THESIS

BOILER TRIALS

K. B. STEVENS E. H. ADAMS

1906

This thesis was contributed by

Mr. K. B. Stevens

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

THESIS

Boiler Trials

on the

Experimental, Internal Furnace, Marine Boilers

at the Power Plant

of the

Michigan Agricultural College.

F. W. Stevens F. W. Allen

1907.

THESIS

12-4-51

POWER PLANT

Object of trial.

Under actual running conditions:

(1) To compare the equivalent evaporation of the boilers.

(2) To compare their thermal efficiencies.

(3) To determine excess of air supplied to furnaces by.(a) Pitot tube.

(b) Chemical analysis.

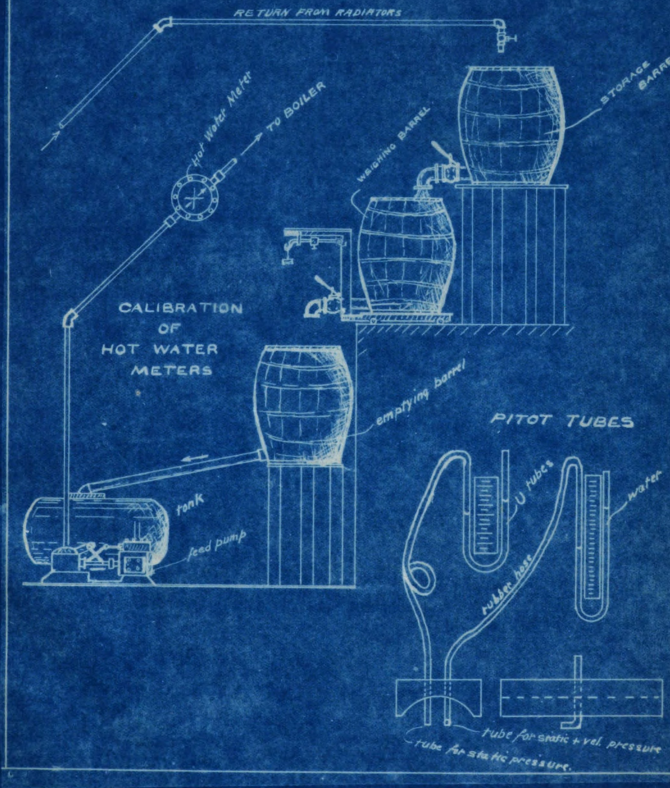
Description of Plant.

These tests were made at the new power house at the Michigan Agricultural College on the boiler plant in Feb. 1906.

The plant is equipped with four horizontal return tubular boilers manufactured by the Springfield Mfg. Co. The coal for supplying these boiler falls from the bins into a car in an elevator pit. The car,when filled,is lifted by the elevator to a covered tram-way,along which the attendant moves it. At the hoppers, the hinged sides of the car are loosened allowing the coal to empty itself. From each hopper the coal falls into an under-feed stroker,which puts it into the furnace.

Forced draught is supplied by an American Blower Co.,11, inch three quarter housed bottom horizontal discharge fan which is driven direct connected by a type "A",A.C.E.,Westinghouse engine.

This engine is driven with steam from the main pipe. The pipe leading steam to the engine is equipped with a valve, being thus throttled lessens its speed,and less air is supplied to the furnaces. Driven by belt from the fan engine is a Columbia exhaust which regulates the pressure of the forced draught


RETURN FROM RADIATORS
Hot Water Meter
TO BOILER
WEIGHING BARREL
STORAGE BARREL
CALIBRATION OF HOT WATER METERS
emptying barrel
tank
feed pump
PITOT TUBES
U tubes
water
rubber hose
tube for static + vel. pressure
tube for static pressure.

strokes work. As the speed of the fan varies, the rate of the stoking is changed. This means that when the air supply is cut down by the throttling of the fan engine, that the rate of coal supply is cut down in the same ratio. Thus the system is perfectly self regulating; and the steam pressure remains practically constant, as may be seen from the data sheets.

Description of tests.

It was necessary, in order to make a comparative test on the boilers, to test one of the battery in battle each day, and the others together as a unit. This made it impossible for us to determine what each individual boiler was doing, but the results obtained from the three operated together each day will not be much in case the weather or other conditions varied.

Apparatus.

The testing apparatus consisted of two hot water meters, (1 $1\frac{1}{4}$" Hersey and 1 $\frac{5}{8}$" National meter) a pressure separating calorimeter, barrels for the weighing of water in the water calibration, a barometer, thermometer, speed counter, Pitot tubes, scales, sheetbarrows, etc.

Water.

The meters were calibrated by weighing the water in barrels equipped with quick opening valves. Both were calibrated under actual test conditions. The return water from the calorimeter, which was used as feed water, ran into a float tank from which it was pumped, part through the small meter to the single boiler, and the remainder through the Hersey meter to the gang -

al fuel of the three boilers running together. The temperature of the feed water varied considerably, hence it was necessary from time to time to supply cold water to the float tank in order to replace the water lost by leakage etc.

The coal.

We could not use the coal hoppers, because it would be very difficult to weigh the coal placed in them from above, so instead thereby sliding the shovels up to the foot of the hoppers, thus preventing any chance for loose coal falling into the stokers. From the extra we drew and weighed our coal in large sheet iron scoops, depositing it in piles near each boiler, from which it was shoveled into the strokers. The amount of coal used for the test of the single boiler was of course kept separate from the other three. At the close of each days test whatever coal remained on the floor was weighed back and deducted.

The air.

The air is supplied to the boilers through two nine inch ~~tubes~~ galvanized iron pipes, one entering on each side below the fire grate. As the change in steam pressure caused a change in the speed of the fan, we had considerable variations of the pressure in the air pipes. The readings on the brake were taken every half hour, and the revolutions of the blower at the same time. Our apparatus for determining the pressure of the air and thence the velocity, consisted of two U shaped tubes graduated to tenth of inches, connected each by a large rubber tube to our Pitot tubes (see fig.) the straight tube gave the

static pressure in the pipe, and the right angled tube gives the total pressure due to the velocity of the air.

Thus the difference in reading between the two will be the pressure caused by the velocity of the air, so by the formula $V=\sqrt{\quad}$ we obtain the velocity of the air due to the boilers. Knowing the velocity of the air, it is then possible to find the volume of air supplied to the boilers. It is then refered to the boiler as air per unit of coal. This is also determined by the analysis of the flue gases as made by the chemical dept.

static pressure in the pipe, and the right ~~left~~ right tube gives the total pressure due to the velocity of the air.

Thus the difference in reading between the two would be due to the pressure caused by the velocity of the air, so by the formula $V=\sqrt{\quad}$ [illegible] the velocity of the air but to the boilers. Knowing the velocity of the air [illegible], by multiplying the volume of air supplied to the boilers. It is then referred to the [illegible] of air [illegible] cubic feet. This is also determined by the analysis of the flue [illegible] by the Orsat Apparatus.

BOILERS №1 & №2-3-4 LOG OF READINGS FEB 24-1906

TIME	WT. of COAL		WT. of Water		TEMPERATURE			PRESSURES			R.P.M. of Blower	Barometer
	For single Boiler	For Three Boilers	For Single Boiler	For Three Boilers	Feed Water	Room	Outside	Static in Air Pipe	Velocity in Air Pipe	Gage		
8. AM.					151							
8.30					152	82	40	.8	1.7	80	244	29.8
9.00					173	95	40	.8	1.8	"	230	29.2
9.30					177	85	43	1.2	2.	"	255	29.16
10.00					180	86	46	1.	2.	"	270	29.18
10.30					176	85	47	1.1	2.	"	270	29.18
11.00					140	85	48	1.	1.9	"	255	29.16
11.30					128	85	48	1.3	2.1	"	283	29.16
12.00					190	86	48	.8	1.1	"	203	29.12
12.30					180	82	50	.9	1.2	"	215	29.1
1.00					122	82	50	1.1	1.4	"	226	29.1
1.30					105	82	48	1.1	1.5	"	232	29.1
2.00					135	83	47	1.2	2.	"	265	29.08
2.30					150	81	47	1.1	1.5	"	234	29.06
3.00					153	86	47	1.	1.4	"	234	29.06
3.30					152	85	47					
AVG.	2856#	8579#	23940#	67576#	154°	84	47	1.03"	1.54"	80#	245	29.12

ONLY INITIAL AND FINAL READINGS TAKEN

Boiler No. I

and

Boiler No. [illegible].

	Boiler No. I	Boiler No. I
Kind of fuel	[illegible]	[illegible]
" " [illegible]	Alternate	[illegible]
Duration of trial	[illegible]	[illegible]
Steam pres. in boiler	[illegible]	[illegible]
Temperature of external air	[illegible]	[illegible]
" " [illegible]	[illegible]	[illegible]
" " feed water	[illegible]	[illegible]
Wet coal consumed	[illegible]	[illegible]
Moisture in coal (%)	I.[illegible]	I.[illegible]
Dry coal consumed	[illegible]	[illegible]
Total dry refuse	[illegible] #	[illegible]
Dry coal consumed per hour	[illegible]	[illegible]
Combustible consumed per hour	[illegible] #	[illegible] #
Quality of steam	[illegible]	[illegible]
Number of heat units per pound coal	[illegible]	[illegible]
Heat units absorbed by boiler per pound steam	[illegible]	[illegible]
Efficiency of boiler	[illegible]	[illegible]
Total water evaporated	[illegible]	[illegible]
Equiv. water from and at 212°	[illegible] #	[illegible] #
Equiv. " " " " " per hr.	[illegible] #	[illegible] #
Water actually evap. per lb. coal	[illegible] #	[illegible] #

Equiv. water evap. per lb. coal from and at 212°	[illegible]	[illegible] #
Water evap. per lb. combustible	[illegible]	[illegible]
Equiv. H_2O per lb. combustible from and at 212°	[illegible] #	[illegible] #
B.H.P. [illegible] rating	99.6	[illegible]
Air per lb. coal by pitot tube	[illegible].96 #	---
Air reqd. for complete combustible	10.84 #	10.[illegible] #
Air per lb. coal from gas analysis	[illegible] #	---

LOG OF READINGS

FEB. 21, 1906

ONLY INITIAL AND FINAL READINGS TAKEN

TIME.	Wt. of Coal		Wt. of Water		Temperatures			Pressures			R.P.M.	Barometer
	# For Single Boiler No 2	# For Three Boilers Nos 1, 3, 4	No 2. For Single Boiler	No 1, 3, 4 For Three Boilers	°F Feed Water	Room	Outside	Static in air pipe	Velocity in air pipe	Gage		
7.30												
8.00					124	74	35	1.9"	2.1	80	240	29.14
8.30					123	81	37	1.8"	2.0	"	242	29.13
9.00					126	81	37	1.8	1.9	"	250	29.13
9.30					90	83	39	2.6	2.8	"	300	29.16
10.00					200	85	40	1.2	2.0	"	245	29.16
10.30					204	84	40	1.2	1.6	"	224	29.18
11.00					138	82	41	1.0	1.6	"	264	29.18
11.30					150	83	40	.8	1.2	"	200	29.18
12.00					150	83	42	.8	1.3	"	208	29.2
12.30					153	85	42	1.0	1.5	"	224	29.19
1.00					147	85	40	1.0	1.8	"	254	29.2
1.30					149	86	40	1.3	1.9	"	259	29.2
2.00					150	86	39	1.4	2.00	"	265	29.22
2.30					140	85	39	.9	1.7	"	240	29.23
3.00					172	83	37	1.0	1.5	"	243	29.25
3.30					160	79	37	1.0	1.7	"	242	29.25
4.00					135	84	37	1.2	1.8	"	240	29.26
4.30					146	84	36	1.0	1.3	"	203	29.28
5.00					153	82	35	.8	1.1	"	200	29.29
5.30					151	80	35	.6	1.0	"	170	29.30
6.00					130	80	34	.6	1.1	"	180	29.30
6.30					134	85	34	.8	1.1	"	190	29.32
7.00					165	85	34	.8	.9	"	192	29.32
7.30										"		
Avg.	4281#	14564#	31800#	117283#	146	82	37	1.06"	1.6	80	230	29.23

Boiler No. [illegible].

and

Boilers Nos. 1,[illegible],[illegible]

[illegible]

	Boiler No. [illegible]	Boilers Nos. 1,[illegible],[illegible]
Kind of coal	Fairmont	[illegible]
" " trial	Alternate	Method
Duration of trial	1[illegible] hrs.	1[illegible] hrs.
Ave. steam press. in boilers	[illegible]	[illegible]
Temp. of external air	[illegible] F	77 F
" " room	[illegible] F	[illegible] F
" " feed water	1[illegible] F	1[illegible] F
Moist coal consumed	[illegible]	14[illegible]4 #
Moisture in coal (%)	1.[illegible]	1.[illegible]5
Dry moisture consumed	[illegible]8 #	1[illegible]11 #
total dry refuse	[illegible].5 #	1[illegible]15 #
total combustible	[illegible]4[illegible] #	1[illegible] #
Dry coal consumed per hr.	[illegible] #	1[illegible]01 #
combustible " " "	[illegible]1[illegible] #	1[illegible] #
quality of steam	[illegible].[illegible]%	[illegible].[illegible]%
No. heat units per lb. coal	1[illegible]	1[illegible]
heat units absorbed per lb. steam from and at 212 F	1[illegible]	1[illegible]
Efficiency of boiler	[illegible]	[illegible]
Total water evaporated	[illegible]1[illegible] #	11[illegible]
Equiv. water from and at 212 F	[illegible] #	1[illegible]
" " per hr. from and at 212 F	[illegible]	[illegible]

Boiler No. [illegible]

and

Boilers Nos. 1,[illegible],4

	Boiler No. [illegible]	Boilers 1,[illegible],4
Water evap. per lb. of coal	7.4[illegible]	[illegible]
Equiv. water evap. from and at 212 F	[illegible].17	[illegible]
Water evap. per lb. combustible	8.[illegible]	[illegible]
Equiv. water evap. per lb. from and at 212 F	[illegible].18	[illegible]
B.H.P.A.S.M.E.	97.4	[illegible]45.5
air per lb. of coal by pitot tube	71.[illegible]	
air req. for complete combustion	10.74	
air per lb. coal from gas analysis	[illegible]	

LOG OF RESULTS

FEB. 22-1906

Time	Wt. of Coal		Wt. of Water		Temperatures			Pressures			R.P.M.	Barometer
	For Single Boiler No 3	For Three Boilers No 1, 2, 4	No 3 For Single Boiler	No 1, 2, 4 For Three Boilers	Feed Water	Room	Outside	Static in air pipe	Velocity in air pipe	Gage		
7.30												
8.00					170	68	30	.9	1.5"	80	239	29.5"
8.30					168	76	31	.7	1.1	"	200	29.5"
9.00					147	78	31	1.0	1.5"	"	242	29.5"
9.30					166	78	32	1.0	1.4	"	239	29.5"
10.00					150	80	32	1.0	1.5"	"	225	29.5"
10.30					153	78	33	1.1	1.4	"	238	29.5"
11.00					150	78	35	1.0	1.3	"	220	29.5"
11.30					155	80	35	1.1	1.5	"	231	29.5"
12.00					160	80	35	1.2	1.7	"	250	29.47
12.30					170	84	36	1.0	1.7	"	246	29.44
1.00					166	83	36	1.0	1.5	"	238	29.41
1.30					164	86	36	1.0	1.4	"	222	29.40
2.00					163	86	36	1.0	1.5"	"	230	29.40
2.30					153	85	39	.6	.8	"	165	29.4
3.00					150	85	40	1.0	1.3	"	205	29.39
3.30					158	84	41	1.0	1.5"	"	229	"
4.00					177	82	41	1.0	1.5"	"	252	29.37
4.30					171	82	41	.9	1.2	"	204	"
5.00					155	82	39	.8	1.1	"	190	"
5.30					172	80	37	1.0	1.2	"	209	29.36
6.00					162	81	37	.9	1.2	"	210	"
6.30					154	80	37	.9	1.1	"	202	29.33
7.00					185	80	37	.6	.8	"	185	"
7.30												
Avg.	4771#	13433#	39880#	107907#	162	80	36	.9	1.33	80	219	29.42

ONLY INITIAL AND FINAL READINGS TAKEN

Boiler No. 3

and

Boilers No. 1,2,4

	Boiler No. 3	Boilers No. 1,2,4
Kind of fuel	Fairmont	Black
" " test	1[illegible] hrs.	1[illegible] hrs.
Duration of trial	[illegible]	[illegible]
Av. steam pres. by gauge	76 F	76 F
Temp. of external air	80 F	80 F
" " room	108 F	108 F
" " feed water	4771 #	17437 #
moist coal consumed	1.05 %	1.05[illegible]
moisture in coal (%)	4771 #	1[illegible]
dry coal consumed	451 #	1801 #
total dry refuse	[illegible] #	1[illegible] #
total combustible	797.6 #	1119 #
Dry coal consumed per hr.	[illegible] #	1006 #
Combustible consumed per hr.	[illegible].1	[illegible].1
Quality of steam	17080	1[illegible]
No. heat units in one lb. coal	11[illegible]	1[illegible]
Heat units per lb. steam from and at 212 F	[illegible]	[illegible]
Eff. of boiler	[illegible] #	10[illegible]%
Total H_2O evap.	[illegible]	1171[illegible]
Equiv. H_2O from and at 212	[illegible]	1[illegible]
" " evap. per hr.	3.77	[illegible]

over

LOG OF READINGS

Boilers Nos 4 & Nos 1-R-3

FEB. 23, 1906

TIME	WT. of COAL		WT. of Water		Temperatures			Pressures			R.P.M. of Blower	Barometer
	For Single Boiler	For Three Boilers	For Single Boiler	For Three Boilers	Feed Water	Room	Outside	Static in Air Pipe	Velocity in Air Pipe	Gage		
7.30												
8.00					173	87	39	.8	1.3	80	223	29.22
8.30					136	89	40	1.1	2.2	"	273	29.22
9.00					132	89	45	1.1	2.	"	268	29.22
9.30					160	90	48	1.1	1.9	"	262	29.22
10.00					150	93	51	1.	1.6	"	248	29.23
10.30					136	93	51	1.	1.7	"	252	29.24
11.00					129	93	55	.8	1.5	"	239	29.24
11.30					121	92	56	1.	1.8	"	262	29.25
12.00					198	92	56	.8	1.3	"	240	29.24
12.30					197	95	56	.8	1.6	"	248	29.24
1.00					158	97	56	1.1	2.	"	282	29.23
1.30					144	99	60	1.2	2.2	"		29.22
2.00					99	96	60	1.4	3.1	"	350	29.24
2.30					148	96	60	1.2	2.	"	265	29.24
3.00					131	94	60	1.	1.5	"	230	29.25
3.30					160	95	58	.5	.9	"	181	29.26
4.00					145	95	55	4	.7	"	166	29.30
4.30					130	94	52	.9	1.1	"	210	29.3
5.00					189	93	48	.6	.8	"	185	29.3
5.30					158	93	48	.5	.8	"	183	29.32
6.00					190	93	48	.6	.9	"	180	29.32
6.30					161	92	46	.6	.9	"	182	29.32
7.00										"		
7.55												
AVE.	4642#	13144#	37080#	108644#	150°	93°	54°	.945"	1.64"	80#	237	29.27

ONLY INITIAL AND FINAL READINGS TAKEN

Boiler No. 4

and

Boilers Nos. 1,2,7

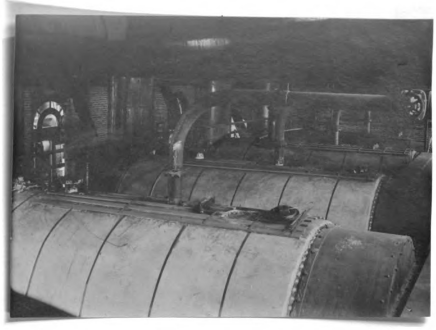
	Boiler No. 4	Boilers Nos. 1,2,7
Kind of fuel	Fairmont	Clock
" " trial	Alternate	Met'od
Duration of trial	12 hrs.	12 hrs.
steam pres. of boilers	80 #	80#
Temp. of external air	50 F	50 F
" " room	98 F	97 F
" " feed water	150 F	150 F
moist coal consumed	[illegible] #	13144 #
moisture in coal (%)	1.05	1.05
dry coal consumed	4594 #	13006 #
total dry refuse	410 #	1180 #
total combustible	41[illegible] #	118[illegible] #
dry coal consumed per hr.	773 #	1040 #
Combustible consumed per hr.	726 #	[illegible]54 #
quality of steam	97.7%	93.7%
No. of heat units in 1 lb. of coal	13020	17020
heat units absorbed by boiler per lb. of steam.	1495	1419
efficiency of boiler	64.[illegible]%	66.7%
total evap.	37000 #	108[illegible]#
equiv. water from and at 212 F	40801 #	1180[illegible]#
" " " " " " per hr.	3400	[illegible]

Boiler No. 4

and

Boilers Nos. 1,2,3

	Boiler No. 4	Boilers Nos. 1,2,3
Water evap. per lb. coal	7.83 #	8.13 #
" " " " coal from and at 212° F	8.70 #	8.99 #
" " " " combustible	8.79 #	9.10 #
Water evap. per lb. combustible from and at 212° F	9.68 #	9.98 #
H.P. A.S.M.E. rating	97.4	270.9
Air per lb. coal by pitot tube	8.4 #	
Air per lb. coal by gas analysis	75.5 #	80.9 #



RESULTS ARRANGED FOR COMPARISON

Number of Boiler	Heat units per lb of steam from and at 212° F.	Efficiency of Boilers	Water evaporated per lb. of coal	Equivalent evaporation per lb of combustible	Avg. Horse Power developed.	Air per lb. of Coal	
						By Pitot tube	By Gas Analysis
1	1388	67 %	8.23	10.02	99.6	28.9#	39.4#
2-3-4	1508	63.1%	7.87	9.64	95.6	—	—
2	1595	60.6%	7.42	9.12	93.4	31.88#	47#
1-3-4	1466	65.9%	8.05	9.89	115	—	—
3	1430	67.5%	8.37	10.11	104.8	25.6#	30.6#
1-2-4	1492	64.9%	8.03	9.7	94	—	—
4	1495	64.5%	7.99	9.66	97.4	33.4	39.9
1-2-3	1449	66.7%	8.26	9.98	91.3	—	—

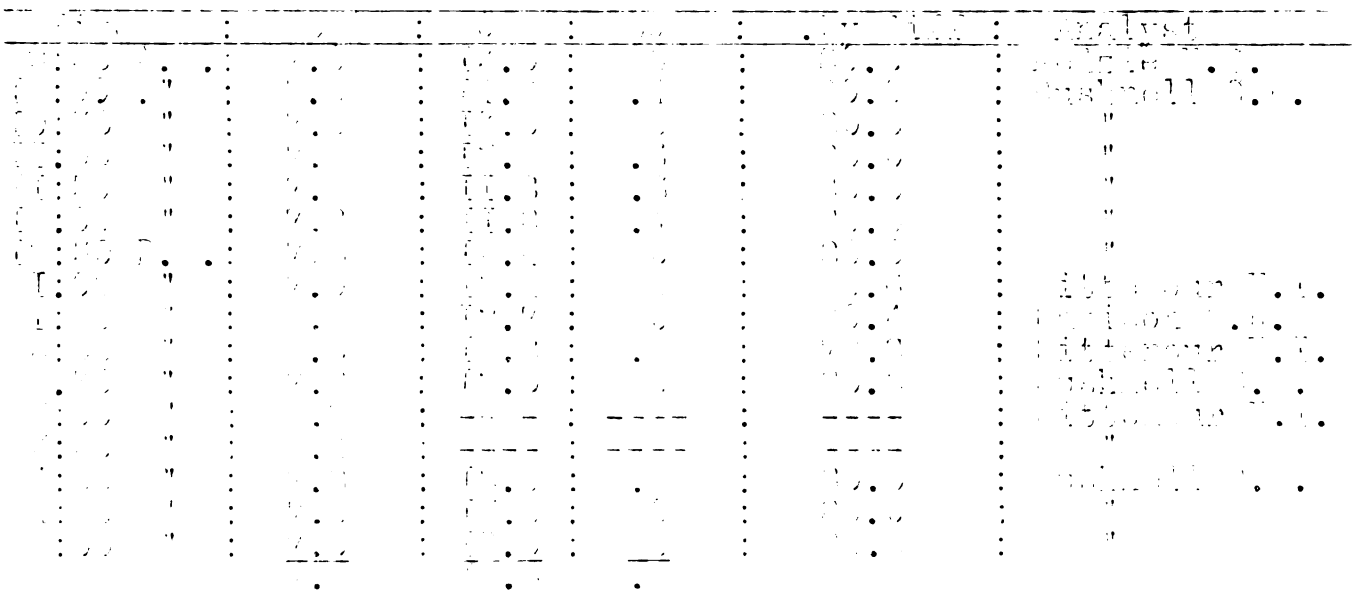
[illegible]

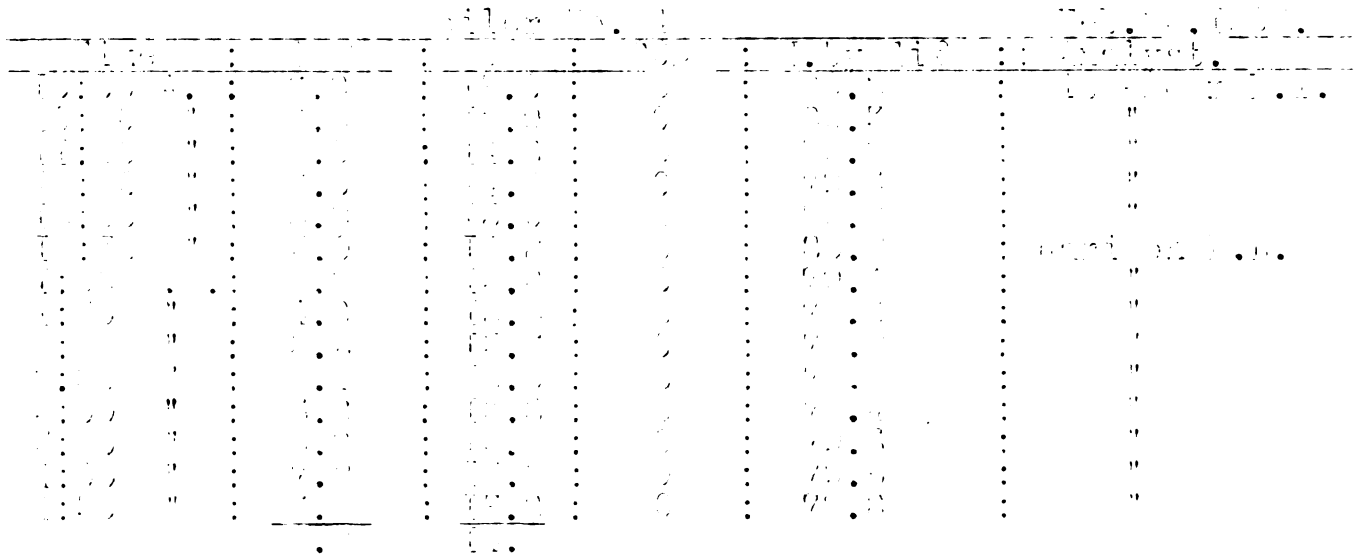
Boiler No. 1 [illegible]

[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]	[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]	"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"
	[illegible]	[illegible]	[illegible]		

Boiler No. [illegible] Feb. 21, [illegible]

[illegible]	7.0	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] "	[illegible]	[illegible]	0.1	[illegible]	Pittenour F.L.
[illegible] "	[illegible]	---	---	---	[illegible]
[illegible] "	[illegible]	[illegible]	0	[illegible]	[illegible] F.L.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] H.S.
[illegible] "	[illegible]	[illegible]	[illegible]	79.6	"
[illegible] "	[illegible]	[illegible]	[illegible]	[illegible]	Pittenour F.L.
[illegible] "	[illegible]	[illegible]	[illegible]	[illegible]	"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"
[illegible] "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]rison F.L.
[illegible] "	[illegible]	[illegible]	[illegible]	[illegible]	"
[illegible] "	[illegible]	[illegible]	[illegible]	[illegible]	Pittenour F.L.
[illegible]	[illegible]	---	---	---	"
[illegible] "	[illegible]	[illegible]	0	[illegible]	[illegible] F.L.
	[illegible]	[illegible]	[illegible]		





[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

Conclusion.

It is noticeable from the results, that boiler 1 and 2 show higher rates of evaporation, and higher efficiencies than boilers 3 and 4. This may be due to the regulation of the dampers. The result also that boilers 1 and 2 were receiving less air; and at the same time were carrying more of a load than the other two. This means that boilers 1 and 2 were loosing less heat up the chimney; and were consequently more efficient than the other two.

It is probable that the air results obtained from the chemical analysis of the flue gases are more nearly correct than those obtained by the use of the pitot tubes; since in the latter method we have no way of telling just what per cent is lost in the friction of the tubes. We will therefore consider only the results of the flue gas analysis in the following calculation of the loss from the excess of air. The average amount of air supplied to the boiler per lb. coal was 20.3 lbs. Of this amount 10.34 ℔ was actually needed for combustion. The excess of air was therefore 97% . Since the temperature of the gases was not taken we will assume a difference of temperature between the chimney and the external air of 700 °.

CO_2	13.01 × 22 =	139
O	14.2 × 14 =	227
CO	neglected (very small)	
N	72.8 × 14	1118
Total	100 %	1477

$\frac{139}{1477}$ × 700 = 7.6 % wt. of CO_2

$\frac{[illegible]7}{1477}$ X [illegible] = [illegible] #--wt. of C.

$\frac{1112}{1477}$ X [illegible] = [illegible].7 # - wt. of [illegible].

Weight of	Specific	Temp. Increase	B.T.U.
[illegible]--3.5	.2169	300	227.5
[illegible]--4.05	.2175	300	[illegible].0
N-- [illegible]	.[illegible]	300	[illegible].0
	Total		[illegible]

Heating power of [illegible] coal [illegible] B.T.U.

$\frac{[illegible]}{[illegible]}$ = [illegible]

Thus with a difference of only 300° between the outside air and the chimney we find that [illegible] of the heat goes up the chimney.

[illegible] ---average efficiency of boilers.

[illegible] ---chimney loss

[illegible] --- combustion and radiation (by difference)

[illegible] --- Total.

From these results, it appears that greater attention should be paid to the regulation of the dampers in the air pipes. The external appearance of the chimney also indicates a large excess of the air, very little smoke appearing at the top.

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