Thesis

Test of Lighting Plant

at Jonesville Mich.

W. C. Strand R. S. Newton

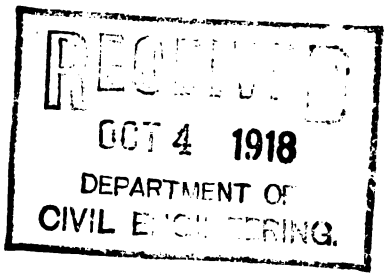
1905

THESIS

This thesis was contributed by

Mr. R. S. Newton

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



THESIS

Test of Lighting Plant at Jonesville, Michigan.

W. C. STRAND.

R. S. NEWTON.

THESIS

12-4-5)

Objects of Test:-

First: To determine the cost per Kilowatt in terms of coal.

Second: To find the amount of water evaporated per # of coal.

Third: To find water consumption per H. P. per hr. of engine.

Fourth: To find thermal efficiency of engine.

Fifth: To find the efficiency of the engine and dynamo taken in combination.

Sixth: To find the efficiency of the dynamo.

The Jonesville lighting plant is owned and operated by the village of Jonesville. It consists of two Mansfield Machine Works' horizontal tubular boilers, one Stillwell-Bierce and Smith-Vale duplex feed pump, one Cookson feed water heater, one 16 x 36 Bates, Corliss engine and one 100 K.W. Warren Alternator. The plant also includes two Stillwell-Bierce and Smith-Vale fire pumps rated at 154,000 gal., neither of these pumps being run during the test.

Boilers.

In the plant are two Mansfield Machine Works' horizontal tubular boilers each 16 ft. long and with a diameter of 60 inches. These boilers are connected by a six inch header. They are set in brick arches with a straight front according to the usual custom. The boilers are hand fired, only one being used at a time. The feed water is supplied by a 1" pressure main connected to the feed water heater and is regulated by means of a float and valve. The feed water is heated by the exhaust steam. The water is pumped from the feed water heater into the boiler by a Stillwell-Bierce and Smith-Vale feed pump. The boilers are also supplied with a No. 4 U.S. injector which can be used in case of emergency.

The following dimensions were taken by actual measurement, as required by the A. S. M. E. in report of boiler trials.

The No. 1 Boiler was used.

Diam. of shell	60 in.
Length of shell	16 ft.
No. of tubes	52
Diam. of tubes	4 in.
Length of tubes	16 ft.
Length of furnace	5 ft.
Width of furnace	5 ft.
Kind of grate bars	Plain Stationary.
Width of air spaces	1/2 in.
Length of air spaces	2 in.
No. of air spaces (each bar)	75
Ratio of area of grate to area of air spaces	1:25
Area of chimney	4.89 sq. ft.
Height of chimney above grate	69.5 ft.
Length of flues connecting to chimney	16 ft.
Area of flues connecting to chimney	4 sq. ft.

Governing proportions of boiler.

Grate surface	25 sq. ft.
Heating surface (water)	969.7 sq. ft.
Area of draught through tubes	4.25 sq. ft.
Ratio of grate to heating surface	1:38.75
Ratio of least draught area to grate	1: 5. 9
Ratio of least draught area to total heating surface	1:228
Water space	164.16 cu. ft.

Steam space	82.08 Cu. ft.
Ratio of grate to water space	1:6.56
Ratio of grate to steam space	1:3.28
Grate surface 5 ft. long,5 ft. wide, area	25 sq. ft.
Water heating surface	969.7 sq. ft.
Ratio of water heating surface to grate surface	1:38.7

Engine.

The engine is a 16 x 36 Bates Corliss made by the Bates Machine Co., Joliet, Ill.

All the following dimensions were taken by actual measurement:

Length of cylinder	36 in.
Diameter of cylinder	16 in.
Diameter of steam pipe	4-1/2 in.
Length of steam pipe	45 ft.
Diameter of exhaust pipe	6 in.
Length of exhaust pipe	67 ft.
Diameter of piston rod	3 in.
Diameter of crank shaft	8.5 in.
Diameter of fly wheel	12 ft.
Width of face of fly wheel	23.5 in.
Width of belt	18 in.
Thickness of belt	7/16in.
R.P.M.	88
Ratio of crank to connecting rod	1:5
Age of engine	8 years.
Engine runs under	
Cylinder Lubricator	Detroit
Capacity one quart	

No. of drops of oil fed to cylinder per min. 6

Engine exhausts into Cookson feedwater heater.

No. of turns in steam pipe 2

No. of turns in exhaust pipe 6

Steam pipe lagged with asbestos.

Cylinder lagged with wood and asbestos.

Exhaust steam used to heat feed water.

Temperature of feed water before entering heater 50.05 F.

Temperature of feed water after leaving heater 201.1 F.

No. of boilers: 2. One used.

Rated at 88 H.P.

Boiler pressure per gauge 85.82

Kind of coal used.

Average consumption of coal per hour 50#*

Apparatus.

The coal was weighed on a set of Buffalo standard scales, which were carefully tested before using. The feed water was measured by an Empire hot water meter connected in a by-pass in feed pipe between feed pump and boiler. The meter was calibrated after the test and found to be absolutely all right. Four thermometers were used. Two for indicating temperature of feed water and the other two used for determing the temperatures of the boiler room and outside atmosphere respectively. The temperature of the feed water was taken between feed pump and water meter also at a point in the cold water main near the feed water heater.

The quality of the steam was determined by means of a Carpenter's separating Calorimeter placed about 18 inches above the throttle valve on the engine. The steam used by the instrument was

allowed to go direct into the atmosphere. The gauge on the Calorimeter was calibrated before test and found to be correct for steam pressures from 75# to 90#, therefore, no corrections were necessary.

The indicator used was a Thompson with a 50# spring; the spring being carefully calibrated before using and was found to read correctly. The indicator was connected to each end of the cylinder by a 1/2 inch steam pipe and a three way cock. A reducing wheel was used.

The R. P. M. was taken at the time of taking each card; they were found to be constant throughout the test.

The load on the engine was kept constant by means of a water rheostat connected in the lighting circuit. The water rheostat used in this test was made by placing two brass plates in a barrel, one of which was stationery in the bottom and the other so arranged that it could be raised or lowered as the load was to be increased or diminished. The electrolite used was water. The rheostat was placed outside the plant at the point where the main wires entered the building and connected in paralell to the commercial circuit and was insulated from the ground by an insulated platform. An approximate elevation is shown in Plate I. The windlass (W) being placed near the switch board.

The dynamo is a Warren alternator; the distance between the centers of the driving pulleys of the engine and dynamo is 36 feet. The diameter of the drive pulley is 15.5 inches and it has a capacity of 100 K. W. The voltage is 1100 and is run at a speed of 800 R. P. M. Number of alternations, 16,000; at full load it will carry 91 amperes. The field coil is excited by an exciter bolted

on the frame of the dynamo and has a drive pulley 18 inches in

diameter connected to a pulley 7 inches in diameter.

The boiler and engine test was of 12 hours duration; and in the last four hours a dynamo test was run. This was made possible by cutting out all the load except the water rheostat, thus having a load that had practically no induction. The results of the dynamo test are only approximate, because of the fact that the voltmeter and ammeter used were not calibrated. The original plans called for a primary wattmeter to measure the output of the dynamo,so that the readings of the voltmeter and ammeter would not enter into the computations; but it was found to be impossible to procure a wattmeter on such short notice so the test was run without it.

The test was made according to the A. S. M. E. specification, the Standard method of starting and stopping the test being used. Readings were taken every ten minutes. They consisted of feed water temperatures; water meter readings, weight of exhaust from feed pump; Calorimeter readings; R. P. M. of engine; ammeter readings and voltmeter readings. A card was taken from the engine at time of getting the R. P. M.

Log of Boiler Trial.

Steam pressure in boiler by gauge	85.82
Absolute steam pressure	99.93
Atmospheric pressure	14.11
Temperature of external air	61 F.
Temperature of boiler room	74.7 F.
Temperature of steam	316.69 F.
Temperature of feed water) from heater	201.1 F.
Temperature of feed water) to heater	50.05 F.

Fuel.

Total amount of coal consumed	6000#
Total refuse	505.5#
Total combustible	5494.5#
Coal consumed per hour	600 #
Combustible consumed per hour	457.9#

Result of Calorimeter Test.

Quality of steam	98.7%
Percentage of moisture in steam	1.3 %

Water.

Total weight of water pumped into boiler and apparently evaporated	45,252.46#
Water actually evaporated corrected for quality of steam	44,664.19#
Equivalent water evaporated into dry steam from and at 212°F.	47,274.95#
Equivalent total heat derived from fuel in B. T. U.	45,619,497.70
Equivalent water evaporated into dry steam from and at 212° F. per hour	3,936.24

Economic Evaporation.

Water actually evaporated per lb. of coal from actual pres. and temp.	7.44#
Equivalent water evaporated per lb. of coal from and at 212° F.	7.87#

Equivalent water evaporated per lb. of
combustible from and at 212°F. 8.59#

Commercial Evaporation.

Equivalent water evaporated per # coal
with 1/6 refuse at 70# gage pressure
from temperature of 100°F. 6.23#

Special.

Coal actually burned per sq. ft. of
grate surface per hour 20#

Water evaporated from and at 212°F. per sq. ft.
of heating surface per hr. 4.05#

Commercial H. P.

On a basis of 30# water per hr. evaporated from
a tem. of 100°F. into steam of 70#
gage (=34-1/2# from and at 212° F.) 114

H. P. Builders rating at 11 sq. ft. per H.P. 88

% developed above rating 29.5%

Steam Consumption of Engine.

Water actually evaporated 44,664.19#

Weight of feed pump exhaust corrected
for quality of steam 1,490.67#

Weight of steam passing through calorimeter
in 12 hours 226.38#

Total weight of steam used by auxillaries 1717.05#

Steam consumption of engine for 12 hours 42,847.14

Steam consumption per I. H. P. per hour 28.59

Thermal efficiency	1.27%

Combined Efficiency of Engine & Dynamo.

Primary voltage	1059
Amperes	74
Watts output	78,366
Watts input (126 x 746)	93,996
Efficiency	83.3%

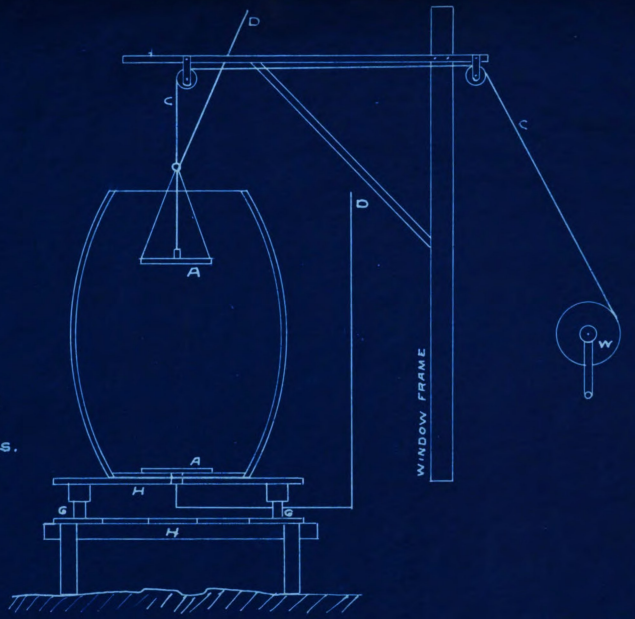
Dynamo.

Primary voltage	1,059
Amperes	74
Watts output	78,366
I. H. P.	126
Friction H. P. (no load)	10.97
Assumption of loss in belt by slipping	5%
I. H. P.-Friction H. P.	115
Watts input (115 x .95 x 746)	81,500.50
Efficiency	96%
Rise of temperature in dynamo during test	85°F.

General Results.

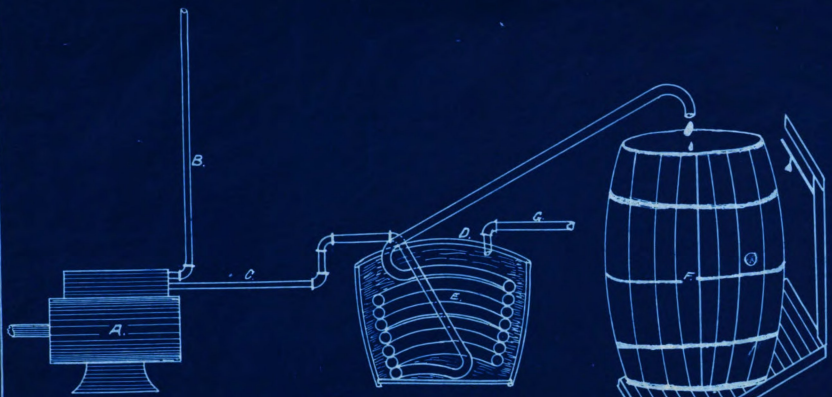
Evaporation (under 75 ampere load)	7.44
Steam consumption	28.59
Thermal efficiency	1.27%
Efficiency of engine and dynamo combined	83.3%
Efficiency of dynamo	96 %
Number of Watts output per # coal	14.2
#Coal per KW. hr.	6.39
#Coal per H.P. hr.	3.97

WATER RHEOSTAT



AA - BRASS PLATES.
DD - TERMINAL WIRES.
CC - CONTROLLING ROPE.
W - REEL.
HH - WOOD PLATFORM.
GG - GLASS INSULATORS.

PLATE I.

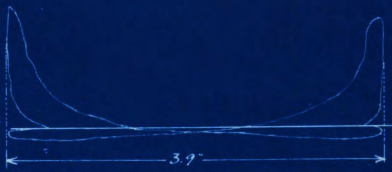


APPARATUS FOR CONDENSING STEAM FROM FEED PUMP.

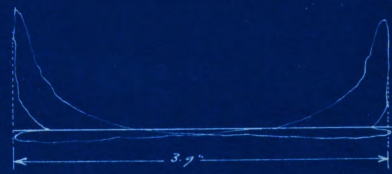
A - FEED PUMP.
B - STEAM PIPE.
C - EXHAUST PIPE.
D - BARREL CONDENSER.
E - COILED LEAD PIPE.
F - WATER BARREL.
G - COLD WATER PIPE.

FRICTION CARDS TAKEN BEFORE TEST.

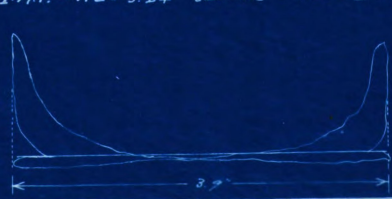
R.P.M. - 88.
M.E.P - H.E = 4.397 # C.E. = 3.14 #
I.H.P — H.E. = 6.98 C.E. = 4.86 TOTAL = 11.84



R.P.M. = 88.
M.E.P - H.E = 4.035 # C.E. = 2.884 #
I.H.P - H.E = 6.46 C.E. = 4.46 TOTAL = 10.92

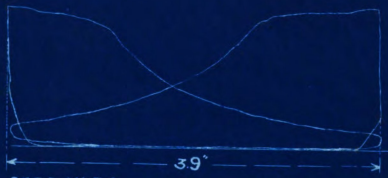


R.P.M. = 88.
M.E.P - H.E. = 3.27 # C.E. = 3.20 #
I.H.P. - H.E = 5.24 C.E = 5.13 TOTAL = 10.37

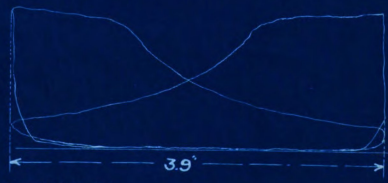


SAMPLE CARDS TAKEN DURING TEST.

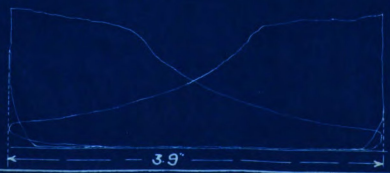
CARD No 5.
R.P.M = 88.
M.E.P - H.E. = 36.21#, C.E. = 42.25#
I.H.P - H.E. = 58.00, C.E. = 65.50 - TOTAL = 123.50.

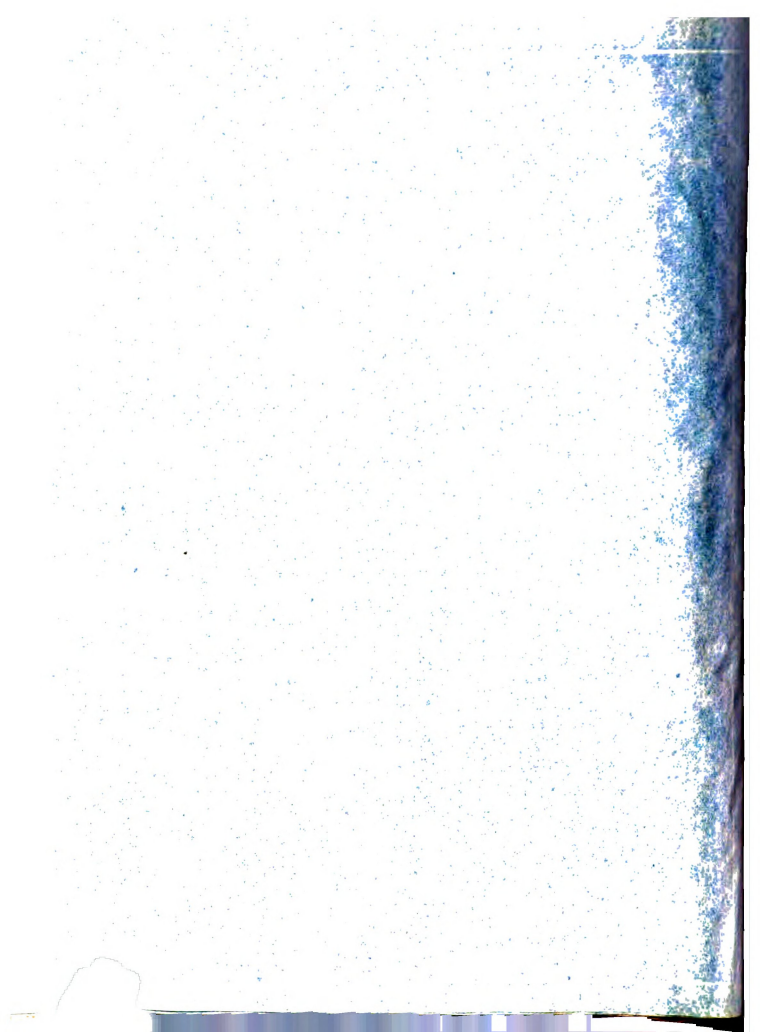


CARD. NO. 34.
R.P.M = 88.
M.E.P - H.E. = 38.06#, C.E. = 40.98#
I.H.P - H.E. = 61.75, C.E. = 63.50 TOTAL = 125.25

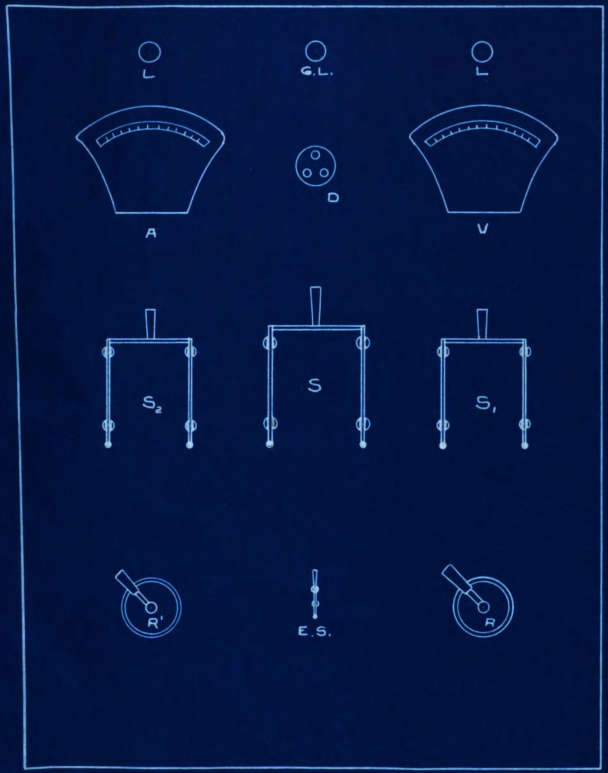


CARD NO. 64.
R.P.M = 88.
M.E.P - H.E. = 39.95#, C.E. = 40.50#
I.H.P - H.E. = 64.00, C.E. = 62.85 TOTAL = 126.86





Switch Board
Front Elevation



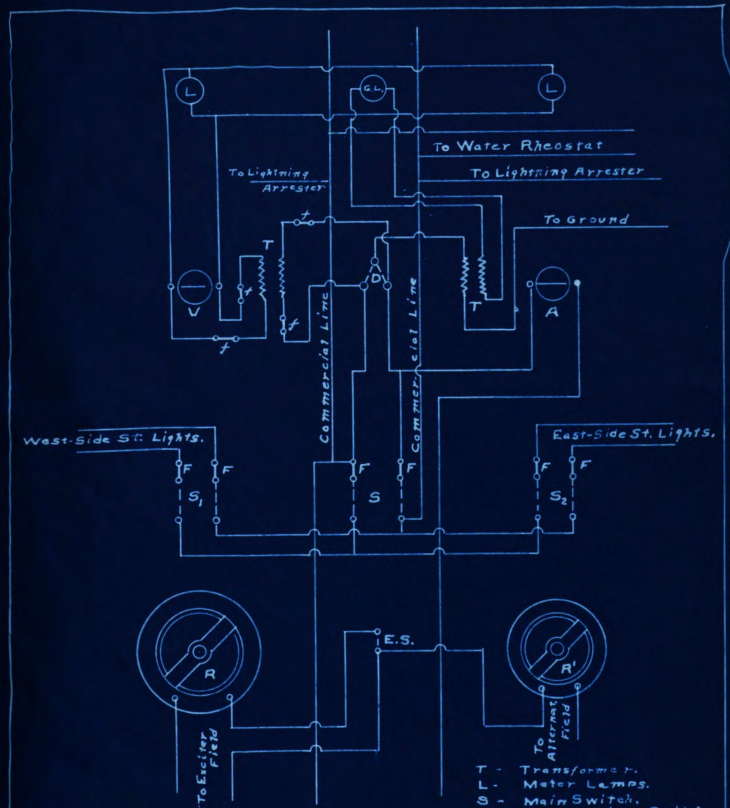
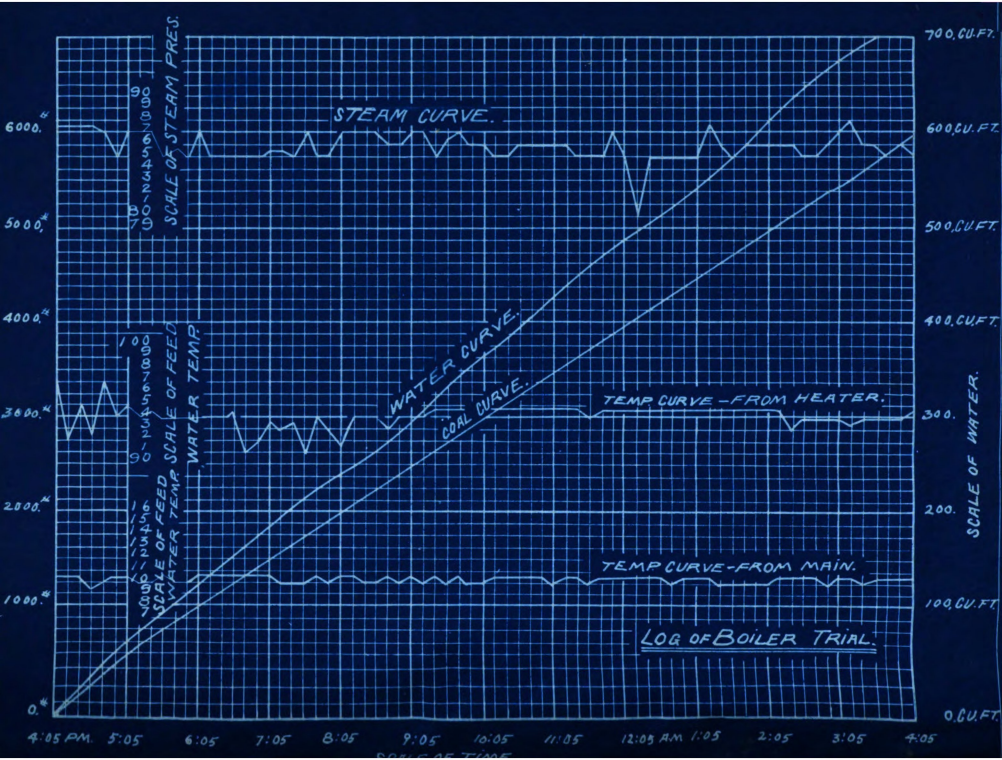


DIAGRAM OF SWITCH-BOARD


STEAM CURVE.
WATER CURVE.
COAL CURVE.
TEMP CURVE – FROM HEATER.
TEMP CURVE – FROM MAIN.
LOG OF BOILER TRIAL.
SCALE OF STEAM PRES.
SCALE OF FEED WATER TEMP.
SCALE OF WATER.
SCALE OF TIME
6000.#
5000.#
4000.#
3000.#
2000.#
1000.#
0.#
700.CU.FT.
600.CU.FT.
500.CU.FT.
400.CU.FT.
300.
200.
100.CU.FT.
0.CU.FT.
4:05 PM.
5:05
6:05
7:05
8:05
9:05
10:05
11:05
12:05 A.M.
1:05
2:05
3:05
4:05

DYNAMO LOG.

NO.	TIME	VOLTS	AMP.	WATTS
49	12:05	109	74	
50	12:15	107	75	
51	12:25	107	75	
52	12:35	107	75	
53	12:45	107	75	
54	12:55	107	75	
55	1:05	107	75	
56	1:15	107	75	
57	1:25	107	75	
58	1:35	107	75	
59	1:45	108	73	
60	1:55	108	74	
61	2:05	107	75	
62	2:15	107	75	
63	2:25	107	75	
64	2:35	107	75	
65	2:45	107	75	
66	2:55	107	75	
67	3:05	107	75	
68	3:15	107	75	
69	3:25	106	76	
70	3:35	107	75	
71	3:45	107	74	
72	3:55	107	75	
73	4:05	107	75	
AVERAGE.		106,8	74,8	7836G

ENGINE

CARD NO	TIME	R.P.M.	M.E.P H.E.	T C.
1	PM 4 05	88		
2	4:15		36.62	4
3	4:25		35.91	4
4	4:35		37.12	4
5	4:45		36.21	4
6	4:55		37.39	4
7	5:05		37.64	4
8	5:15		36.21	4
9	5:25		38.03	4
10	5:35		36.57	4
11	5:45		36.69	4
54	12:55		39.01	4
55	1:05		39.40	4
56	1:15		38.15	4
57	1:25		38.55	3
58	1:35		38.60	4
59	1:45		39.10	4
60	1:55		38.65	4
61	2:05		39.30	4
62	2:15		38.99	4
63	2:25		38.65	3
64	2:35		39.95	4
65	2:45		39.80	4
66	2:55		41.01	3
67	3:05		39.80	3
68	3:15		39.20	3
69	3:25		38.65	4
70	3:35		38.70	3
71	3:45		39.50	3
72	3:55		38.90	4
73	4:05		39.20	3

ENGINE LOG

CARD NO	TIME	R.P.M.	M.E.P. H.E	M.E.P. C.E	I.H.P. H.E	I.H.P. C.E
1	PM 4.05	88				
2	4.15		3662	4150	5861	6435
3	4.25		3591	4045	5752	6291
4	4.35		3712	4225	5930	6550
5	4.45		3621	4225	5800	6650
6	4.55		3759	4160	5791	6500
7	5.05		3764	4040	6074	6345
8	5.15		3621	4150	5800	6441
9	5.25		3803	4030	6101	6230
10	5.35		3657	4181	5850	6510
11	5.45		3619	4241	5797	6580
12	5.55		3781	4044	5760	6291
13	6.05		3630	4180	5820	6490
14	6.15		3719	4060	5930	6300
15	6.25		3710	4020	5940	6235
16	6.35		3780	4044	6060	6291
17	6.45		3670	4041	5863	6235
18	6.55		3710	4444	5940	6296
19	7.05		3730	4410	5975	6250
20	7.15		3715	3960	5910	6150
21	7.25		3715	3955	5960	6141
22	7.35		3730	4020	5975	6235
23	7.45		3687	3931	5850	6205
24	7.55		3720	3915	5960	6160
25	8.05		3570	4189	5760	6510
26	8.15		3692	4060	5920	6380
27	8.25		3567	4044	5863	6291
28	8.35		3701	3925	6210	6306
29	8.45		3863	4042	6198	6375
30	8.55		3825	4060	6181	6380
31	9.05		3769	4085	6350	6340
32	9.15		[illegible]