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Efficiency of the Missouri School of Mines power plant and cost of operation

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EFFICIENCY OF THE MISSOURI SCHOOL OF MINES POWER PLANT AND COST OF OPERATION.

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THESIS

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Bachelor of Science in Mine Engineering.

Rolla Mo.

Approved by Austin L. McRae

Professor of Physics.

CONTENTS.

EFFICIENCY OF THE MISSOURI SCHOOL OF MINES POWER PLANT AND COST OF A KILOWATT HOUR AS MADE.

These tests were made for the purpose of getting the efficiency of the electric power plant as it was being run and the cost of operating it.

Tests were first made on the boilers separately. The load at the time of the test was too heavy for one boiler and too light for two, part of the steam being used for heating the buildings and for the air-compressor. This made it so that no combined test of the boilers and generating couple could be made until the warm weather came and the laboratories using compressed air were closed, which was too late in the year for the complete test on a medium load.

The load varied somewhat so that the tests were not as good as could be made on a full constant load. These tests therefore represent what the plant is doing, not what it could do. This should be born in mind while comparing these results with others as they represent the efficiency and cost of operating the plant as it is run.

The coal is stored in the boiler room in front of the boilers so that rehandling is eliminated. The boilers are Heine water-tube boilers, set in a row facing the North, the one on the West end of the row being# 1.

The boiler settings are bad and leak air badly. The dampers are about useless and are left the same for all loads .

The engine room is adjacent to the boiler room so the steam pipe ie only about thirty feet long. The generating set is described elsewhere. The board is only about two feet from the dynamo.

CALIBRATION OF INSTRUMENTS.

Thermometers used for the measuring of all the temperatures were checked up with a known standard thermometer in several different temperatures of water and were found to be close enough that no corrections were necessary for our use.

The water-meter (an Empire Hot Water Meter) was calibrated to read pounds of water direct by weighing from it three barrels of water, noting the meter reading before and after. Weight of water divided by the reading of the meter gives the calibration in pounds. Thus $\frac{1188}{142} = 8.366\#$. This then is the value in pounds of one division on the water meter called UNITS in the log.

The Steam Gages were calibrated with a Crosby Steam Gage Tester. The gage on boiler# 1 read 2# high, # 2 read 6# high and # 3 read 2# high on pressures from 80 to 120# pressures. Corrected gage readings are plotted on the log.

The scales for weighing coal were balanced and checked with the Gage Tester weights.

The draft was acertained by use of an Ellison Differential Draft Gage, attached close to the stack.

BOILER TESTS.

The object of these tests was to determine the efficiency of the boilers and the cost of evaporation.

The apparatus used during the tests was located as follows:-

Thermometers. The thermometer for measuring the temperature of the outside air was hung outside where it was sheltered from the sun. The one for measuring the temperature of the boiler room was hung inside where it was not effected by drafts. The one for feed-water temperature measurments was in the discharge line from the pump to the boiler. The temperature of the flue-gas was obtained by a thermometer placed in the flue between the boiler and the damper.

Water Meter:-The meter was placed in the discharge line of the pump that fed the boiler.

The coal was weighed out in 200# lots and dumped in front of the boiler as it was needed.

The Quality of the steam was determined by the use of a throttling calorimeter made of pipe fittings as advised in Carpenter's Experimental Engineering. It consists of 3/4 inch pipe-fittings arranged as shown in Fig.1. The steam-pipe W is made of 1/2 inch

pipe ,and the throttling orifice is made by screwing into the end of W,a plug with the top cut off and an 1/8 inch hole drilled thru it. The thermometer cup C is made of a thin brass tube,sealed at the lower end and screwed into a bushing at the top of the Tee and also projecting well below the orifice. The thermometer was inserted in the cup and surrounded with heavy oil. The pipe S is about ten inches long and open at the end. This makes the pressure in S so nearly that of the atmosphere that no correction was used in the calculation. The calculation was done by use of Fig. 2 which is the equation $x = \frac{H+s(T-t)-q}{r}$,worked out graphically.

H =Latent heat of water.

T = Temperature in the calorimeter.

t = Temperature of boiling water at atmospheric pressure.

s = Specific heat of steam.

q = Sensible heat of the liquid at boiler pressure.

r is the latent heat of vaporization at boiler pressure.

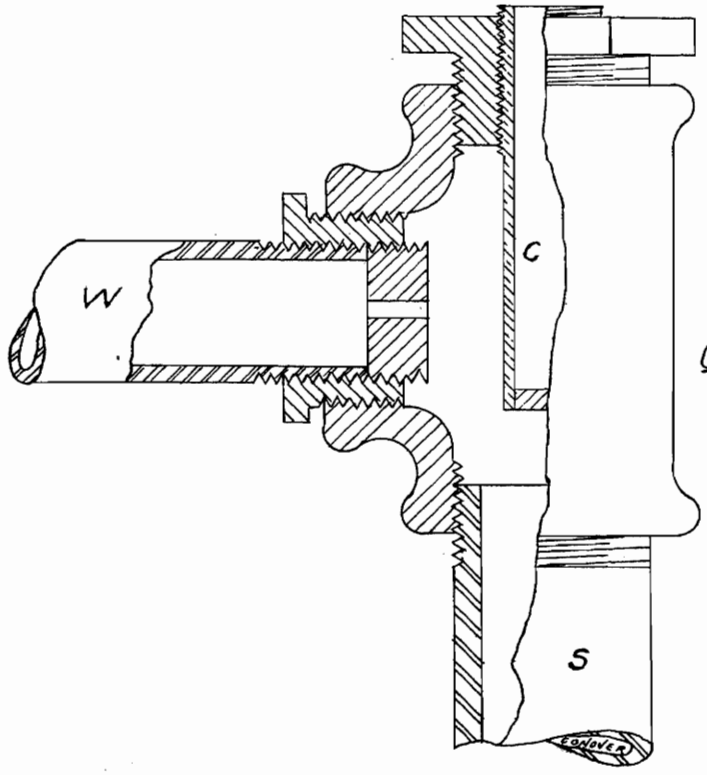


FIG. 1.

THROTTLING CALORIMETER

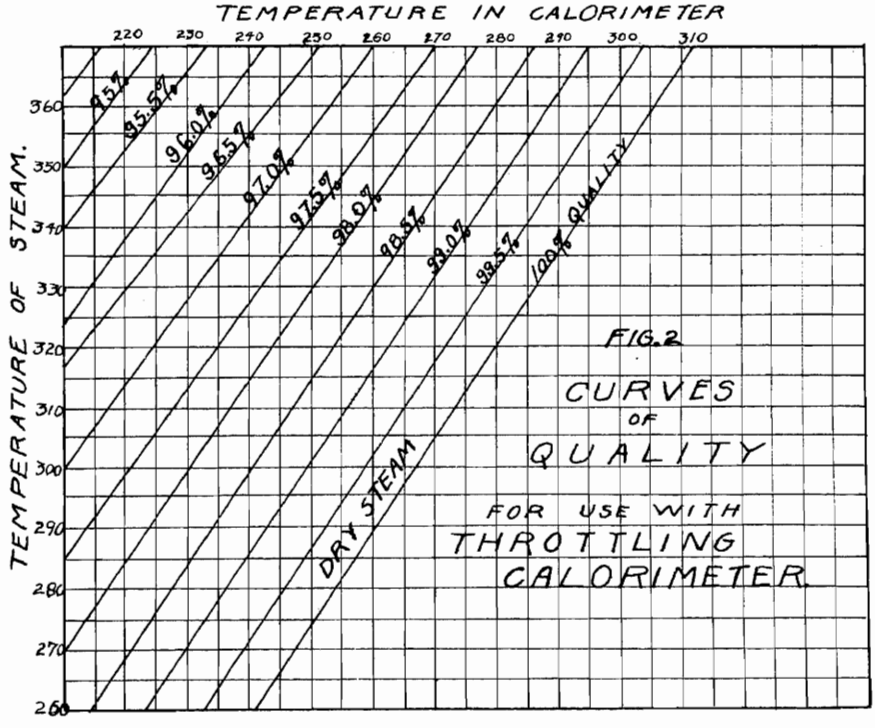


FIG. 2

CURVES OF QUALITY

FOR USE WITH THROTTLING CALORIMETER

The calorimeter was attached to the steam main about a foot above the boiler so that no condensation took place in the steam before reaching the calorimeter. It was connected as advised in Carpenter's Experimental Engineering.

WATER.

The water used during the tests was measured by means of an Empire Hot Water Meter which had been calibrated by us to read pounds as shown under Calibration of Instruments. IN tests on boilers 1 and 3 the water was taked from the return from the heating system so was hot. In test 2 the water was taken from the well so it was cold.

COAL.

The coal was weighed in a box and then dumped in front of the boiler under test. From here it was fed into the fire-box as needed. The sample of coal used for our Proximate Analysis and Calorimetric tests was obtained by taking one shovel-full out of ten as the box was filled. This sample at the end of the test was worked down by cone and quartering to a five pound sample. This was put into a fruit jar and tightly sealed . This was afterwards bucked down to

a fifty gram sample thru an 80 mesh screen and sealed in tubes for analysis. The moisture sample was taken when the coal passed a 20 mesh screen.

The Proximate Analysis of the coal was made by the scheme authorized in Low, Technical Analysis of Ores.

The calorific power of the fuel was determined in a Bomb Calorimeter on dried samples. Calculation is on the following page. In making the tests it was noted that no appreciable temperature change took place before firing of after the Maximum temperature was reached. This was due to the fact that the stirrer was running fast enough to supply heat as fast as it was being radiated.

FLUE GASES.

The flue gases were analyzed every two hours for Carbon Dioxide, Carbon Monoxide and Oxygen and Nitrogen by subtraction. The sample was obtained continuously from the flue by means of an aspirator connected by ruber tubes to a half-inch glass tube which extended into the flue about Four inches. The analysis was made with an Orsat Apparatus.

CALORIFIC POWER OF COALS.

	Test # 1	Test # 2	Test # 4
Weight of Sample	1.000 gm.	1.002 gm.	1.004 gm.
Time minutes and seconds.		Temperatures.	
0	23.39	22.55	23.30
30	23.39	22.56	23.31
1	23.39	22.56	23.31
30	"	"	"
2	"	"	"
30	"	"	"
3	"	"	"
30	"	"	"
4	"	"	"
30 FIRE----------	"	"	"
5	23.41	23.00	23.33
30	23.75	34.50	25.56
6	25.40	25.20	25.36
30	25.15	25.40	26.08
7	26.30	25.50	26.30
30	26.51	25.55	26.46
8	26.55	25.61	26.47
30	26.56	25.62	27.47
9	26.56	25.63	26.47
30	26.57	25.63	26.47
10	26.57	25.63	26.47
30			
11			
30	No change in temperature.		
12			
30			
13			
30	26.57	25.63	26.47
Total temp. rise.	3.16	3.07	3.16
Temp.rise per gm.	3.16	3.063	3.15
Weight of water	1600gm.	1600gm,	1600gm.
Water equivalent of bomb and fixtures--------		476	
Gram Calories. -----	6560	6353	6539
B.T.U.----------	11810	11420	11771

FUEL.

The coal used in test of boilers # 1 and # 3 was a fair grade of Illinois lump having passed over a two inch screen. It was dry and contained a high percent of ash. The coal used in testing boiler # 2 was a fairly good grade of Illinois Mine-run of about the same quality as the other coal used.

STACKS.

Boilers # 1 and # 2 feed to the same stack. During the interval between the tests on these two boilers a severe wind storm blew off about twenty-five feet of the stack. This caused a low draft on boiler #2. The stack was originally 100 feet high from the grates. The other stack that takes the flue gases from #3 is 80 feet high from the grate. Both are sheet-iron stacks. At the present time a new tile-concrete stack 110 feet high is in the course of construction.

FEED WATER.

During cold weather live steam from the boilers and exhaust from the engine is used to heat Norwood Hall, Chemical Hall, Mechanical Hall, the Rolla Building, and the Powerhouse. The condensation is pumped

back into a receiver by vacuum pumps and fed to the boilers by an automatic pump. The water feed to the boiler at such times is at a temperature of from 80 to 200 degrees F. When not heating, the injector is used. As there was not enough room to install the water meter in the injector line, it was put in the pump line. Enough hot water came back to feed one boiler when two were being used. As the heating system was in operation at the time of tests on boilers 1 and 3, hot water was used. When test 2 was made, no heating was being done so tap water was run into the receiver to supply it and to prevent trouble of moving the meter. As steam was used for the air-compressor during test #2 no combined test could be made on both engine and boilers. This combined test was made May 19 lasting three hours with a light load, care being taken that no steam was used but that used by the engine. The same care was taken as was taken in the other tests.

The start and finish of these tests were made as advised in Carpenter's Engineering, under the head of the Alternate Method of Starting and Stopping Boiler Tests.

DATA AND RESULTS OF EVAPORATIVE TEST.

Made on Heine water tube boiler #1 at the Missouri School of Mines.

Kind of fuel-----Bituminous coal,lump.

Alternate Method of starting and stopping the test.

Duration of trial--- 6 hours.

DIMENSIONS AND PROPORTIONS.

Grate surface--width 5'-7''.length---5'-0.--area 27.9

Water heating surface 1065 sq.ft.

Superheating surface 13 sq.ft.

Ratio of water heating surface to grate surface 38 to 1.

Diameter of stack.------42 inches.

Height of stack---------100 feet.

AVERAGE PRESSURES.

Steam pressure by gage ----------83.5#

Draft between boiler and damper--------.60 ins.water.

AVERAGE TEMPERATURES.

External Air----------61.2 Degrees F.

Fireroom----------47.0

Steam in boiler----------326.0

Steam in calorimeter----------219.4

Feed water---------- ----------155.0

Flue gases---------- 436.

FUEL.

Size and condition----------2' lump,dry.

Weight of coal as fired----------2400#

Percent moisture in coal----------3.16

Total weight of dry coal consumed----2324#

Total ash and refuse----------345#

Quality of ash and refuse----fair,few clinkers.

Percent of ash and moisture in dry coal- 14.8

Total combustible consumed----------2045#

Proximate Analysis of Coal

Fixt Carbon----------45.23 %

Volatile Matter------39.87%

Moisture----------3.16%

Ash----------11.74%

Total----------100.00%

Analysis of refuse.

Ash----------96.0%

Carbon---------- 4.0%

Total-- ----------100.0%

Calorific power of fuel-------11810.B.T.U.

FUEL PER HOUR.

Dry coal per hour---------- 387.3#

Combustible per hour----------340.9#

Dry coal per sq.ft.grate surface per hour---14.0#

Combustible per sq.ft.of heating surface per hour--- 0.32#

QUALITY OF STEAM.

Per cent moisture in steam----------3.5

Degrees superheat in calorimeter-- -7.4

Quality of steam---------- ----96.5

Water.

Total water fed to the boiler-------13370#

Water actually evaporated----------12841#

Water heated in steam as moisture-----529#

Equivalent water evaporated from and at 212 F.-14142#

ECONOMIC RESULTS.

Water apparently evaporated per pound coal as fired-5.55

Water evaporated from and at 212 per # coal as fired-5.89

" " " " " " " " dry coal-----6.09
" " " " " " " " combustible--6.92

EFFICIENCY OF BOILER.

Efficiency of the boiler including the grate;heat absorbed by the boiler per pound of dry coal, divided by the heat value of a pound of dry coal----49.%

COST.

Cost per ton of two thousand pounds in boilerroom--$2.95

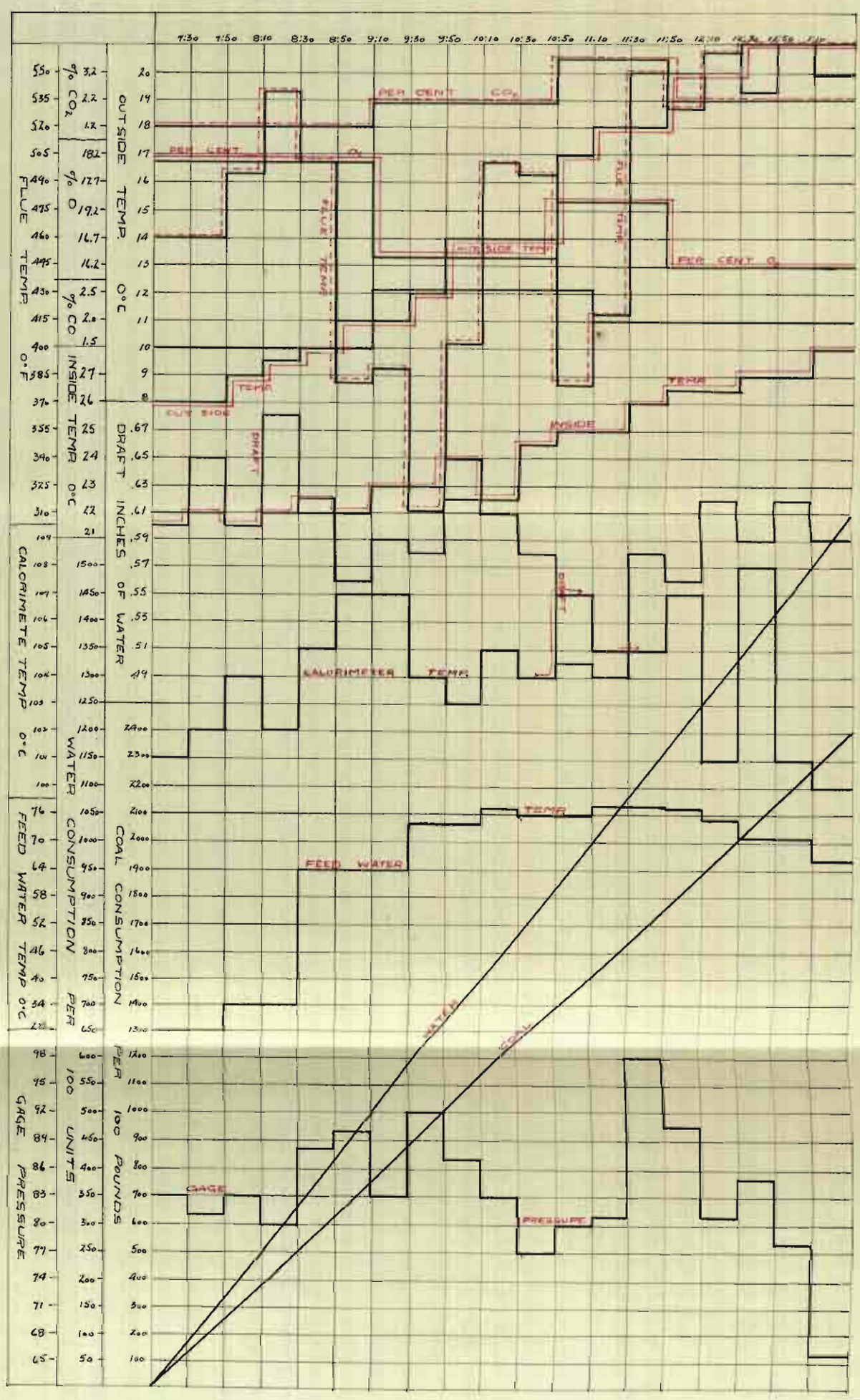
Cost of fuel for 1000# water as observed---------26.49¢

Cost of fuel for 1000# water from and at 212-----24.96¢

ANALYSIS OF FLUE GAS.

Carbon Dioxide	2.5%
Oxygen	17.0
Carbon Monoxide	2.0
Nitrogen	78.5
Total	100.0%

GRAPHICAL LOG BOILER No. 1.



DATA AND RESULTS OF EVAPORATIVE TEST.

Made on boiler # 2 at the Missouri School of Mines.

Heine Water Tube boiler.

Kind of fuel--Bituminous coal.

Alternate method of starting and stopping test.

Duration of trial---6 hours.

DIMENSIONS AND PROPORTIONS.

Grate surface, width 5'-7''. Length 5-0". Area 27;9sq.ft.

Water heating surface----------1065 sq.ft.

Superheating surface----------15 " ".

Ratio of water heating surface to grate surface 38 to 1.

Diameter of stack ----------42 in.

Height of stack----------75 ft.

AVERAGE PRESSURES.

Steam pressure by gage---------- ---81.7 # per sq.in.

Draft between boiler and damper--------.30 in.water.

AVERAGE TEMPERATURES.

External air----------75.5 deg.F.

Fire room---------- --------79.0 " "

Steam in boiler----------324.4 " ".

Steam in Calorimeter----------233.6 " "

Feed water---------- 72.5 " ".

Flue gases---------- 522 " C.

FUEL.

Size and condition-------dry mine run.

Weight of coal as fired----------3400#

Percent moisture in coal----------8.05

Total dry coal consumed---------3126#

Total ash and refuse----------346#

Quality of ash and refuse ---------fair.

Percant ash and moisture in coal 18.77

Total combustible consumed ----------2762#

Proximate Analysis of coal.

Fixt Carbon---------43.67%

Volatile matter-----37.56

Moisture----------8.05

Ash----------10.72

Total----100.00%

Analysis of ash and refuse.

Carbon----------3.26%

Ash----------96.74

Total------100.00%

Calorific power of fuel----------11420 B.T.U.

FUEL PER HOUR.

Dry coal per hour----------521#

Combustible per hour----------460#

Dry coal per sq.ft. grate surface per hr.-18.6

Combustible per sq.ft.of heating surface per hour-----0.43

Quality of Steam.

Moisture in steam----------2.7%

Degrees superheat in calorimeter--------21.6 Deg.F.

Quality of steam--- ----------97.3

WATER.

Total water fed to boiler----------16950#

Water actually evaporated----------16493#

Water heated as moisture in steam---------457#

Equivalent water evaporated into steam from and at 212 --19493#

ECONOMIC RESULTS.

Water evaporated per pound coal as fired---5.0

Water evaporated from and at 212 per # coal fired--5.73

" " " " " " " " dry coal---6.24

" " " " " " " " combustible-7.06

EFFICIENCY OF BOILER.

Efficiency of boiler and grate;heat absorbed per pound of dry coal divided by the calorific power of coal--52.6%

COST.

Cost per ton of 2000# coal---------$295

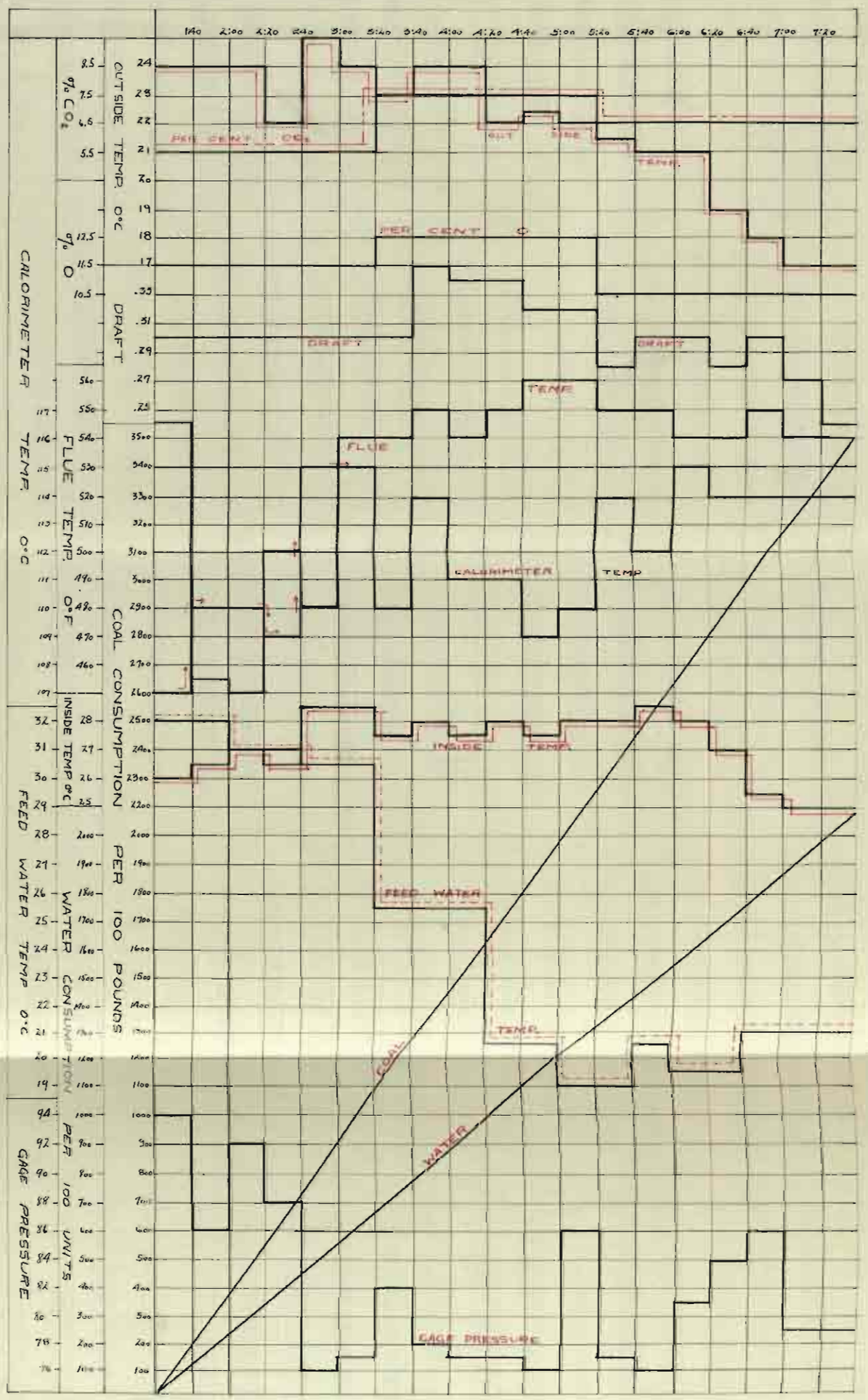
Cost of fuel per 1000# water as observed---29.4¢

" " " " " " from and at 212--25.63¢

ANALYSIS OF FLUE GASES

Carbon Dioxide	6.5%
Oxygen	11.2
Carbon Monoxide	00.0
Nitrogen	82.3
Total	100.0%

GRAPHICAL LOG BOILER No. 2.



DATAAND RESULTS OF EVAPORATIVE TEST.

Made on boiler # 3 at the Missouri School of Mines.

Heine water tube boiler.

Kind of fuel--------Bituminous coal.

Alternate method of starting and stopping test.

Duration of trial-----6 hours.

Dimensions and Proportions.

Grate surface-------width--5'7".Length 5'0" Area 27.9 sq,ft.

Water heating surface------- 1965 sq.ft.

Superheating surface----------13 " "

Ratio of water heating surface to grate surface~~38~~ to 1.

Diameter of stack.---------- --36".

Height of stack-----------80'.

AVERAGE PRESSURES.

Steam pressure-- ----------85#

Draft between boiler and damper---.48 in.water.

AVERAGE TEMPERATURES.

External air----------17 deg.C.

Fireroom----------28 " ".

Steam in boiler---------- - -327 deg.F.

Steam in calorimeter---------- 250 " "

Feed water----------160 " ".

Flue gases----------685 " ".

FUEL.

Size and condition.----------2" lump dry.

Weight of coal as fired----------2753#

Percent moisture in coal----------3.41

Total weight of coal as fired(dry)-2659#

Total ash and refuse----------340#

Quality of ash and refuse-----fair.

Percent of ash and moisture in coal--14.96

Total combustible consumed---------2617#

Proximate Analysis of Coal.

Fixt Carbon----------45.44%

Volatile matter------39.60

Moisture----------3.41

Ash----------11.55

Total----100.00%

Analysis of ash and refuse.

Corbon----------3.04%

Ash----------96.96

Total- ----100.00%

Calorific power of fuel- ----------11771B.T.U,

FUEL PER HOUR.

Dry coal per hour----------458#

Combustible per hour--------436#

Dry coal per square foot of grate surface per hour------16.4#

Combustible per square foot of heating surface per hour------ 0.43

QUALITY OF STEAM.

Moisture in steam----------1.9%

Degrees superheat in calorimeter---38 F.

Quality of steam- ----------98.1%

Water.

Total water fed to boiler ----------16540#

Water actually evaporated----------16226#

Water heated in steam as moisture----------314#

Equivalent water from and at 212F.----------19228#

Economic Results.

Water apparently evaporated per# coal fired-----6.0#

Water from and at 212 per pound coal fired----6.99#

" " " " " " " dry coal-----7.24#

" " " " " " " combustible-- 7.35#

EFFICIENCY OF BOILER.

Efficiency of the boiler including grate;heat absorbed by boiler divided by the heat of one pound of dry coal54%.

COST.

Cost per ton of 2000# coal----------$2.95

Cost per 1000# water as observed------ -----29.5¢

Cost of fuel per 1000# water from and at 212-21.0¢

ANALYSIS OF FLUE GASES.

Carbon Dioxide--------- ------5%

Oxygen ----------14.5

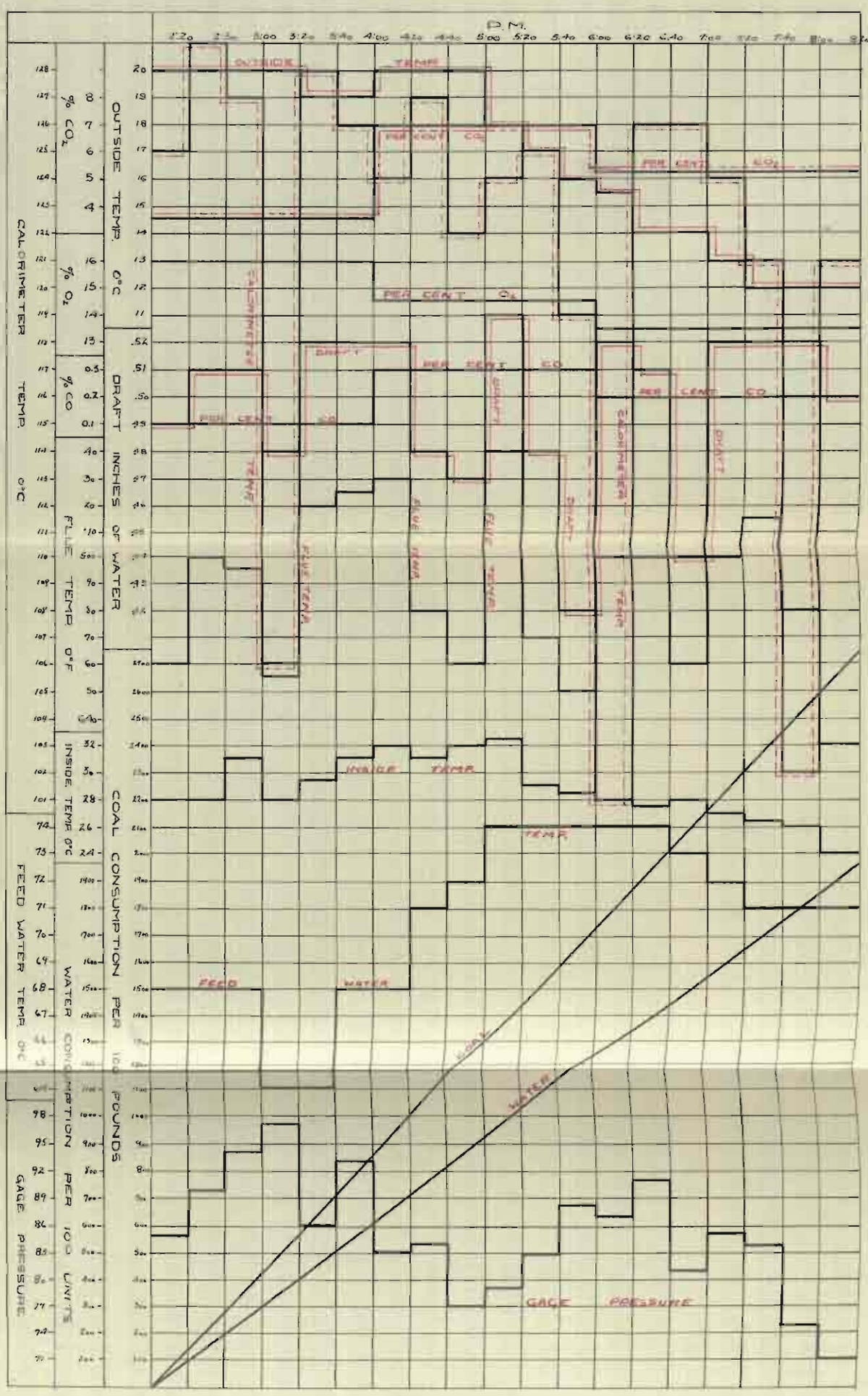
Carbon Monoxide----------0.2

19.7%

Nitrogen- ----------80.3

Total-------100.%

GRAPHICAL LOG BOILER No. 3.



TEST OF GENERATING SET.

The engine is an Ideal,a simple,high speed,centre crank,self oiling,automatic,horizontal,right hand direct connected engine with a slide valve. It develops 75 H.P. at 266 R.P.M. This rating is based on 90# innitial pressure and 1/4 cutoff. The cylinder is 11'x12'. The feed pipe 3 1/4" in diameter. It is connected direct to a Direct Current 50Kilowatt compound wound Westinghouse genarator. It is designed to run at 280 R.P.M. to 300 R.P.M. with a load of 200 amperes at 250 volts.

Tests were made on the engine running with full, medium,light,and no loads. The different loads were secured by running the motors about school. The no load test was made by disconnecting the field coils so that the generator acted merely as a flywheel.

The calorimeter was connected below the separator. The reducing motion was as the manufactors had made it.

GENERATING COUPLE TEST.

Duration of test-----3 hours.

Diameter of cylinder---11", Length of stroke---12".

Piston Displacement---------- -------.660 cu.ft.

Clearance----------.02063 cu.ft., 303% of Piston Dis.

M.E.P. for mean load----H.E.--36#,C.E.---34#

R.P.M.----276

I.H.P.---=H.E.-28.6,-----C.E.----27,Total--55.6

Temperature in calorimeter---106Deg.C.,Steam Pressure--81#.

Percentwater in steam----3.2,Water per revolution---.160428

Water per I.H.P hour----47.685#

Reading Voltmeter----220,Ammeter---150,H.P.equivalent--44.23

Water per H.P.delivered per hour----59.96#

Efficiency of couple-----79.5%

M.E.P.at no load --3.75#,R.P.M.280, I.H.P.-----6.00

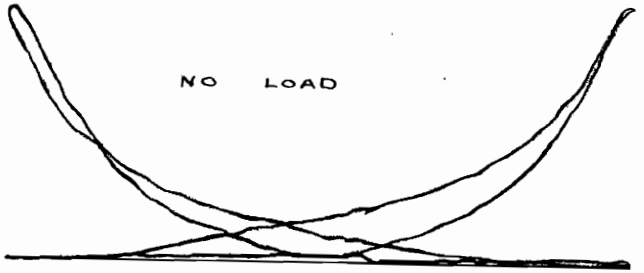
Total I.H.P.delivered to the dynamo at mean load--49.6

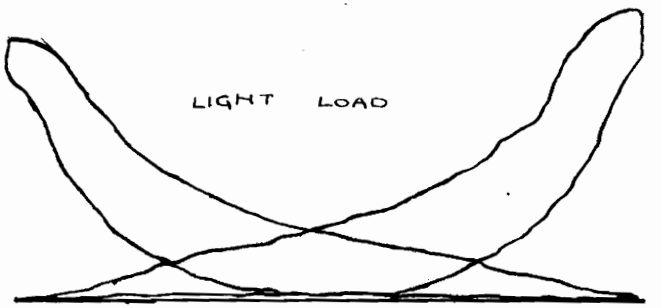
H.P. delivered at mean load----------44.2

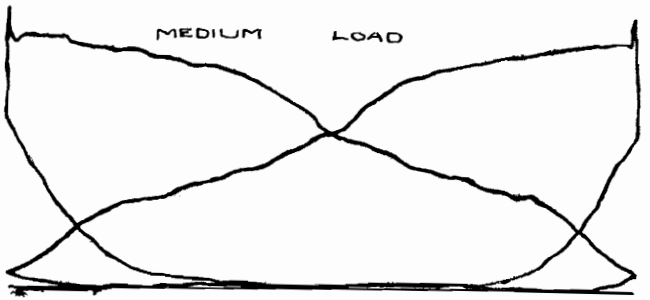
Efficiency of dynamo----------89.0%

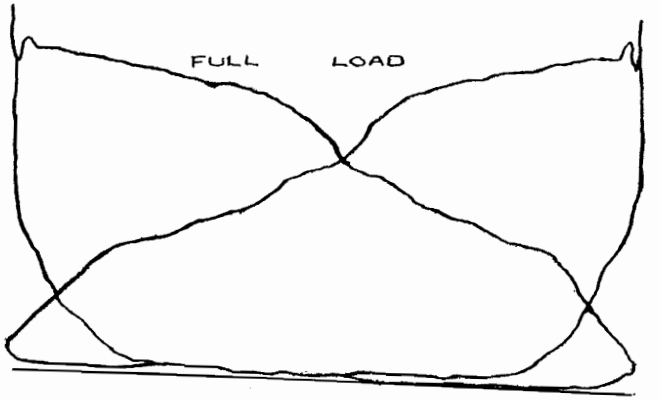
Efficiency of engine----------87.5%

INDICATOR CARDS. SCALE 1-1
IDEAL ENGINE.









CARD No	MEP HE	MEP CE	LAN. 3000	RPM	INDICATED HORSE-POWER CE	INDICATED HORSE-POWER HE	INDICATED HORSE-POWER TOTAL	TOTAL WATTS INPUT	TOTAL WATTS OUTPUT	EFFICIENCY
1	5.5	1.5		280	1.19	4.38	5.57	4150		
2	5.5	2.0		"	1.59	4.38	5.97	4449		
3	6.0	3.0		"	2.39	4.88	7.27	5420		
4	11.0	7.0	.795	276	5.56	8.75	14.31	10700	7100	66.35
5	14.0	10.0	"	"	7.95	11.12	19.07	14200	9100	64.10
6	12.5	8.0	"	"	6.36	9.25	15.61	11590	9325	80.50
7	16.5	12.0	"	"	9.55	13.10	22.65	16900	12760	75.50
8	16.5	15.0	"	"	11.92	13.10	25.02	18650	12760	68.45
9	17.0	17.0	"	"	13.50	13.50	27.00	20140	15533	77.10
10	25.0	22.0	"	"	17.50	19.90	37.40	27950	22500	80.50
11	29.0	28.0	"	"	22.25	23.20	45.45	33850	26400	78.00
12	31.0	29.0	"	"	23.20	24.61	47.81	35620	28200	79.00
13	33.0	33.0	"	"	26.22	26.22	52.44	39200	30800	78.60
14	36.0	34.0	"	"	27.00	28.60	55.60	41500	33000	79.50
15	40.0	40.0	"	"	31.80	31.80	63.60	47500	39600	83.40
16	41.5	40.0	"	"	31.80	33.00	64.80	48300	39600	82.00
17	45.0	44.5	"	"	35.40	35.80	71.20	53200	41800	78.50
18	47.0	46.0	"	"	36.60	37.40	74.00	55200	44950	81.25
19	50.0	49.0	"	"	39.00	39.80	78.80	58750	46250	78.85
20	50.0	49.5	"	"	39.40	39.80	79.20	59000	48000	81.25
21	51.5	49.0	"	"	39.00	41.00	80.00	59700	49350	82.60
22	52.0	49.0	"	"	39.00	41.35	80.35	59900	50200	84.00
23	52.0	52.0	"	"	41.35	41.35	82.70	61650	50650	82.00

COST OF 33 K.W.

Water per K.W.hour----------80.4#

Average water evaporation per # coal------5.52#

Coal per K.W.----------14.5#

Cost coal per k,w. @ $295 per ton---------2.14¢

Two quarts dynamo oil @$.37 per gal.----$00.185

Six " cylinder " "$.67 " "------- 1.005

Salaries per week--- ----------24.25

Fixt cost per week-----$25.44

Plant runs 15 hours a day,six days a week.

Fixt cost per K.W.hour-- ----------$0.00829

Coal cost " " " ----------$0.0214

Total cost per K.W.Hr.----------2.97¢

COST PER K.W.HOUR AT 220V.AND67.2 A.

This test was made to get the cost of producing a K.W.HR. at a small load.It was made with boiler #2 and running under same conditions as it was in the other tests.The start and finish was made by the Alternate Method,as in the other tests.

As the steam was being used for other purposes (Heating and Air Compressor) while the other tests were being made,nothing like this could be attempted until warm weather came and laboratories were closed. The test covered a three hour run.The load was made constant thruout the time and observations taken every ten Minutes.

RESULTS OF TEST.

Average amperes----------67.20

Average Volts-----220 Average K.W.---14.78

Coal used----1004# @ $2.95 per ton ----- $1.48

Cost coal per hour $0.493 , per K.W.Hr.--$0.03335

Wages etc.per K.W.Hr. ------- ----------$0.00164

Total cost per K.W.Hr. $0.03499

3 1/2 cents per K.W.HR.

BIBLIOGRAPHY.

Experimental Engineering----------Carpenter.

Handbook for Mechanical Engineers----Kent.

Thermodynamics of Steam Engines------Peabody.

Steam Boilers-- ----------Peabody and Miller.

Engines and Boilers----------Le Van.

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Direct Current Machines---------- ---Sheldon andHausemann.

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COST OF PUMPING WATER FROM THE DEEP WELL AT SCHOOL OF MINES.

This test was made by Professor Harris about the same time that Boiler Test # 2 was made. Boiler # 2 furnished the steam and had just been cleaned. The stack had been blown off at that time as stated else where. The coal was the same also.

We put it in with these tests to have it recorded along with the other tests that were made at the same time.

PUMPING TEST SCHOOL OF MINES.
April 20.1911.

Capacity of Cisterns per Vertical Foot.

Elliptical Cistern	2811 gal.
Rectangular "	1785 "
Total	4596 "
Fourteen foot tank in Norwood Hall	1151 gal.

Record of run.

Elliptical Cistern	
To surface at beginning	10.24 ft.
To surface at end	4.1 "
	6.14 ft.
Rectangular Cistern	
To surface at beginning	10.24 ft.
To surface at end	4.1 "
	6.14 "

Gallons Pumped.

Elliptical Cistern	17147.1 gal.
Rectangular Cistern	10959.0 "
Storage cistern	3453.0 "
Used in Boiler	1000.0 "
Total Pumped	32560.0 "

Record.

Air Pressure	140 #
Steam Pressure	1000#
Air lift operated 5 hrs.20 min.	
Coal consumption	2000#
Coal cost at $2.95 per ton	$2.95
Labor cost at 20¢ per hour	1.10
Total Cost of operation of air lift	4.05

Cost of air lift per 1000 gal	$0.1244
Cost of operating gasoline engine per 1000 gal.	.019

Total cost per 1000 gallons--0.1434