Dry coal per " " heating surface.		2.13
Combustible per " " "		2.75

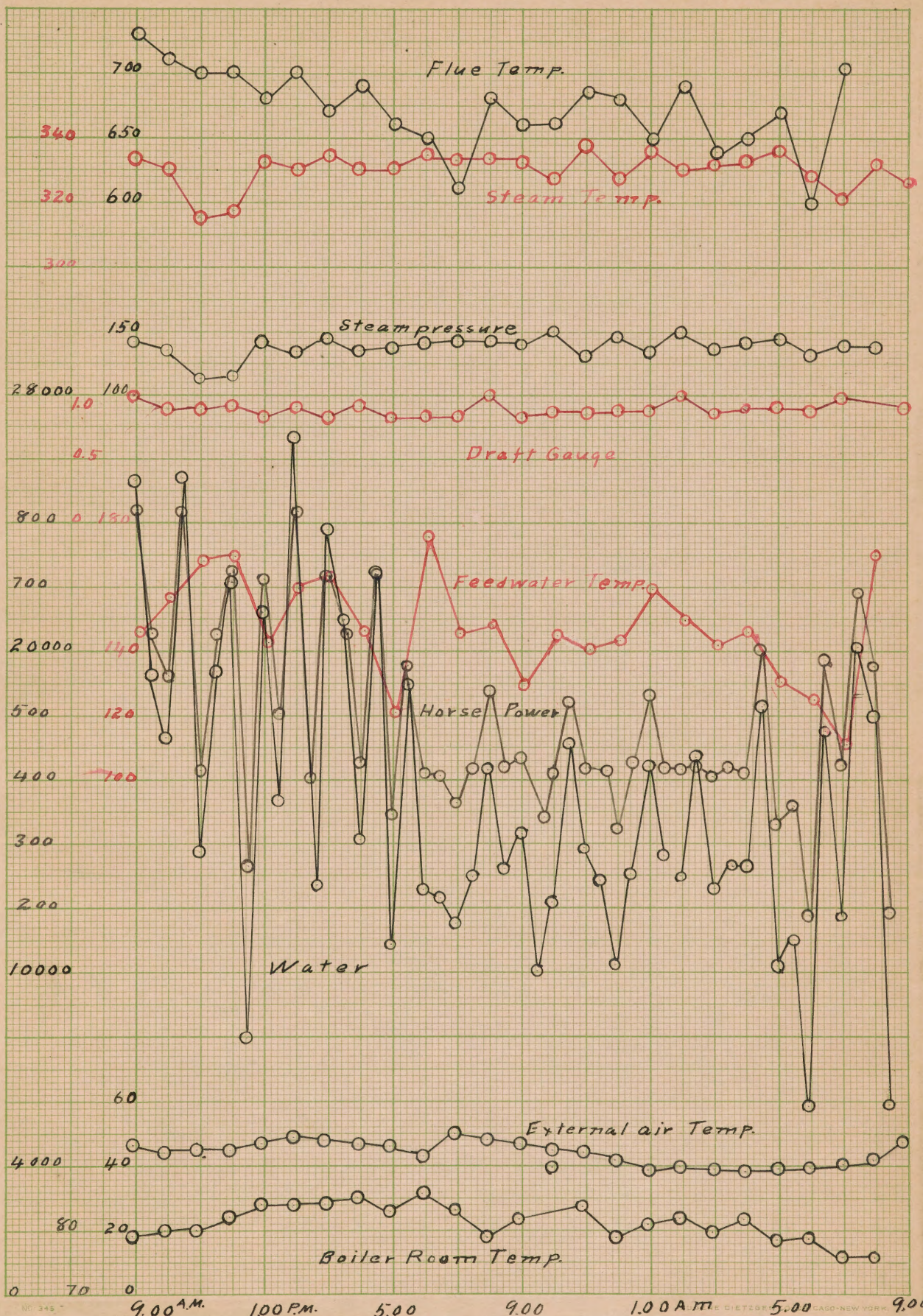
		B.W.- B
FLUE GAS.		
CO_2	Per cent. of volume	6.2 - 4.2
CO	" " "	0 0
H	" " "	
Free oxygen	" " "	13.6 - 14.5
Air	Excess co-efficient.	
Quality of steam	Per cent.	98.6
Superheat	Degrees.	0
TOTAL WATER.		
Total weight water used	Pounds.	729437
Total evaporated, dry steam	"	719226
Factor of evaporation		1.11
Equivalent evaporated from and at 212°	"	798337
WATER—PER HOUR.		
Amount used	Pounds.	31080
Evaporated dry steam	"	30603
Equivalent evaporated from and at 212°	"	33969
ECONOMIC EVAPORATION.		
Per Pound of Fuel.		
Actual, per lb. dry coal	Pounds.	5.3
Eqnivalent from and at 212° [dry coal]	"	6.2
Per Pound of Combustible		
Actual	Pounds	6.8
Equivalent evaporated from and at 212°	"	7.9
RATE OF EVAPORATION.		
Per Sq. Foot of Grate per Hour		
Actual from feed-water temperature	Pounds	104.2
Equivalent from and at 212°	"	115.7
Per sq. Foot of Water-heating Surface per Hour.		
Actual	Pounds	2.6
Equivalent from and at 212°	"	2.8
Per sq. Foot of Least Draught Area per Hour.		
Actual	Pounds.	
Equivalent from and at 212°	"	
HORSE POWER.		
*On basis 34½ pounds equiv. evap. per hour	H. P.	984
Builders' rating	"	1200
Ratio of commercial to builders' rating	%	82
Heat generated per pound dry coal	B. T. U.	10171
Heat absorbed per pound dry coal	"	7629
Heat lost in flue per pound dry coal	"	
" " incomplete combustion lb. of coal	"	
" " in refuse, lb. of coal	"	
" " by radiation, etc., lb. coal	"	
(a) Efficiency of boiler	%	
(b) Efficiency of boiler and grate	%	56

NOTE.—Actual evaporation signifies the evaporation from feed-water temperature to dry steam at gauge pressure. It is apparent evaporation corrected for calorimeter determination.

*Standard commercial H. P. (a) Computed from combustible. (b) Computed from coal.

(c) This is dry coal less refuse.

(3)


Flue Temp.
700
650
600
340
320
300
Steam Temp.
Steam pressure
150
100
28000
1.0
0.5
Draft Gauge
800
700
20000
500
400
300
200
10000
0
130
140
120
100
Feedwater Temp.
Horse Power
Water
60
40
4000
80
20
0
70
0
External air Temp.
Boiler Room Temp.
9.00 A.M.
1.00 P.M.
5.00
9.00
1.00 A.M.
5.00
9.00