THE DETERMINATION OF THE OPTIMUM CO_2 FOR OPERATING NUMBER 6 BOILER

by

R. L. PARET AND W. W. SELLEW, JR.

Thesis submitted to the Graduate Faculty of the

Virginia Polytechnic Institute

in candidacy for the degree of

MASTER OF SCIENCE

in

POWER AND FUEL ENGINEERING

APPROVED:

Louis A. Pardue
Director of Graduate Studies

E. B. Norris
Dean of Engineering

APPROVED:

J. B. Jones
Head of Department

J. B. Jones
Chairman, of Advisory Committee

June 10, 1951

Blacksburg, Virginia

153084

Table of Contents

ACKNOWLEDGEMENTS

Many persons have contributed the advise and assistance without which this thesis could never have been satisfactorily completed. The authors do herewith express their grateful appreciation to the following associates:

The Thesis Committee, comprised of Professor J. B. Jones, Mechanical Engineering Department Head, C. F. DuBusk, Utility Engineer, and G. F. Moore, Instructor in Mechanical Engineering, for their valuable criticism, suggestions, and guidance.

C. H. Long, Associate Professor of Power and Fuel Engineering and Mechanical Engineering, for his support and encouragement.

The following plant personnel for their willing cooperation throughout the tests upon which this investigation is based: W. M. Broce, Plant Superintendent, C. F. Martin, J. S. Hamlin, L. Barnett, S. J. Pratt, K. H. Salmon, E. F. Hale, Jr., W. W. Henderson, H. Grissom.

J. F. Ryman, Associate Professor of Physics, for his assistance in calibrating the instruments used in this investigation.

F. M. Morris, Assistant Professor of Mining Engineering, for the use of the mining laboratory equipment.

Clarence Dowdy and Roy Duncan for their aid in mixing and storing the test coal used in the investigation.

The 1951 Graduate Students of Power and Fuel Engineering, for their interest, cooperation, and moral support.

INTRODUCTION

The addition of a two-drum steam-generating unit became necessary at the Virginia Polytechnic Institute Heating and Power Plant in 1949. The increased heating and lighting load acquired upon the completion of new buildings on the campus and the revamping of the old heating system to allow for future expansion induced the need for this installation.

Built by the Edgemoor Iron Works, the new two-drum unit was designed for a working pressure of 250 pounds per square inch at a temperature of 100^{o}F. superheat. The unit has a rated maximum continuous capacity of 60,000 pounds of steam per hour when burning bituminous coal and 45,000 pounds of steam when burning semi-anthracite culm.

Incorporated in the design of the unit are two methods of heat recovery. A 3,030 square foot tubular air preheater is used to increase the temperature of the combustion air, while fly ash, collected in hoppers under the second and last pass and in the dust collector, is reinjected into the combustion space by air jets that supply the secondary air.

The design of the unit includes a Detroit Roto-grate Stoker, which is a combination of an overthrow spreader stoker with a traveling grate. The Roto-grate Stoker is designed for burning coal which has an ash content of 19.6 percent by weight. Coal is burned partly in suspension and part on the fuel bed in this type of stoker.

Blacksburg is located in the center of the Virginia anthracite region. Therefore upon the consideration of economy and availability, it was desirable to use as much as possible of the semi-anthracite culm that is located near by. The design of the unit was made with the expectation that 100% semi-anthracite culm could be burned. Experience, however, proved this to be unfeasible. The reinjection of the fly ash smothered the fire, and an excessive amount of carbon in the refuse was also encountered. Nevertheless, because of a contract which binds the college to the purchasing of 10,000 tons of Merrimac Culm each year over a ten year period, a thesis was run in March of 1950 to determine the most economical mixture of Merrimac Culm and Capital Bituminous Coal to burn at a load of 45,000 pounds of steam per hour.

The most satisfactory and economical grade of fuel determined by this thesis was six parts of Merrimac Culm to one part of Capital Bituminous Coal. Since the completion of this thesis, operating conditions of the boiler have necessitated a decrease in the ratio of the bituminous coal to the semi-anthracite culm. To increase the load and maintain pressure requirements of the boiler, a ratio of 1 to 4 was instigated.

It has now become a point of interest to determine by exact test what degree of gross efficiency is possible under normal working conditions. It is this subject with which this thesis will deal. A study shall consequently be made of the effect of the variable percent CO_2 in the flue gas. The test load on the boiler will be held constant at 50,000 pounds of steam per hour since this is the average load at which the boiler operates.

Included with the automatic combustion control apparatus used with the new steam generating unit is a Hays CO_2 Recorder that operates on the Orsat principle of volumetric measurement and chemical absorption. It is the purpose of this thesis to establish a standard so that the boiler operators can use the Hays CO_2 Recorder as a firing guide to achieve efficient operation of the new unit.

REVIEW OF LITERATURE

Efficient operation is the desire of every power plant engineer. His aim is to determine the highest possible efficiency at some predetermined rating of the boiler and then to maintain this efficiency as much of the time as possible.

The minimum percentage of excess air with complete combustion of the fuel will produce the highest boiler efficiency. However, if the excess air is reduced to nearly theoretical conditions, complete combustion will not exist and poorer efficiency, as well as higher operating costs, will be encountered. [1]

Furnace temperature, unburned fuel, and the sensible heat carried away in the dry flue gases; these are the limiting factors that are closely related to the percentage of excess air. The theoretical temperature of combustion increases about 200° F. with each 10% reduction in excess air, an important factor to be considered in combustion efficiency. Adequate consideration must also be given to the effect of the increased temperature on furnace maintenance as well as to the forming of clinkers on the fuel bed. Reduction of excess air causes imperfect mixing of oxygen with the combustible in the fuel; this results in the existence of unburned fuel.[2] Indications of such incomplete combustion are the appearance of CO in the exit flue gases (a case where all the heat in the fuel has not been liberated) and the increase in the ash pit losses caused by unburned carbon in the refuse. On the other hand, an increase in the excess air dilutes the products of combustion. Lost with the dry flue gases will be the heat required to raise this free air from room temperature to the temperature of the flue gas leaving the boiler.[3]

In order to avoid the possibilities of incomplete combustion caused by improper mixing or stratification of air and of excessive maintenance caused by high furnace temperatures, an amount of air in excess of that theoretically required must be supplied. However, this excessive air must be balanced against an increase in the heat losses incurred from heating the excess air.[4] The best percentage of excess air used in any boiler will vary with individual furnace conditions and therefore must be determined experimentally.[5]

In a boiler there is a definite relationship for each fuel burned between the percentage of CO_2 in the exit gases and the excess air.[6] This relationship between the percentage of CO_2 and the excess air will vary more than one percent with different types of coal and will vary from 3% to 8% between units firing with oil and gas. The CO_2 as an indicator can only be used to determine the percent of excess air with a coal having a certain hydrogen - carbon ratio for which it was tested.[7] A high percentage of CO_2 in the exit gases with complete combustion indicates low excess air, while a low CO_2 with complete combustion indicates high excess air.

Since a certain percentage of CO_2 may indicate either a deficiency or an excess of air, the boiler operator need only increase the fuel feed and examine the CO_2 recorded. If the percentage increases, an excess of air is indicated; if there is a decrease, a deficiency of air is similarly indicated. This is evident from inspecting a curve of percent CO_2 versus air required for combustion.* The percent CO_2 in the flue gases is at a maximum at theoretical conditions and decreases as excess air and deficiency of air increases.

Where extreme accuracy is desired in maintaining proper air fuel ratios, spot sampling of the flue gases is an unreliable guide for combustion control.[8] Because of stratification, in commercial practice it is often times feasible to collect the sample across a length of the gas pass instead of at one point. It is important that the sample be taken from a high velocity section close to the combustion zone. This eliminates errors incurred from the leakage of air outside the combustion zone.

For a unit that uses uniform fuel consistently, an efficient, accurate, and reliable CO_2 recorder is an indicator that will help achieve the desired high efficiency.

---

* Heat Power Engineering, Part II by Barnard, Ellenwood, and Hirshfield. John Wiley & Sons, Inc., New York, 1935, p. 416, fig. 533.

This is possible since it allows for control of the largest of the controllable boiler house losses, that is, losses through excess air. With the Roto-grate Stoker, there is very little active fuel in the furnace at any one time; therefore, the stoker is very responsive to changes in fuel and air supply. The CO_2 recorder gives a record of the CO_2 in the exit flue gases every 1.9 minutes. This record is available to indicate whether or not the fire is being properly maintained at all times. Thus, rapid adjustments of controls are possible to achieve the desired combustion results.[9]

INVESTIGATION

OBJECT

The object of this investigation was to determine the percent CO_2 that would produce the highest boiler efficiency for the Edge Moor Boiler of V. P. I.'s Heating and Power Plant, when the output is 50,000 pounds of steam per hour and a mixture of 4 parts semi-anthracite culm and 1 part bituminous coal is burned.

PROCEDURE

The boiler tests were run under conditions similar to plant operation in order to determine the maximum practicable gross efficiency of the steam generating unit at a load of 50,000 pounds of steam per hour. These tests were conducted to comply as closely as possible to the Test Code for Stationary Steam Generating Units set by the American Society of Mechanical Engineers. The efficiency was determined by a direct measurement of the input and output to the unit, while a heat balance was run to check the input-output results.

Throughout the tests, the boiler was operated at an approximate load of 50,000 pounds of steam per hour and readings were taken to determine what percent CO_2 produced the highest feasible gross efficiency, using 4 parts of Merrimac culm to 1 part bituminous coal.

In order to get a uniform mixture of coal, it was piled on the ground in the following order, two payloader scoops of culm, one of bituminous, and two more of culm; then the pile was dumped through the grate to the screw conveyer. The CO_2 in the flue gas was varied as near as possible from 9% to 13% in increments of 1%. The percent CO_2 was regulated by varying the fuel feed and the grate speed; all other variables were held as constant as possible. To vary the air-fuel ratio, the fuel feed was used; to control the fuel bed thickness,the grate speed was used. The grate speed was adjusted to hold the fuel bed thickness within the limits of 3 inches plus or minus 1/2 an inch.

Included in the preparation for each test was a boiler blowdown and the operation of the soot blowers. All thermometers were checked and put in place; solutions in the Orsat apparatus were renewed and the Orsat zeroed before analyzing the flue gases.

To check the operation of all instruments, a preliminary run was made. At this time, the observers and other test personnel were made familiar with the equipment and recordings they were to make during the test. All minor adjustments were made on the boiler and proper combustion conditions achieved and maintained in this period. When the stabilization was completed, the test run was started. Immediately preceding the starting of the test, the ashes were removed from the ash pit and the fly ash cleaned out of the down spouts from the dust collector. As soon as possible thereafter, but before the cleaning of the ash pit during the test run, the silo was emptied of all ash so that the total refuse for the test could be collected at this point and weighed after the completion of the run. The truck scales were calibrated by a service mechanic before the tests were started, but at the end of the tests the scales were checked and found to be inaccurate. Due to this inaccuracy the calculated refuse was used for the results. Combustion conditions, rate of feeding fuel, rate of feeding water, water level in the drum, excess air, and all controllable temperatures and pressures were as nearly as possible the same at the end of the run as at the beginning. Initial readings were taken for all instruments. Except for quantitative measurements, readings were recorded every 15 minutes when possible. Any sudden variations in readings were recorded as often as seemed necessary to determine a true average. The duration of the run was five hours. (The utility engineer recommended the test run be limited to five hours in view of plant operation and existing operating conditions). For all settings of the boiler two runs were made.

The continuous blowdown on the boiler was measured for the total length of time by a flow meter. Refuse from the ash pit and the down spouts of the dust collectors was pulled every one and a half hours. At such times, the load was allowed to increase to accomplish this work. Small adjustments were also made in the fuel feed to hold the CO_2 at the same setting throughout the run.

All automatic settings on the boiler were noted and recorded every 15 minutes. Special attention was paid the Hays CO_2 Recorder, which operates every 1.9 minutes. Taken from the chart at this time interval, the recordings were averaged for a fifteen minute period and compared with the Orsat readings. These readings were taken every fifteen minutes if possible during the test run by an Orsat type flue gas analyzer.

Samples of the fuel were obtained by passing the spout of the weigh larry across a box provided to get a complete cross section of the stream of coal. This method is recommended in A. S. T. M. Standards on coal sampling. Each time the hoppers were loaded, samples were taken and placed in airtight containers to be analyzed in the Fuel Analysis Laboratory for heating value, moisture, volatile matter, and ash. By Evan's Empirical Relations the hydrogen and carbon content of the combustible matter in the coal were determined.* The total weight of the sample taken was subtracted from the

---

* "Empirical Relations for Coals in the United States", by C. B. Evans, Engineering Experiment Station of Cornell University, Bulletin N. 3.

weight of coal measured by the weigh larry to give the weight of coal fired. The refuse was sampled by putting a suitable amount, collected from piles in the truck, into a container every time the refuse was removed from the ash silo. This method of sampling was used so that a representative mixture of refuse from the ash pit and the fly-ash could be obtained.

All instruments used to obtain test data were calibrated at the beginning of the test runs.

APPARATUS

Steam Generator:

The steam generator was designed and built by the Edge Moor Iron Works, Edge Moor, Delaware. This boiler designated in the V. P. I. heating and power plant as boiler number 6, is a two drum bent tube boiler. The following are some of the more important design features:

Maximum evaporation (semi-anthracite culm)

45,000 lb of steam per hour

Maximum evaporation (bituminous coal)

60,000 lb of steam per hour

Operating Pressure .... 250 psig

Temperature rise through superheater... 100 F

Heater surfaces:

Boiler	6034 square feet
Water Walls	1120 square feet
Superheater	475 square feet
Airheater	3030 square feet

Stoker:

The stoker is a Detroit Rotograte Stoker. It is a three unit, spreader type stoker that throws the coal from the front to the rear of the boiler. Some of the coal burns in suspension and the rest burns on the continuously moving grate. The refuse is dischared over the front of the grate to the ash pit.

<u>Ash Removal System</u>:

The ash removal system is a vacuum type system. The vacuum is created by a steam-jet ejector. All of the refuse from the grate, the down spouts, and from the dust collector hoppers is removed through a pipe line to an ash silo and then hauled away by truck.

<u>Dust Collector</u>:

A Thermix tubular dust collector manufactured by Prat-Daniel Corporation is installed at the base of the stack. The collector was designed to clean 83,000 pounds of flue gas at 500 degrees Fahrenheit.

<u>Cinder Return Fan</u>:

The cinder return fan is a Buffalo Forge type 6-E blower driven by a 15 hp General Electric induction motor at a speed of 3480 rpm.

<u>Forced Draft Fan</u>:

The forced draft fan is a F. D. Sturtevant, size 85, Silent Vane Fan designed to handle 20,800 cubic feet per minute at standard conditions. It is driven by a 30 hp Westinghouse Induction Motor at a speed of 1170 rpm.

<u>Induced Draft Fan</u>:

The induced draft fan manufactured by the Prat-Daniel Corporation is driven by a 75 hp Westinghouse induction motor through an American hydraulic coupling.

The design output of the fan is 36,000 cubic feet per minute at 425 degrees Fahrenheit.

Auxiliary Air Fan:

The auxiliary air fan was manufactured by the Clarage Fan Company. It is driven by a General Electric 2 hp induction motor at a speed of 1735 rpm.

Combustion Controls:

The boiler is controlled by a Hays Combustion Control System. The master control is regulated by the superheater pressure, which in turn controls the forced draft fan and fuel feed. The induced draft fan is controlled by the furnace draft pressure. The outlet damper is hand controlled and changed only for extreme conditions.

Boiler Feed Water Pumps:

The main feedwater pump, driven by an electric motor, is a multi-stage centrifugal pump. The auxiliary feedwater pump, also a multi-stage centrifugal pump, is driven by a steam turbine. Both pumps have a capacity of 115 gallons per minute.

Coal and Ash Testing Equipment:

Analysis of the coal and ash samples were performed in the Mining Engineering Laboratory with the following equipment:

Burrell Moisture Oven	Roll-Crusher

Electric Muffel Furnace

Vertical Electric Furnace

Jaw Crusher

Disc Pulverizer

Various Size Screens and Splitters

Miscellaneous Apparatus:

Drum and Superheater Pressure Gages

Barometer

Steamflow Meter

Blow Down Meter

Weigh Larry

Platform Scales

Thermometers

Orsat Apparatus

CO_2 Recorder

Temperature Recorders

Draft Gages

DATA SHEET

TEST NO. 1

January 30, 1951

Coal Mixture: 4 Semi-Anthracite to 1 Bituminous

Time	Control Settings				Draft, inches of water						Flue Gas Analysis					Steam
	Fuel Feed	Inlet Damper	Master	Fuel-bed Thickness	Air in Hrt.	Wind box	Furnace	Last Pass	Air out Hrt.	I.D. Fan	Board CO_2	Orsat CO_2	Orsat CO	Orsat O_2	Orsat N_2	Integrator
10:00	28	60	10.3	3	3.7	2.1	.37	1.5	3	6	9.7	9	0	8	83	600332
10:15	27	60	9.5		3.5	1.9	.38	1.5	3	6	9.7	9	0	8.5	82.5	
10:30	24	60	9.7	3	3.3	1.7	.38	1.5	3	6	9.7	9.5	0	8.3	82.2	
10:45	24	60	8.8		3.2	1.8	.42	1.5	3	6	9.8	10	0	9	81	
11:00	25	60	9.2	3	3.4	2.1	.26	1.5	3	6	8.5	8	0	9	83	601100
11:15	25	60	9.0		3.2	1.8	.33	1.5	3	5.8	9.4	10.5	0	7.3	82.2	
11:30	23	60	9.6	3	4.0	2.2	.22	1.5	3	6	9.5	9.2	0	8	82.8	
11:45	19	60	10.5		4.0	2.3	.12	1.5	3	6	9.5	9.5	0	8.3	82.2	
12:00	21	60	10.3	3	4.1	2.3	.25	1.5	3	6	8.3	9.2	0	8	82.8	601870
12:15	18	60	10.4		3.3	1.8	.23	1.5	3	6	10	9.8	0	7.2	83	
12:30	19	60	9.9	2.5	4.0	2.2	.22	1.5	3	6	9.2	9.4	0	9.4	81.2	
12:45	18	60	10.7		3.6	2.1	.27	1.5	3	6	10.2	10	0	8	82	
1:00	20	60	9.4	3	4.2	2.4	.11	1.5	3	5.9	10	9	0	9.2	81.8	602626
1:15	18	60	10.7		4.3	2.5	.09	1.5	3	5.9	9.1	10	0	8	82	
1:30	17	60	10.2	3	4.3	2.3	.10	1.5	3	6	10.7	10	0	8.2	81.8	
1:45	17	60	9.0		4.2	2.4	.11	1.5	3	6	10	11.4	0	5.8	82.8	
2:00	11	60	9.6	3	4.3	2.4	.10	1.5	3	6	8.9	9	0	7	84	603390
2:15	11	50	10.8		3.2	1.9	.15	1.5	3	5.9	11.2	12	0	6	82	
2:30	11	56	10.2	3	3.5	2.0	.15	1.5	3	6	10.6	12.2	0	6.3	81.5	
2:45	19	56	10.8		3.8	1.9	.22	1.5	3	6	10	9.6	0	9.4	81	
3:00	19	56	9.3	3	4.1	2.3	.20	1.5	3	6	8.7	9	0	9.2	81.8	604158
Avg.	19.4	59.7	9.9	2.95	3.77	2.11	0.22	1.5	3	6	9.67	9.38	0	8.27	82.2	3826

Blowdown Meter: Start 439740
End 440354

Weight of coal fired 36,776 lbs.
Weight of coal sample 69.2 lbs.
Weight of refuse 13,706.4 lbs.

DATA SHEET

TEST NO. 1

Time	Pressure			Temperature, °F					Temperature, °F							
				Recorder					Thermometer							
	Drum psig	Supht psig	Ba-rom-eter	Gas to Hrt.	Gas from Hrt.	Air to Hrt.	Air from Hrt.	Feed-water	Gas from Hrt.	Gas to Hrt.	Air from Hrt.	Supht inlet	Supht Outlet	Dry	Wet	Fuel
10:00	269	252	28.20	612	450	70	320	223	409	470	320	404	493	66	54	57
10:15	270	255		610	450	67	320	225	406	460	320	404	496	65	51	
10:30	275	255		610	447	70	320	226	402	480	322	404	494	66	51	
10:45	272	256		610	445	70	322	227	402	490	330	404	492	69	54	
11:00	267	253	28.21	610	445	74	320	230	430	402	320	404	494	73	57	55
11:15	272	255		610	445	75	325	227	402	510	330	404	490	73	57	
11:30	269	254		610	445	75	320	226	404	500	330	405	494	73	57	
11:45	267	252		610	448	70	320	227	406	485	335	405	494	70	54	
12:00	265	252	28.21	610	443	70	317	228	402	505	330	404	497	69	54	54
12:15	263	253		610	450	70	323	228	402	527	330	405	500	67	53	
12:30	266	251		610	443	70	318	228	400	488	325	404	493	67	53	
12:45	268	254		610	440	70	317	230	396	508	330	404	491	64	51	
1:00	266	251	28.19	610	440	70	311	230	397	495	330	404	496	67	52	55
1:15	267	255		610	440	70	310	227	394	500	327	404	492	67	52	
1:30	265	250		610	440	70	310	227	389	490	322	400	490	68	53	
1:45	266	252		610	440	70	310	230	392	522	328	405	496	68	53	
2:00	265	252	28.18	610	440	70	310	230	395	525	320	404	493	67	53	58
2:15	267	251		610	440	70	320	230	398	494	330	401	486	67	52	
2:30	270	252		610	445	70	320	230	400	515	332	404	492	68	53	
2:45	264	250		610	445	70	316	230	400	540	325	404	496	67	53	
3:00	267	253	28.19	610	445	70	315	227	399	545	330	404	493	66	52	56
Avg.	268	252.5	28.2	610	444	70.5	317	228	399.5	603	327	404	493	68	52.6	56

Remarks: Maintaining the fire on the back part of the grate proved difficult.
Any slight variation in the boiler operation resulted in a drop in boiler pressure.

DATA SHEET

TEST NO. 2

February 2, 1951

Coal Mixture: 4 Semi-Anthracite to 1 Bituminous

Time	Control Settings				Draft, inches of water						Flue Gas Analysis					Steam
	Fuel Feed	Inlet Damper	Master	Fuel-bed Thickness	Air in Hrt.	Wind box	Furnace	Last Pass	Air out Hrt.	I. D. Fan	Board	Orsat				Integrator
											CO_2	CO_2	CO	O_2	N_2	
10:00	19	59	8.5	3	3	1.5	.35	max	max	5.8	9.5	10.3	0	7.5	82.2	622168
10:15	26	59	8.1		2.7	1.5	.25	1.47	2.6	4.8	10.5	10.6	0	7.8	81.6	
10:30	28	59	7.9	3	3	1.6	.3	max	3	5.5	9.9	10.2	.3	8.3	81.2	
10:45	29	59	8.3		3	1.5	.35	max	3	5.7	10.5	10.5	0	7.5	82	
11:00	29	59	7.5	3	2.7	1.5	.15	1.2	2.2	4.3	10.5	11	0	7.8	81.2	622940
11:15	31	59	7.7		2.9	1.6	.15	1.47	2.5	4.5	10.1	11.2	0	6.8	82	
11:30	27	59	7.9	3	2.7	1.4	.3	max	2.8	5.2	11	11.5	0	6.7	81.8	
11:45	30	59	8.5		2.9	1.5	.25	max	2.7	5.2	11	11.5	0	6.5	82	
12:00	30	59	7.9	3	2.9	1.5	.25	1.45	2.5	4.9	11.1	11	.2	7	81.8	623706
12:15	30	59	7.9		2.9	1.6	.12	1.25	2.4	4.5	10	11.5	0	7.2	81.3	
12:30	30	59	7.3	3	2.6	1.4	.12	1.3	2.4	4.6	10.5	10.3	0	8	81.7	
12:45	27	59	8.5		2.6	1.4	.25	max	3	5.6	10	10.2	.2	7.8	81.8	
1:00	30	59	7.7	3	2.5	1.3	.34	1.5	2.6	4.9	10	9.8	0	9.7	80.5	624473
1:15	36	59	7.5		3.1	1.6	.3	1.4	2.5	5	9.8	9.5	.1	8.4	82	
1:30	34	59	7	3.5	2.7	1.3	.5	max	3	5.9	9.1	9.1	0	9.1	81.7	
1:45	31	59	7.6		2.7	1.3	.3	max	2.8	5.3	9	10.7	.1	7.5	81.8	
2:00	36	59	7.5		2.9	1.6	.3	max	2.8	5.1	10.5	10.5	.1	7.0	82.4	625250
2:15	31	59	8.5		2.4	1.3	.3	1.4	2.5	4.5	11	10.5	0	6.4	83.1	
2:30	36	59	7.7	3	3	1.6	.25	1.5	3	5.6	10.5	10.4	0	7.5	82.1	
2:45	38	59	8.4		2.5	1.3	.18	1.3	2.5	4.5	10.5	10.1	0	6.9	83	
3:00	38	59	8.1	3.5	2.4	1.3	.18	1.1	2.4	4.5	11					626097
Avg.	31	59	7.9	3	2.76	1.44	.26	1.43	2.68	5.05	10.3	10.5	.05	7.6	81.8	

Blowdown Meter: Start 446085
End 449700

Weight of coal fired 35,287.4 lbs
Weight of coal sample 64.5 lbs
Weight of refuse 11,984 lbs

DATA SHEET

TEST NO. 2

Time	Pressure			Temperature, °F					Temperature, °F							
				Recorder					Thermometer							
	Drum psig	Supht psig	Barometer	Gas to Hrt.	Gas from Hrt.	Air to Hrt.	Air from Hrt.	Feed water	Gas from Hrt.	Gas to Hrt.	Air from Hrt.	Supht Inlet	Supht Outlet	Dry	Wet	Fuel
10:00	266	255	28.19	590	439	67	318	230	400	575	322	403	517	61	48	58
10:15	269	257		586	434	67	319	225	398	575	340	404	515	60	47	
10:30	267	258		585	435	63	315	231	395	575	338	403	514	56	44	58
10:45	266	255		590	435	60	312	230	396	580	338	403	514	55	43	
11:00	269	258	28.2	590	430	60	310	232	395	570	338	404	517	54	44	62
11:15	268	257		580	430	61	312	230	394	564	334	405	514	55	44	
11:30	267	257		580	428	60	308	235	388	560	334	404	512	54	45	56
11:45	265	253		582	429	61	308	231	394	570	332	403	516	56	45	
12:00	267	257	28.21	585	430	60	310	230	390	575	338	404	515	55	44	56
12:15	267	256		585	429	62	308	230	388	570	334	404	516	57	45	
12:30	269	258		581	425	64	312	230	392	570	342	404	508	61	48	53
12:45	262	255		580	435	65	320	230	404	575	338	404	515	62	48	
1:00	269	258	28.19	590	440	65	320	230	398	572	346	403	509	61	48	54
1:15	266	257		590	440	65	318	230		585	338	404	520	57	45	
1:30	267	257		590	440	63	318	230		582	338	404	520	56	45	54
1:45	268	258		590	438	70	320	225		580	339	404	516	71	54	
2:00	264	255	28.18	580	430	70	315	230		573	340	404	514	68	53	
2:15	267	255		580	430	70	315	230		562	342	403	516	71	54	
2:30	269	255		590	438	72	318	230		577	340	404	518	73	55	62
2:45	266	255		580	430	74	320	230		565	345	404	514	73	55	
3:00	267	256	28.16	580	425	74	320	230		567	344	404	516	72	54	67
Avg.	267	256.2	28.2	585	433	65.5	315	230	396	573	338	403.8	515	60.3	48	58

DATA SHEET

TEST NO. 3

February 2, 1951

Coal Mixture: 4 Semi-Anthracite to 1 Bituminous

Time	Control Settings				Draft, inches of water						Flue Gas Analysis					Steam
	Fuel Feed	Inlet Damper	Master	Fuel-bed Thickness	Air in Hrt.	Wind box	Furnace	Last Pass	Air out Hrt.	I. D. Fan	Board CO_2	Orsat CO_2	Orsat CO	Orsat O_2	Orsat N_2	Integrator
4:20	50	52	8.6	3	4	2.1	.2	1.45	3	5.8	10	10.5	.1	7.5	81.9	627011
4:35	49	53	9		3	1.5	.25	1.43	2.5	5	11	11.1	0	7.3	81.6	
4:50	52	53	9	3	3	1.5	.3	1.45	2.8	5.2	11.5					
5:05	44	52	7.5		2	1	.25	1.1	2	3.7	13					
5:20	42	55	8	3	2.2	1.2	.25	1.3	2.3	4.3	11.5					627770
5:35	42	55	8		2.2	1.1	.2	1.23	2.3	4.3	11.5	11.3	.1	7.7	80.9	
5:50	43	55	7.8	3	2.7	1.4	.2	1.45	2.8	4.8	11	10.2	0	8.6	81.2	
6:05	43	53	7		2.7	1.4	.35	1.45	3	5.5	11	11	.1	7.9	81	
6:20	45	52	7.5	3	2.3	1.3	.2	1.2	2.2	4.1	11.5					628570
6:35	46	52	7.5		2.5	1.2	.25	1.3	2	3.5	13	11.5	.1	7.6	80.8	
6:50	46	53	7.5	3	2.6	1.3	.35	1.45	2.8	5.2	11.5	12	.1	7.1	80.8	
7:05	46	53	8		2.3	1.3	.2	1.2	2.2	4	11.5					
7:20	46	53	7.5	3	2.3	1.2	.15	1.3	2.5	4.7	10.5	10.9	.2	8.3	80.6	629290
7:35	46	53	7.5		2.2	1.1	.2	1.3	2.5	4.5	11.3	10.4	0	8	81.6	
7:50	46	53	6.5	3	2	1.1	.2	1.1	2	3.5	11	13.2	0	6	80.8	
8:05	46	53	6.5		2	1	.3	1.3	2.2	4	11.8					
8:20	46	54	8	3	2	1	.35	1.3	2.1	4	11.3	13	.2	6.5	80.3	630075
8:35	42	54	8		2.2	1.1	.25	1.2	2.2	4.1	13	12	0	7.6	80.9	
8:50	42	47	7	3	2.3	1	.35	1.3	2.2	4.1	11.6	11	0	7.2	81.7	
9:05	49	48	7		2	1	.2	1.3	2.3	4.5	11.3					
9:20	47	55	8	3	1.5	.8	.22	1	1.9	3.6	12					630840
Avg.	45.5	52.8	7.7	3	2.38	1.22	.25	1.29	2.37	4.4	11.5	11.4	.085	7.44	81	

Blowdown Meter: Start 450700
End 454470

Weight of coal fired 35,611.7 lbs.
Weight of coal sample 59.1 lbs.
Weight of refuse 12,034 lbs.

DATA SHEET

TEST NO. 3

Time	Pressure			Temperature, °F Recorder					Temperature, °F Thermometer								
	Drum psig	Supht psig	Barometer	Gas to Hrt.	Gas from Hrt.	Air to Hrt.	Air from Hrt.	Feed water	Gas from Hrt.	Gas to Hrt.	Air from Hrt.	Supht inlet	Supht Outlet	Dry	Wet	Fuel
4:20	260	250	28.18	595	440	75	320	230		567	308	403	515	74	55	46
4:35	265	253		580	430	75	315	230		577	320	402	513	70	54	
4:50	265	255		585	430	75	320	230		570	320	402	514	71	55	43
5:05	270	260		575	425	75	320	234		570	338	404	513	71	54	
5:20	270	255	28.23	580	430	75	320	231		567	336	404	513	73	55	42
5:35	270	260		580	435	72	325	235		565	338	404	516	66	51	
5:50	268	258		590	440	70	328	230		580	340	403	510	65	50	44
6:05	265	255		580	435	70	320	227		565	336	404	518	64	49	
6:20	268	257	28.23	580	430	70	320	228		567	332	404	513	61	47	45
6:35	270	260		580	430	72	320	227		554	330	404	511	70	53	
6:50	265	257		575	435	72	320	226		565	330	404	516	70	53	45
7:05	265	255		585	425	72	320	227		566	332	404	516	69	53	
7:20	265	255	28.26	580	435	70	325	228		565	336	404	514	64	48	46
7:35	270	258		580	435	70	330	232		560	334	404	508	66	51	
7:50	270	260		580	430	70	320	232		560	332	404	504	70	54	46
8:05	270	260		580	430	75	320	232		554	335	405	510	70	54	
8:20	270	257	28.27	575	430	75	325	230		560	336	404	513	71	54	45
8:35	265	255		580	425	75	320	230		556	335	404	514	71	54	
8:50	270	260		580	430	73	320	230		560	334	404	510	69	54	46
9:05	270	260		580	435	70	330	230		565	342	404	512	65	49	
9:20	267	255	28.29	580	430	70	330	230		560	340	404	514	63	48	45
Avg.	267.5	256.9	28.25	581	431.6	72.5	322.3	229.9		564	332.8	403.8	512.7	68.3	52.2	44.8

DATA SHEET

TEST NO. 4
Coal Mixture: 4 Semi-Anthracite to 1 Bituminous

February 3, 1951

Time	Control Settings				Draft, inches of water						Flue Gas Analysis					Steam
	Fuel Feed	Inlet Damper	Master	Fuel-bed Thickness	Air in Hrt.	Wind box	Furnace	Last Pass	Air out Hrt.	I. D. Fan	Board CO_2	Orsat CO_2	Orsat CO	Orsat O_2	Orsat N_2	Integrator
9:45	57	50	6.5	3.5	2.2	1.2	.35	1.5	2.5	4	12.2	12	0	6.1	81.9	640233
10	57	50	8		2.1	1.2	.2	1.2	2.1	4.1	12.6	12	0	6.2	81.8	
10:15	50	50	6.5	2.5	1.9	1.1	.3	1.4	2.4	4	15	15	0	3	82	
10:30	53	50	8		2.1	1.1	0	.8	1.5	2.9	13.1	12	0	6.5	81.5	
10:45	54	50	6.9	3	2.1	1.1	.3	1.5	2.7	5.5	12	11	0	7.7	81.3	641025
11	55	50	7.9		2.1	1.2	.12	1.15	2.1	4	12.5	12.8	.2	6	81.2	
11:15	55	50	7.5	3	2.1	1.1	.22	1.1	1.7	3.3	11.5	11.5	0	7.5	81	
11:30	55	50	7.2		2.1	1.2	.2	1.2	2.4	3.9	12.4	12.8	0	5.7	81.5	
11:45	55	50	7.4	3.5	2.1	1.1	.3	1.4	2	4.4	11.5					641810
12	55	50	6.9		2.1	1.1	.2	1.2	1.8	3.3	13.5	12.8	0	5.9	81.3	
12:15	55	50	7.7	3	2.1	1.1	0	.8	1.5	3	11.5	12.6	0	6.3	81.1	
12:30	55	50	7.5		2.1	1.1	.17	1.15	2	3.8	12.2	12.5	.1	6.5	81	
12:45	57	50	8.1	3	2.2	1.2	.14	1.1	2	3.8	12.1	11.7	0	7.1	81.2	642580
1	54	50	6.9		2.2	1.2	.02	.95	1.8	3.5	12	13.4	0	5.3	81.3	
1:15	54	50	7.5	3	2.1	1.1	.15	1.15	2	3.8	12.7	11.6	0	7.6	80.8	
1:30	54	50	7.7		2.2	1.2	.15	1.15	1.7	3.5	12.5	12.2	0	6.6	81.2	
1:45	54	50	7.2	3	2.1	1.2	.13	.97	1.7	3.2	12.5	13.2	0	5.7	81.8	643372
2	52	50	7.6		2	.9	.2	.97	1.7	3.2	13	13	0	6	81	
2:15	53	50	6.9	3	2.2	1.2	.15	1.15	2	3.9	12	12.2	0	6.8	81	
2:30	53	50	7.1		2.5	1.2	.37	1.5	2.3	4.2	12.2	12.8	0	6.2	81	
2:45	54	50	7	3	2	1	.2	1.2	2.1	4	12.5	12.4	0	6.6	81	644130
Avg.	54.3	50	5.33	3	2.12	1.14	.18	1.17	2	3.77	12.75	12.48	.015	6.37	81.3	

Blowdown Meter: Start 467175
End 480270

Weight of coal fired 33,858.8 lbs.
Weight of coal sample 48.6 lbs.
Weight of refuse 10,612 lbs.

DATA SHEET

TEST NO. 4

Time	Pressure			Temperature, °F					Temperature, °F							
				Recorder					Thermometer							
	Drum psig	Supht psig	Barometer	Gas to Hrt.	Gas from Hrt.	Air to Hrt.	Air from Hrt.	Feed water	Gas from Hrt.	Gas to Hrt.	Air from Hrt.	Supht Inlet	Supht Outlet	Dry	Wet	Fuel
9:45	267	260	28.25	570	420	68	320	233		560	332	404	505	64	49	53
10	269	257		580	430	68	318	236		550	350	405	510	61	47	
10:15	267	260		570	420	68	315	230		550	346	404	512	64	49	54
10:30	272	260		570	420	68	315	235		550	352	405	508	64	49	
10:45	268	256	28.25	580	430	68	317	233		580	342	405	512	62	47	45
11	269	257		580	420	69	317	235		575	342	405	510	63	49	
11:15	271	261		576	420	70	320	230		545	350	404	504	66	50	48
11:30	270	260		580	428	69	320	230		565	346	406	514	62	48	
11:45	269	259	28.24	580	428	68	320	230		560	346	405	516	63	49	48
12	269	256		575	420	70	315	230		560	342	404	511	64	48	
12:15	271	259		580	425	69	320	232		560	346	404	514	64	48	47
12:30	270	258		587	432	69	320	233		565	350	408	510	62	47	
12:45	270	258	28.22	580	427	70	320	235		570	344	404	510	66	51	51
1	270	260		575	420	70	318	235		560	346	404	508	66	51	
1:15	270	257		580	425	70	320	232		570	350	406	504	66	51	48
1:30	267	256		577	420	70	315	235		560	348	404	509	72	57	
1:45	270	259	28.21	570	420	75	320	235		555	348	405	514	75	58	49
2	271	260		580	425	76	320	235		555	348	405	518	76	58	
2:15	268	257		579	425	76	320	235		555	348	405	514	70	55	49
2:30	265	259		585	430	79	320	235		565	348	404	512	66	52	
2:45	270	258	28.21	580	430	75	328	235		550	352	405	513	75	59	47
Avg.	269.2	258.5	28.23	578	424.5	70.8	319	233.3		559.9	346.5	404.6	510.7	66.3	51	49

Remarks: I. D. Fan cut out momentarily when ashes were pulled resulting in a positive furnace pressure.

DATA SHEET

TEST NO. 5

February 5, 1951

Coal Mixture: 4 Semi-Anthracite to 1 Bituminous

Time	Control Settings				Draft, inches of water						Flue Gas Analysis					Steam
	Fuel Feed	Inlet Damper	Master	Fuel-bed Thickness	Air in Hrt.	Wind box	Furnace	Last Pass	Air out Hrt.	I. D. Fan	Board CO_2	Orsat CO_2	Orsat CO	Orsat O_2	Orsat N_2	Integrator
2:45	54	50	7	3	1.8	2	.2	1.2	2.1	4	12.5	12.4	0	6.6	81	644130
3	55	50	8		1.9	1	.15	1.5	2	3.6	13.5	13.5	0	7	79.5	
3:15	58	48	7.4	3	2	1	.25	1.2	2	3.7	13.5	12.6	.1	6.5	80.8	
3:30	58	48	6.8		2	1	.4	1.45	2.5	4.6	13.7					
3:45	58	45	7.5	3	2	1	.2	1.1	2	3.5	12.6					644902
4	58	40	7		1.8	1	.13	1.1	2	3.5	12.5	12.2	0	7	80.8	
4:15	65	37	8	3	1.6	.8	.2	1.1	2	3.5	13.8	12.4	.1	5.9	81.6	
4:30	65	37	6.5		1.4	.7	.15	.9	1.5	2.9	15					
4:45	65	40	7	3	1.8	1	.2	1	1.6	3.1	13.7					645700
5	53	50	6		2	1	.15	1.4	2	4	13.2	14.1	.2	4.9	80.8	
5:15	50	46	9	3	2.3	1.3	.4	1.9	1.5	3	12.5	13.3	0	5.9	80.8	
5:30	53	54	6.8		1.8	1	.1	1	2	3.8	12.5	13.5	0	6.2	81.3	
5:45	46	54	6	3	1.7	.9	.1	.9	1.7	3.2	15					646516
6	46	54	7.5		2	1	.17	1.2	2.2	4	13.3	12	.8	6.3	81.3	
6:15	52	54	7	3	1.5	.7	.3	1	2	5	13.3	13.6	.1	5.4	80.9	
6:30	52	54	6.5		1.7	.9	.2	1	1.9	3.8	14.5	12.8	.3	4.2	82.7	
6:45	46	54	6.3	3	1.8	1	.2	.4	2.5	4.7	13.5					647264
7	50	54	8		2	1	.15	1	2	4	12.2	12	0	5.2	82.8	
7:15	50	54	6	3	1.8	1	.15	1.1	2.2	4	14	12.6	0	5.9	81.5	
7:30	48	54	6		1.5	.8	.1	.8	1.5	3	14	13.6	0	4.4	81	
7:45	48	54	6	3	1.6	.8	.25	1.2	2	4	13.3					648026
Avg.	54	49	7	3	1.82	.95	.20	1.02	1.97	3.46	13.45	12.9	.057	5.8	81.1	

Blowdown Meter: Start 480270
End 493650

Weight of coal fired 33,424.3 lbs.
Weight of coal sample 59.7 lbs.
Weight of refuse 9,767 lbs.

DATA SHEET

TEST NO. 5

Time	Pressure			Temperature, °F					Temperature, °F							
				Recorder					Thermometer							
	Drum psig	Supht psig	Barometer	Gas to Hrt.	Gas from Hrt.	Air to Hrt.	Air from Hrt.	Feed water	Gas from Hrt.	Gas to Hrt.	Air from Hrt.	Supht Inlet	Supht Outlet	Dry	Wet	Fuel
2:45	270	258	28.21	570	430	75	328	235		550	352	405	513	75	59	47
3:00	275	260		560	430	75	325	235		560	342	405	509	68	54	
3:15	270	257		575	425	75	325	235		555	341	404	512	73	58	45
3:30	265	257		580	430	75	320	235		553	342	404	510	72	57	
3:45	270	260	28.19	580	430	75	325	235		552	342	404	508	73	57	46
4:00	270	258		575	425	75	325	235		557	346	404	510	73	57	
4:15	267	255		575	425	75	325	234		557	348	404	508	70	55	46
4:30	272	260		570	425	75	335	230		557	346	405	503	68	51	
4:45	265	260	28.16	570	425	75	330	233		557	346	405	502	71	55	47
5:00	270	258		575	425	75	325	234		560	344	404	506	73	57	
5:15	265	260		580	430	78	325	234		550	338	405	512	74	59	48
5:30	270	260		580	430	78	330	234		540	344	405	516	74	58	
5:45	270	260	28.17	570	420	78	325	235		565	348	405	506	74	58	46
6:00	270	260		580	430	78	330	235		565	343	404	516	70	54	
6:15	275	260		585	440	75	340	232		550	352	405	510	69	53	48
6:30	275	260		580	435	75	335	233		557	350	405	510	68	52	
6:45	270	258	28.14	580	430	72	330	232		560	343	405	509	67	50	47
7:00	270	255		580	430	72	325	232		561	342	405	512	66	50	
7:15	275	265		580	430	70	330	232		550	342	405	506	65	50	48
7:30	275	262		575	425	70	330	232		561	354	406	510	64	48	
7:45	275	260	28.12	580	440	70	340	231		580	360	404	510	65	49	48
Avg.	267.4	259.2	28.16	576.5	429	74.4	328.7	233.5		560	346	404.6	509.5	70	54.5	46.4

Remarks: Slag appeared on all four walls.

DATA SHEET

TEST NO. 6

Coal Mixture: 4 Semi-Anthracite to 1 Bituminous

February 16, 1951

Time	Control Settings				Draft, inches of water						Flue Gas Analysis					Steam
	Fuel Feed	Inlet Damper	Master	Fuel-bed Thickness	Air in Hrt.	Wind box	Furnace	Last Pass	Air out Hrt.	I. D. Fan	Board	Orsat				Integrator
											CO_2	CO_2	CO	O_2	N_2	
10:10	30	50	7.9	2.5	2.4	1.5	.38	1.4	2.9	5.4	9.6	11.5	0	6.5	82	875290
10:25	30	50	9.4		2.7	1.4	.28	1.3	2.8	5.3	10	10.7	0	7.3	82	
10:40	22	50	7.8	2.5	2.2	1.3	.2	1.4	3	5.8	12.9	10.8	0	7.2	82	
10:55	24	50	7.4		2.8	1.2	.3	1.4	2.7	5	10.5	11.4	0	7.8	81.6	
11:10	16	50	8.1	3	2.4	1.3	.16	1.3	2.7	5.2	10	11.5	.1	7.3	81.1	876041
11:25	20	50	8.9		2.4	1.2	.25	1.4	2.9	5.5	10.9	11.0	.1	7.9	81	
11:40	39	50	9	3	3	1.6	.27	1.4	3	5.8	8.9	11.3	0	7.7	81	
11:55	36	50	8.3		2.7	1.4	.2	1.25	2.7	5.1	9	11.2	.1	8.	80.7	
12:10	31	50	7.9	3	2.7	1.4	.27	1.45	2,9	5	10.9	11.3	0	7.5	81.2	876809
12:25	30	50	9.5		2.5	1.4	.28	1.3	2.9	5.5	10.5					
12:40	37	50	8.5	2.5	2.6	1.4	.23	1.25	2.7	5.2	8.8	12.1	0	6.9	81	
12:55	37	50	9.1		2.6	1.4	.23	1.2	2.6	5	11.6	11	0	8	81	
1:10	34	50	9	2.5	2.7	1.5	.15	1.3	3	5.8	9.8	11.4	.1	8	80.5	877498
1:25	34	50	8.1		3.3	1.7	.15	1.4	3	6	9.8	11.8	0	7.2	81	
1:40	34	50	6.9	2.5	2.4	1.3	.21	1.05	2.2	4.2	9.6					
1:55	30	50	8.9		2.4	1.2	.2	1.2	2.6	4.9	9.4	10.5	0	8.5	81	
2:10	45	50	8.2	3	3.5	1.8	.2	1.5	3	6	8	11.1	0	7.9	81	878202
2:25	50	50	8		2.5	1.3	.2	1.3	2.4	6	10.4	10.6	0	8.2	81.2	
2:40	40	50	8.8	2.5	2.7	1.5	.3	1.5	3	6	10					
2:55	44	50	8.9		2.5	1.3	.15	1.3	2.3	4.5	10.7	12.4	.1	6.4	81.1	
3:10	28	50	9	2.5	3.1	1.7	.18	1.5	3	6	9.2					878930
Avg.	33	50	8.5	2.5	2.68	1.41	.23	1.35	2.8	5.45	Out	11.28	.03	7.55	81.2	

Blowdown Meter: Start 518133
End 518901

Weight of coal fired 34,260.6 lbs
Weight of coal sample 110 lbs
Weight of refuse 10,926 lbs

DATA SHEET

TEST NO. 6

Time	Pressure			Temperature, °F					Temperature, °F							
				Recorder					Thermometer							
	Drum psig	Supht psig	Barometer	Gas to Hrt.	Gas from Hrt.	Air to Hrt.	Air from Hrt.	Feed water	Gas from Hrt.	Gas to Hrt.	Air from Hrt.	Supht Inlet	Supht Outlet	Dry	Wet	Fuel
10:10	268	258	28.43	620	445	62	328	230		632	344	402	504	61	48	71
10:25	266	255		620	439	63	320	230		632	338	401	511	63	49	
10:40	265	251		618	435	62	320	227		635	338	403	506	62	48	70
10:55	265	251		620	440	62	320	228		640	338	403	512	61	48	
11:10	267	256	28.43	619	439	60	321	230		640	342	402	516	61	48	72
11:25	265	255		619	440	63	320	230		649	344	402	506	61	48	
11:40	262	252		620	440	63	318	228		655	340	402	511	61	48	74
11:55	265	255		620	440	63	319	226		660	340	402	510	62	48	
12:10	265	257	28.41	620	438	63	320	226		660	340	402	507	61	47	75
12:25	263	252		620	438	60	317	227		660	338	402	510	56	45	
12:40	265	255		620	440	60	320	227		660	336	402	511	60	47	75
12:55	265	255		620	438	61	320	226		660	338	402	506	60	47	
1:10	263	252	28.38	620	441	62	321	226		660	340	402	510	61	48	76
1:25	254	255		625	450	63	321	226		655	340	403	511	63	50	
1:40	266	258		620	438	63	323	225		655	340	402	513	61	48	74
1:55	266	255		620	438	63	320	226		665	338	403	508	63	48	
2:10	255	255	28.35	622	445	63	320	226		665	340	402	525	63	49	74
2:25	267	256		620	440	63	326	226		665	336	402	514	61	48	
2:40	262	252		620	441	62	322	225		665	340	402	514	64	50	73
2:55	267	256		622	440	63	325	226		665	340	403	509	62	48	
3:10	265	255	28.36	620	450	64	325	230		660	346	401	511	63	50	74
Avg.	267.5	254.5	28.4	620	441	62.1	322	227		655	339	402	512	61.7	47.8	73.5

Remarks: CO_2 recorder was not functioning properly.

DATA SHEET

TEST NO. 7

March 9, 1951

Coal Mixture: 4 Semi-Anthracite to 1 Bituminous

Time	Control Settings				Draft, inches of water						Flue Gas Analysis					Steam
											Board	Orsat				Integrator
	Fuel Feed	Inlet Damper	Master	Fuel-bed Thickness	Air in Hrt.	Wind box	Furnace	Last Pass	Air out Hrt.	I. D. Fan	CO_2	CO_2	CO	O_2	N_2	
10:15	36	50	8	2.5	2	1	.3	1.4	2.5	4.5	13.7	11.5	.1	6.3	82.1	136962
10:30	34	50	8		2.1	1	.45	1.5	2.7	4.9	14	11.3	0	6.5	82.2	
10:45	38	50	8	3	2.5	1.4	.05	1	1.7	3.5	14.5	11	0	7	82	
11:00	38	50	7.7		2	1.1	.3	1	1.7	3.2	15	13.3	.1	4.7	82	
11:15	38	50	7.3	3	2.4	1.3	.18	1.2	2.2	4.2	14.7	13	.1	5.1	81.9	137736
11:30	38	50	7.3		2.5	1.3	.18	1.2	2.2	4.2	15	13.8	0	4.4	81.8	
11:45	30	50	8	3	2	1.1	.35	1.5	3	5.7	14.2	15.4	.2	2.8	81.6	
12:00	30	50	8		3	1.6	.22	1.5	2.2	4	14.7	13	0	5.1	81.9	
12:15	32	50	8	3	2.8	1.5	.2	1.5	2.5	4.6	14.4	12.1	0	6.1	81.8	138538
12:30	32	50	7.2		2	1	.3	1.3	2.3	4.1	15	13.8	0	4.5	81.7	
12:45	34	50	7.2	3	2.4	1.2	.4	1.5	2.7	5	14	13	0	6	81	
1:00	32	50	7.3		2	1	.25	1	1.6	2.7	14	13.8	.1	5	81.1	
1:15	33	50	7.3	3	2	1.3	.1	1.2	2.2	4.1	14.6	13.4	0	5.2	81.4	139305
1:30	28	50	6.5		2	1	.35	1.4	2.3	4.1	14.7	13.5	0	5.3	81.2	
1:45	32	50	7	3	2.2	1.1	.32	1.4	2.5	4.6	13.5	12.8	0	6.2	81	
2:00	38	50	7.5		3	1.6	.15	1.5	3	5.5	12.5	12	0	6.7	81.2	
2:15	32	50	8	3	2.2	1.2	.05	1	1.9	4	15.2	12	0	6.5	81.5	140196
2:30	24	50	8		2.5	1.4	.1	1	2	4	14.3	12.8	0	5.7	81.5	
2:45	20	50	7.8	3	2.2	1.2	.26	1.3	2.4	4.5	13.9	13.2	0	5.5	81.3	
3:00	18	50	8.5		2.4	1.4	.17	1.5	3	6	14.5	13.8	0	4.7	81.5	
3:15	18	50	8	3	2.7	1.3	.35	1.5	3	6	13	12.1	0	6.6	81.3	140840
Avg.	31	50	7.6	3	2.33	1.24	.23	1.3	2.36	4.45	14.3	12.9	.03	5.5	81.5	

Blowdown Meter: Start 886300
End 892560

Weight of coal fired 34,717 lbs
Weight of coal sample 62.1 lbs
Weight of refuse 12,562 lbs

DATA SHEET

TEST NO. 7

Time	Pressure			Temperature, °F					Temperature, °F							
				Recorder					Thermometer							
	Drum psig	Supht psig	Barometer	Gas to Hrt.	Gas from Hrt.	Air to Hrt.	Air from Hrt.	Feed water	Gas from Hrt.	Gas to Hrt.	Air from Hrt.	Supht Inlet	Supht Outlet	Dry	Wet	Fuel
10:15	274	263	28.13	580	430	77	330	230		525	345	402	506	75	53	
10:30	270	261		580	430	78	330	232		540	350	402	507	76	54	
10:45	273	262		580	430	78	325	230		550	350	403	506	77	55	56
11:00	273	263		580	420	80	320	232		555	345	404	501	78	55	
11:15	272	263	28.14	580	430	80	325	230		540	345	404	506	78	55	58
11:30	273	263		580	430	80	320	228		560	340	404	506	78	55	
11:45	272	262		580	430	80	325	228		560	340	405	501	78	55	58
12:00	270	260		585	435	75	325	227		560	345	404	510	73	51	
12:15	271	261	28.14	590	440	78	320	228		570	350	403	510	73	51	59
12:30	271	261		570	420	78	320	227		570	350	403	505	75	53	
12:45	267	260		580	430	79	320	228		570	350	403	504	77	53	60
1:00	274	264		570	425	79	320	228		565	350	404	508	74	52	
1:15	273	265	28.13	579	425	79	325	227		550	340	404	504	76	53	62
1:30	274	265		580	430	78	330	215		540	350	404	506	74	50	
1:45	272	264		580	435	78	330	220		560	350	404	512	74	52	60
2:00	272	262		590	450	79	335	220		565	350	403	516	74	52	
2:15	273	264	28.13	575	430	78	325	215		570	350	404	506	72	50	62
2:30	271	261		580	430	78	330	220		570	345	403	510	80	56	
2:45	268	260		570	430	80	325	220		560	340	403	504	80	56	62
3:00	271	261		585	440	80	320	220		560	345	403	506	81	57	
3:15	266	258		580	440	80	325	220		560	345	404	506	76	53	
Avg.	271.4	262	28.14	579	431.4	79.3	325	225.2		557	346	403.5	506	76.1	53.4	60

Remarks: There seemed to be a tendency for the I.D. Fan to slow down causing a positive furnace pressure momentarily. Slag running off the side walls arched over the grate resulting in a distorted fuel bed.

DATA SHEET

TEST NO. 8

March 9, 1951 — Coal Mixture: 4 Semi-Anthracite to 1 Bituminous

Time	Control Settings				Draft, inches of water						Flue Gas Analysis					Steam
											Board	Orsat				
	Fuel Feed	Inlet Damper	Master	Fuel-bed Thickness	Air in Hrt.	Wind box	Furnace	Last pass	Air out Hrt.	I.D. Fan	CO_2	CO_2	CO	O_2	N_2	Integrator
5:00	30	50	7.5	3	2.2	1.2	.2	1.2	2	4	13	13.5	0	5.3	81.2	142180
5:15	18	50	7.5		2	1	.4	1.5	2.4	4.5	14.5	12	0	6.9	81.1	
5:30	18	50	7.5	2.5	2.3	1	.3	1.4	2	4	13.5	11	0	6	82.4	
5:45	18	50	8		2	1.1	.23	1.1	2	4	14.5					
6:00	17	50	8	3	2	1	.3	1.3	2	4.1	13.5					142960
6:15	30	50	7.5		2	1	.28	1.5	2.5	5	14	11.8	0	7.6	80.6	
6:30	38	50	8	3	2.5	1.3	.38	1.5	3	6	12.5	11.8	0	7.1	81.1	
6:45	40	50	7.5		2.5	1.2	.3	1.5	2.5	4.5	11	12	.2	7	80.8	
7:00	45	50	8	3	2.5	1.3	.2	1	1.8	3.5	12					143710
7:15	48	50	7		2.2	1.1	.35	1.5	2.6	4.9	12.5	11.6	0	7.3	81.1	
7:30	60	50	7	2.5	2.5	1.3	.35	1.5	3	5.7	12.5	11.8	0	7	81.2	
7:45	65	50	7		1.8	.8	.35	1.5	2.5	4.5	14.5	13.5	0	5.5	81	
8:00	52	60	7	3	2.6	1.5	.25	1.5	3	5.7	13.5					144470
8:15	20	50	7.3		2	1.2	.1	.7	1.3	2.8	15.5	12.7	0	6.2	81.1	
8:30	22	50	6.5	3	2.2	1.1	.35	1.5	2.5	4.8	13.5	11.7	0	7	81.3	
8:45	23	50	8.2		2	1	.3	1.2	2	4	13.5	11.5	0	7.7	80.8	
9:00	60	50	7.5	2.5	2	1	.3	1.5	2.5	4.5	11.5					145210
9:15	65	50	7.2		2	.9	.42	1.5	2.4	4.7	13	11	.3	8.1	80.6	
9:30	58	50	7.5	3	2.5	1.1	.4	1.5	2.6	5	12	11.3	0	7.3	81.1	
9:45	66	50	6		2	1	+.1	.6	1.5	3.5	15.8	11.8	.3	7.1	80.8	
10:00	64	50	7.5	3	2.3	1	.3	1.5	3	5,5	14					145960
Avg.	42	50	7.4	3	2.2	1.15	.3	1.38	2.34	4.53	13.3	11.93	.05	6.87	81	

Blowdown Meter:	Start	894920
	End	900780

Weight of coal fired	36,789.8	lbs
Weight of coal sample	61.5	lbs
Weight of refuse	12,890	lbs

DATA SHEET

TEST NO. 8

Time	Pressure			Temperature, °F					Temperature, °F								
				Recorder					Thermometer								
	Drum psig	Supht psig	Barometer	Gas to Hrt.	Gas from Hrt.	Air to Hrt.	Air from Hrt.	Feed water	Gas from Hrt.	Gas to Hrt	Air from Hrt.	Supht Inlet	Supht Outlet	Dry	Wet	Fuel
5:00	270	260	28.16	590	440	80	340	224		575	358	404	517	83	58	66
5:15	270	262		580	430	85	330	225		560	350	402	503	81	56	
5:30	273	263		580	430	85	330	225		540	348	402	503	85	58	63
5:45	270	260		580	430	85	330	225		540	348	402	508	84	58	
6:00	270	260	28.18	580	430	85	335	225		540	352	402	504	83	58	65
6:15	275	265		590	440	80	340	222		536	354	402	508	73	51	
6:30	270	260		600	450	75	340	222		560	352	402	515	73	57	58
6:45	270	260		590	440	80	335	220		559	344	402	506	78	54	
7:00	270	260	28.22	590	440	80	330	219		550	340	402	511	76	53	61
7:15	275	265		590	440	78	330	218		550	350	402	510	75	52	
7:30	270	262		590	440	75	330	218		560	356	403	514	74	54	62
7:45	275	265		585	435	70	340	220		555	362	404	506	69	49	
8:00	265	260	28.23	590	440	75	335	221		560	348	403	520	72	50	64
8:15	275	265		570	420	80	320	222		540	342	403	500	77	54	
8:30	270	260		580	430	75	330	222		530	350	402	503	76	52	64
8:45	273	263		580	430	80	330	224		530	350	402	508	76	54	
9:00	273	262	28.24	580	440	75	335	224		525	362	404	512	66	47	58
9:15	270	260		590	440	65	340	225		540	354	403	515	65	47	
9:30	270	260		585	435	70	325	226		540	342	402	509	73	52	60
9:45	270	260		580	430	70	320	225		530	352	403	509	73	52	
10:00	277	265	28.25	585	435	70	330	224		530	354	404	512	67	48	62
Avg..	272	262.2	28.22	586	435.5	77	332	222.7		545	351	402.5	509	75.2	52.8	62

DATA SHEET

TEST NO. 9

March 10, 1951

Coal Mixture: 4 Semi-Anthracite to 1 Bituminous

Time	Control Settings				Draft, inches of water						Flue Gas Analysis					Steam
	Fuel Feed	Inlet Damper	Master	Fuel-bed Thickness	Air in Hrt.	Wind box	Furnace	Last Pass	Air out Hrt.	I.D. Fan	Board CO_2	Orsat CO_2	Orsat CO	Orsat O_2	Orsat N_2	Integrator
12:35	34	50	8.7	3	3.2	1.6	.35	1.5	3	6	11.5	9.3	0	9.6	81.1	157214
12:50	40	50	8.8		2.6	1.4	.34	1.5	2.6	4.8	12.5	10.5	0	8.4	81.1	
1:05	37	50	8.1	3	3	1.6	.17	1.5	2.6	4.9	12.7	10.2	0	8.8	81	
1:20	37	50	8		2.5	1.4	.16	1.2	2.2	4.2	12	11.3	0	7.6	81.1	
1:35	30	50	8.5	3	2.6	1.4	.15	1.3	2.2	4.1	13.5	11.1	0	7.6	81.3	157989
1:50	40	50	9		3	1.5	.2	1.4	3	6	12.5	10.8	0	8.2	81	
2:05	35	50	8.8	3	3	2	.15	1.4	3	6	11.7	12.6	0	6.1	81.3	
2:20	36	50	8.5		3	1.5	.2	1.5	3	5.5	11.7	11.1	0	7.7	81.2	
2:35	36	50	8.5	3	3	1.6	.1	1.4	2.3	4.5	13.0	11.9	0	6.8	81.3	158823
2:50	30	50	9.2		3	1.5	.17	1.5	2.5	4.7	12.5	11	.1	7.5	81.4	
3:05	36	50	8.3	3	3.2	1.7	.16	1.5	2.9	5.5	12.3					
3:20	34	50	9		2.5	1.3	.2	1.35	2.3	4.3	11.9	10.8	0	8	81.2	
3:35	42	50	9	3	1.8	1.5	.25	1.5	2.7	5.1	12.7	10.7	0	7.9	81.4	159390
3:50	39	50	9		2.1	1.1	.35	1.2	1.7	3	12.3	11	0	7.8	81.2	
4:05	40	50	9.1	3	2.8	1.4	.21	1.4	2.4	5	12	11	0	7.8	81.2	
4:20	42	50	8.4		2.4	1.3	.3	1.25	2	4	14	11.5	0	7	81.5	
4:35	42	50	8.3	3	2.8	1.4	.23	1.4	3	5.8	13.7	10.4	0	8	81.6	160154
4:50	42	50	9.4		2.8	1.8	.18	1.5	3	5.9	11.6	11.6	0	7.2	81.2	
5:05	44	50	9.1	3	2.7	1.6	.25	1.5	2.9	5.6	13.4					
5:20	48	50	7.3		2.7	1.5	.13	1.5	2.6	5.1	13.6	11.4	0	7	81.6	
5:35	48	50	9.1	3	2.5	1.2	.32	1.3	2.2	4.2	12	10.7	0	8	81.3	160930
Avg.	38.6	50	8.6	3	2.72	1.49	.22	1.4	2.57	4.96	12.52	11	0	7.7	81	

Blowdown Meter: Start 919080
End 925650

Weight of coal fired	35,886	lbs
Weight of coal sample	58.7	lbs
Weight of refuse	12,851	lbs

DATA SHEET

TEST NO. 9

Time	Pressure			Temperature °F						Temperature °F						
				Recorder						Thermometer						
	Drum psig	Supht psig	Baro-meter	Gas to Hrt.	Gas from Hrt.	Air to Hrt.	Air from Hrt.	Feed water	Gas from Hrt.	Gas to Hrt.	Air from Hrt.	Supht inlet	Supht Outlet	Dry	Wet	Fuel
12:35	267	258	28.28	610	455	70	333	220		600	355	404	524	74	52	57
12:50	269	259		600	450	70	337	220		580	360	406	524	74	52	
1:05	269	260		590	440	70	325	220		580	350	406	519	76	52	57
1:20	271	261		590	435	70	325	223		570	345	406	512	76	53	
1:35	272	260	28.26	590	430	75	320	225		575	350	406	510	75	53	56
1:50	267	260		590	440	75	320	225		570	345	404	514	73	51	
2:05	268	258		600	442	70	325	225		550	340	404	514	71	50	56
2:20	269	259		600	442	70	325	225		560	345	404	515	72	50	
2:35	269	260	28,24	590	430	75	320	225		570	354	404	518	76	53	56
2:50	266	260		590	430	75	320	225		560	340	404	506	76	53	
3:05	265	257		593	435	75	320	225		540	335	404	510	77	53	58
3:20	269	257		590	435	75	325	225		550	340	404	511	76	53	
3:35	267	259	28.24	600	445	75	325	225		580	350	405	520	74	53	58
3:50	270	257		595	450	75	327	225		570	350	405	510	72	50	
4:05	265	260		600	440	75	325	223		560	340	404	518	78	54	58
4:20	270	256		595	440	77	330	222		570	350	405	509	79	56	
4:35	270	260	28.24	600	445	78	330	220		590	355	404	508	79	55	58
4:50	268	260		603	445	78	330	221		590	355	404	520	78	54	
5:05	269	259		600	445	79	330	223		580	350	404	519	76	53	58
5:20	271	258		600	445	75	332	226		590	355	405	514	74	51	
5:35	269	261	28.24	595	440	75	330	225		590	355	405	518	78	54	58
Avg.	268.6	258.9	28.25	596	441	74.1	326.3	223.4		587	348	404.6	515	75.4	52.5	57.3

DATA SHEET

TEST NO. 10

March 10, 1951 Coal Mixture: 4 Semi- Anthracite to 1 Bituminous

Time	Control Settings				Draft, inches of water						Flue Gas Analysis					Steam
	Fuel Feed	Inlet Damper	Master	Fuel-bed Thickness	Air in Hrt.	Wind box	Furnace	Last Pass	Air out Hrt.	I. D. Fan	Board CO_2	Orsat CO_2	Orsat CO	Orsat O_2	Orsat N_2	Integrator
6:30	20	50	9.2	3	2.8	1.5	.32	1.5	2.9	5.5	12	10	0	8.8	81.2	161630
6:45	38	50	8		2.4	1.5	.22	1.5	2.9	5.9	13	9.8	0	8.7	81.5	
7:00	36	50	max	3	3.3	1.7	.26	1.5	3	6	12.5	10.1	0	9.1	80.8	
7:15	22	50	9		3.1	1.7	.25	1.5	2.9	5.6	13	10.2	0	6.6	81.2	
7:30	31	50	9.7	3	2.9	1.5	.26	1.5	2.7	5.2	11	10.2	0	8.6	81.2	162615
7:45	26	50	9		3.3	1.7	.25	1.5	3	5.8	12	9.8	0	8.2	82	
8:00	38	50	9	3	3.7	1.8	.15	1.5	2.9	5.7	11.7	10	0	9	81	
8:15	38	50	8		2.7	1.3	.32	1.5	3	5.7	12	9.7	0	9.1	81.2	
8:30	38	50	8.3	3	2.8	1.5	.31	1.5	2.8	5.2	12	9.5	0	9.3	81.2	163180
8:45	26	50	8.3		2.7	1.4	.23	1.45	2.5	4.9	12.4	10	0	8.5	81.5	
9:00	32	50	8.9	3	3.2	1.6	.27	1.5	3	5.9	12	9.8	0	9.1	80.1	
9:15	36	50	8.2		3	1.5	.25	1.5	2.8	5.4	12.5	10.3	0	8.7	81	
9:30	32	50	9	3	3	1.6	.25	1.5	3	6	13	9.7	0	9.2	81.1	163930
9:45	38	50	max		3	1.4	.38	1.5	3	6	11.6	10.5	0	8.5	81	
10:00	23	50	8.1	3	2.9	1.5	.18	1.3	2.3	4.6	12	9.7	0	9.1	81.2	
10:15	9	50	7.9		2.4	1.25	.2	1.35	2.3	4.3	12	9.4	0	8.2	81.4	
10:30	21	50	8	3	3.1	1.65	.17	1.5	3	6	12.5	9.9	0	8.7	81.4	164700
10:45	28	50	7.8		3	1.4	.3	1.5	2.3	4.8	12	10	0	8.8	81.2	
11:00	26	50	8.3	3	3.5	1.8	.23	1.5	3	6	11.4					
11:15	0	50	7.8		2.5	1.2	.25	1.5	2.6	5	14.3	12	0	6.5	81.5	
11:30	0	50	8	3	2.1	1.1	.17	1.1	1.9	3.6	15	14		4.1	81.9	165460
Avg.	29.3	50	80.4	3	2.9	1.5	.24	1.53	2.75	5.38	12.4	10.4	0	8.46	81.3	

Blowdown Meter: Start 927059
End 934585

Weight of coal fired 35,222.4 lbs.
Weight of coal sample 44.9 lbs.
Weight of refuse 11,752 lbs.

DATA SHEET

TEST NO. 10

Time	Pressure			Temperature, °F					Temperature, °F							
				Recorder					Thermometer							
	Drum psig	Supht psig	Barometer	Gas to Hrt.	Gas from Hrt.	Air to Hrt.	Air from Hrt.	Feed water	Gas from Hrt.	Gas to Hrt.	Air from Hrt.	Supht Inlet	Supht Outlet	Dry	Wet	Fuel
6:30	269	259	28.24	600	445	77	330	225		575	348	402	517	78	53	58
6:45	269	260		600	450	72	333	220		580	354	404	518	72	50	
7:00	269	260		600	450	70	330	220		575	352	404	517	71	50	58
7:15	266	257		600	443	73	325	222		575	348	404	515	74	52	
7:30	266	257	28.24	600	443	73	328	222		565	350	403	514	74	51	58
7:45	266	259		600	441	73	328	223		565	346	404	510	73	51	
8:00	266	256		600	445	73	325	223		585	350	403	518	74	52	58
8:15	269	257		604	450	70	325	225		570	350	404	516	70	49	
8:30	270	259	28.24	600	440	70	325	225		565	340	404	516	75	53	58
8:45	270	260		600	440	70	325	225		565	338	404	510	72	52	
9:00	265	256		600	440	70	320	225		560	342	404	512	75	54	57
9:15	267	259		600	450	70	320	225		555	344	404	510	74	53	
9:30	268	256	28.24	605	450	67	325	225		575	350	404	520	66	48	57
9:45	268	257		605	440	67	330	225		575	348	404	524	70	50	
10:00	269	259		600	435	70	325	226		555	348	404	518	73	52	57
10:15	270	260		590	450	70	325	226		555	344	404	520	72	52	
10:30	270	260	28.24	600	445	70	330	226		565	352	405	516	72	52	58
10:45	269	260		605	440	70	330	226		555	352	406	517	72	52	
11:00	265	255		600	435	70	320	225		530	342	406	517	70	51	62
11:15	267	257		590	425	70	320	225		530	342	404	510	70	51	
11:30	270	260	28.24	580	440	70	320	225		525	336	404	512	69	51	64
Avg.	268	258	28.24	559	443	70.5	325.6	224.4		562	347	404	515.6	72.2	51.4	58.6

Remarks: A poor mixture of coal was encountered twice during the test, resulting in a high percentage of bituminous coal being fired at these times.

LOG OF RESULTS

RUN NO. 1

1. PROXIMATE ANALYSIS: (percent)	"air-dried"	"combustible"	"as fired"
Air drying loss	4.77		
Moisture	1.7		6.4
Volatile matter	13.0	17.6	12.4
Ash	24.2		23.0
Fixed carbon	61.1	82.4	58.2
2. ULTIMATE ANALYSIS:			
Carbon content	lb per lb coal		63.54
Hydrogen content	lb per lb coal		3.41
Higher heating value	btu per lb coal		11,130
3. REFUSE:			
Weight of refuse	lb		13,706.4
Weight of carbon in the refuse	lb per lb coal		0.127
Percent refuse	lb per lb coal		37.3
Percent carbon in refuse	lb per lb refuse		32.8
4. CARBON BURNED	lb per lb coal		0.5084
5. WEIGHT OF DRY FLUE GAS	lb per lb coal		13.5
6. AIR:			
Theoretical air for complete combustion	lb per lb coal		8.49
Air supplied for combustion	lb per lb coal		13.55
Percent excess air			59.6
7. SPECIFIC VOLUME OF SUPERHEATED STEAM	cubic feet per lb		2.036

LOG OF RESULTS

RUN NO. 1

8. HOURLY QUANTITIES:

Coal fired	lb per hr	36,776
Steam generated	lb per hr	49,710.6
Blowdown	lb per hr	6,140

9. EVAPORATION FACTOR: . . . . lb steam per lb coal 6.764

10. PRESSURES AND TEMPERATURES: (corrected)

Barometric pressure	in. hg.	28.2
Boiler drum pressure	psig	263
Superheater pressure	psig	246
Superheater temperature	F	493
Feedwater temperature	F	228
Fuel temperature	F	56
Dry bulb temperature	F	68
Wet bulb temperature	F	52.6

11. ENERGY BALANCE:

	btu per lb	percent
Gross efficiency	7183.3	64.5
Loss due to CO	0.0	0.0
Loss due to unburned carbon	1797.1	16.1
Loss due to dry flue gases	1218.2	10.9
Loss due to moisture in the coal	79.2	0.7
Loss due to hydrogen in the coal	379.6	3.4
Loss due to water vapor in the air	10.7	0.1
Loss due to blowdown	59.3	0.5
Radiation and unaccounted for losses	402.6	3.8
Total	11,130.0	100.0

LOG OF RESULTS

RUN NO. 2

		"air-dried"	"combustible"	"as fired"
1.	PROXIMATE ANALYSIS: (percent)			
	Air drying loss	3.92		
	Moisture	1.4		5.3
	Volatile matter	13.3	18.0	12.8
	Ash	24.5		23.6
	Fixed carbon	60.7	82.0	58.3
2.	ULTIMATE ANALYSIS:			
	Carbon content	lb per lb coal		63.9
	Hydrogen content	lb per lb coal		3.48
	Higher heating value	btu per lb coal		11,202
3.	REFUSE:			
	Weight of refuse	lb		11,984
	Weight of carbon in the refuse	lb per lb coal		0.1036
	Percent refuse	lb per lb coal		34.0
	Percent carbon in the refuse	lb per lb refuse		30.6
4.	CARBON BURNED	lb per lb coal		0.536
5.	WEIGHT OF DRY FLUE GAS	lb per lb coal		12.7
6.	AIR:			
	Theoretical air for complete combustion	lb per lb coal		8.55
	Air supplied for combustion	lb per lb coal		12.68
	Percent excess air			48.88
7.	SPECIFIC VOLUME OF SUPERHEATED STEAM	cubic feet per lb		2.071

LOG OF RESULTS

RUN NO. 2

8. HOURLY QUANTITIES:

Coal fired	lb per hr	35,287.4
Steam generated	lb per hr	50,232
Blowdown	lb per hr	3,615

9. EVAPORATION FACTOR: lb steam per lb coal 7.117

10. PRESSURES AND TEMPERATURES: (corrected)

Barometric pressure	in. hg	28.2
Boiler drum pressure	psig	262.5
Superheater pressure	psig	250
Superheater temperature	F	515
Feedwater temperature	F	230
Fuel temperature	F	58
Dry bulb temperature	F	60.3
Wet bulb temperature	F	48

11. ENERGY BALANCE:

	btu per lb	percent
Gross efficiency	7631.0	68.1
Loss due to CO	25.9	0.2
Loss due to unburned carbon	1465.9	13.1
Loss due to dry flue gases	1136.0	10.1
Loss due to moisture in the coal	65.2	0.6
Loss due to hydrogen in the coal	385.2	3.5
Loss due to water vapor in the air	9.3	0.1
Loss due to blowdown	35.6	0.3
Radiation and unaccounted for losses	448.0	4.0
Total	11,202.1	100.0

LOG OF RESULTS

RUN NO. 3

1. PROXIMATE ANALYSIS: (percent)

	"air-dried"	"combustible"	"as fired"
Air drying loss	5.75		
Moisture	1.0		6.7
Volatile matter	13.6	18.6	12.8
Ash	26.0		24.5
Fixed carbon	59.4	81.4	56.0

2. ULTIMATE ANALYSIS:

Carbon content	lb per lb coal	0.6178
Hydrogen content	lb per lb coal	0.0341
Higher heating value	btu per lb coal	10,830

3. REFUSE:

Weight of refuse	lb	12,034
Weight of carbon in the refuse	lb per lb coal	0.0929
Percent refuse	lb per lb coal	33.8
Percent carbon in the refuse	lb per lb refuse	27.6

4. CARBON BURNED	lb per lb coal	0.5244
5. WEIGHT OF DRY FLUE GAS	lb per lb coal	11.46

6. AIR:

Theoretical air for complete combustion	lb per lb coal	8.28
Air supplied for combustion	lb per lb coal	11.25
Percent excess air		34.9

7. SPECIFIC VOLUME OF SUPERHEATED STEAM	cubic feet per lb	2.065

LOG OF RESULTS

RUN NO. 3

8. HOURLY QUANTITIES:

Coal fired	lb per hr	35,611.7
Steam generated	lb per hr	
Blowdown	lb per hr	49,101

9. EVAPORATION FACTOR: . . . . . . lb steam per lb coal 6.894

10. PRESSURES AND TEMPERATURES: (corrected)

Barometric pressure	in. hg	28.25
Boiler drum pressure	psig	260
Superheater pressure	psig	250
Superheater temperature	F	512.7
Feedwater temperature	F	229.9
Fuel temperature	F	44.8
Dry bulb temperature	F	68.3
Wet bulb temperature	F	52.2

11. ENERGY BALANCE:

	btu per lb	percent
Gross efficiency	7380.7	68.2
Loss due to CO	39.6	0.4
Loss due to unburned carbon	1314.5	12.1
Loss due to dry flue gases	999.2	9.2
Loss due to moisture in the coal	83.3	0.8
Loss due to hydrogen in the coal	381.4	3.5
Loss due to water vapor in the air	7.5	0.1
Loss due to blowdown	36.7	0.3
Radiation and unaccounted for losses	587.3	5.4
Total	10,830.2	100.0

LOG OF RESULTS

RUN NO. 4

1. PROXIMATE ANALYSIS: (percent)

	"air-dried"	"combustible"	"as fired"
Air drying loss	7.1		
Moisture	.7		7.7
Volatile matter	13.4	18.2	12.5
Ash	25.4		23.6
Fixed carbon	60.5	81.8	56.2

2. ULTIMATE ANALYSIS:

Carbon content	lb per lb coal	0.6176
Hydrogen content	lb per lb coal	0.03349
Higher heating value	btu per lb coal	10,820.6

3. REFUSE:

Weight of refuse	lb	10,612
Weight of carbon in the refuse	lb per lb coal	0.0774
Percent refuse	lb per lb coal	31.4
Percent carbon in the refuse	lb per lb refuse	24.7

4. CARBON BURNED	lb per lb coal	0.5402
5. WEIGHT OF DRY FLUE GAS	lb per lb coal	10.9

6. AIR:

Theoretical air for complete combustion	lb per lb coal	8.26
Air supplied for combustion	lb per lb coal	10.66
Percent excess air		29.06

7. SPECIFIC VOLUME OF SUPERHEATED STEAM	cubic feet per lb	2.0342

LOG OF RESULTS

RUN NO. 4

8. HOURLY QUANTITIES:

Coal fired	lb per hr	33,858.8
Steam generated	lb per hr	50,804
Blowdown	lb per hr	13,105

9. EVAPORATION FACTOR: lb steam per lb coal 7.5

10. PRESSURES AND TEMPERATURES: (corrected)

Barometric pressure	in.hg	28.23
Boiler drum pressure	psig	259
Superheater pressure	psig	252.5
Superheater temperature	F	510.7
Feedwater temperature	F	233.3
Fuel temperature	F	49
Dry bulb temperature	F	66.3
Wet bulb temperature	F	51

11. ENERGY BALANCE:

	btu per lb	percent
Gross efficiency	7995.0	73.9
Loss due to CO	6.6	0.1
Loss due to unburned carbon	1095.2	10.1
Loss due to dry flue gases	1008.7	9.3
Loss due to moisture in the coal	95.1	0.9
Loss due to hydrogen in the coal	372.3	3.4
Loss due to water vapor in the air	12.4	0.1
Loss due to blowdown	134.0	1.2
Radiation and unaccounted for losses	101.3	1.0
Total	10,820.6	100.0

LOG OF RESULTS

RUN NO. 5

1. PROXIMATE ANALYSIS: (percent)

	"air-dried"	"combustible"	"as fired"
Air drying loss	6.36		
Moisture	.8		7.1
Volatile matter	14	18.6	13.1
Ash	24		22.5
Fixed carbon	61.2	81.4	57.3

2. ULTIMATE ANALYSIS:

Carbon content	lb per lb coal	0.6322
Hydrogen content	lb per lb coal	0.03487
Higher heating value	lb per lb coal	11,082

3. REFUSE:

Weight of refuse	lb	9,767
Weight of carbon in the refuse	lb per lb coal	0.0672
Percent refuse	lb per lb coal	29.2
Percent carbon in the refuse	lb per lb refuse	22.8

4. CARBON BURNED: lb per lb coal 0.565

5. WEIGHT OF DRY FLUE GAS . . . . lb per lb coal 11.01

6. AIR:

Theoretical air for complete combustion	lb per lb coal	8.47
Air supplied for combustion	lb per lb coal	10.77
Percent excess air		27.15

7. SPECIFIC VOLUME OF SUPERHEATED STEAM . . . . cubic feet per lb 2.034

LOG OF RESULTS

RUN NO. 5

8. HOURLY QUANTITIES:

Coal fired	lb per hr	33,424.26
Steam generated	lb per hr	50,700
Blowdown	lb per hr	13,380

9. EVAPORATION FACTOR: . . . . lb steam per lb coal 7.584

10. PRESSURES AND TEMPERATURES: (corrected)

Barometric pressure	in. hg	28.16
Boiler drum pressure	psig	260
Superheater pressure	psig	253
Superheater temperature	F	509.5
Feedwater temperature	F	233.5
Fuel temperature	F	46.4
Dry bulb temperature	F	70
Wet bulb temperature	F	54.5

11. ENERGY BALANCE:

	btu per lb	percent
Gross efficiency	8,077.0	72.9
Loss due to CO	25.3	0.2
Loss due to unburned carbon	950.9	8.6
Loss due to dry flue gases	948.6	8.6
Loss due to moisture in the coal	88.0	0.8
Loss due to hydrogen in the coal	389.1	3.5
Loss due to water vapor in the air	9.7	0.1
Loss due to blowdown	142.0	1.3
Radiation and unaccounted for losses	451.4	4.0
Total	11,082.0	100.0

LOG OF RESULTS

RUN NO. 6

1. PROXIMATE ANALYSIS: (percent)

	"air-dried"	"combustible"	"as fired"
Air drying loss	4.7		
Moisture	0.3		5.0
Volatile matter	14.3	18.5	13.6
Ash	22.4		21.4
Fixed carbon	63.0	81.5	60.0

2. ULTIMATE ANALYSIS:

Carbon content	lb per lb coal	0.661
Hydrogen content	lb per lb coal	0.0364
Higher heating value	btu per lb coal	11,585.7

3. REFUSE:

Weight of refuse	lb	10,926
Weight of carbon in the refuse	lb per lb coal	0.105
Percent refuse	lb per lb coal	31.8
Percent carbon in the refuse	lb per lb refuse	32.9

4. CARBON BURNED: . . . . . lb per lb coal 0.556

5. WEIGHT OF DRY FLUE GAS . . . . . lb per lb coal 12.33

6. AIR:

Theoretical air for complete combustion	lb per lb coal	8.86
Air supplied for combustion	lb per lb coal	12.126
Percent excess air		36.9

7. SPECIFIC VOLUME OF SUPERHEATED STEAM . . . . . cubic feet per lb 2.072

LOG OF RESULTS

RUN NO. 6

8. HOURLY QUANTITIES:

Coal fired	lb per hr	34,260.6
Steam generated	lb per hr	46,520
Blowdown	lb per hr	8,772

9. EVAPORATION FACTOR: lb steam per lb coal 6.789

10. PRESSURES AND TEMPERATURES: (corrected)

Barometric pressure	in. hg	28.4
Boiler drum pressure	psig	260.5
Superheater pressure	psig	249
Superheater temperature	F	512
Feedwater temperature	F	227
Fuel temperature	F	73.5
Dry bulb temperature	F	61.7
Wet bulb temperature	F	47.8

11. ENERGY BALANCE:

	btu per lb	percent
Gross efficiency	7,289.3	62.9
Loss due to C O	15.0	0.1
Loss due to unburned carbon	1,485.7	12.8
Loss due to dry flue gases	1,122.4	9.7
Loss due to moisture in the coal	60.9	0.5
Loss due to hydrogen in the coal	399.1	3.5
Loss due to water vapor in the air	7.8	0.1
Loss due to blowdown	88.9	0.8
Radiation and unaccounted for losses	1,116.9	9.6
Total	11,585.7	100.0

LOG OF RESULTS

RUN NO. 7

1. PROXIMATE ANALYSIS: (percent)

	"air-dried"	"combustible"	"as fired"
Air drying loss	4.83		
Moisture	0.6		5.4
Volatile matter	13.4	18.6	12.8
Ash	27.1		25.8
Fixed carbon	58.9	81.4	56.0

2. ULTIMATE ANALYSIS:

Carbon content	lb per lb coal	0.6178
Hydrogen content	lb per lb coal	0.0341
Higher heating value	btu per lb coal	10,830

3. REFUSE:

Weight of refuse	lb	12,562
Weight of carbon in the refuse	lb per lb coal	0.1039
Percent refuse	lb per lb coal	31.8
Percent carbon in refuse	lb per lb refuse	32.9

4. CARBON BURNED	lb per lb coal	0.5139
5. WEIGHT OF DRY FLUE GAS	lb per lb coal	10.02

6. AIR:

Theoretical air for complete combustion	lb per lb coal	8.26
Air supplied for combustion	lb per lb coal	9.85
Percent excess air		19.25

7. SPECIFIC VOLUME OF SUPERHEATED STEAM	cubic feet per lb	1.994

LOG OF RESULTS

RUN NO. 7

8. HOURLY QUANTITIES:

Coal fired	lb per hr	34,717
Steam generated	lb per hr	51,480
Blowdown	lb per hr	6,260

9. EVAPORATION FACTOR: . . . . lb steam per lb coal 7.41

10. PRESSURES AND TEMPERATURES: (corrected)

Barometric pressure	in. hg	28.14
Boiler drum pressure	psig	279.3
Superheater pressure	psig	256
Superheater temperature	F	506
Feedwater temperature	F	225.2
Fuel temperature	F	60
Dry bulb temperature	F	76.1
Wet bulb temperature	F	53.4

11. ENERGY BALANCE:

	btu per lb	percent
Gross efficiency	7,936.0	73.3
Loss due to CO	12.1	0.1
Loss due to unburned carbon	1,471.0	13.6
Loss due to dry flue gases	856.0	7.9
Loss due to moisture in the coal	66.2	0.6
Loss due to hydrogen in the coal	419.0	3.8
Loss due to water vapor in the air	6.4	0.1
Loss due to blowdown	63.0	0.6
Radiation and unaccounted for losses	0.3	0.0
Total	10,830.0	100.0

LOG OF RESULTS

RUN NO. 8

1. PROXIMATE ANALYSIS: (percent)

	"air-dried"	"combustible"	"as fired"
Air drying loss	6.83		
Moisture	0.6		7.4
Volatile matter	13.8	18.9	12.9
Ash	26.3		24.5
Fixed carbon	59.3	81.1	55.2

2. ULTIMATE ANALYSIS:

Carbon content	lb per lb coal	0.619
Hydrogen content	lb per lb coal	0.0338
Higher heating value	btu per lb coal	10,716

3. REFUSE:

Weight of refuse	lb	12,890
Weight of carbon in the refuse	lb per lb coal	0.1055
Percent refuse	lb per lb coal	36
Percent carbon in refuse	lb per lb refuse	30

4. CARBON BURNED . . . . lb per lb coal 0.5135

5. WEIGHT OF DRY FLUE GAS . . . . lb per lb coal 10.78

6. AIR:

Theoretical air for complete combustion	lb per lb coal	8.27
Air supplied for cumbustion	lb per lb coal	
Percent excess air		27.8

7. SPECIFIC VOLUME OF SUPERHEATED STEAM . . . cubic feet per lb 2.010

LOG OF RESULTS

RUN NO. 8

8. HOURLY QUANTITIES:

Coal fired	lb per hr	36,789.8
Steam generated	lb per hr	49,790
Blowdown	lb per hr	5,760

9. EVAPORATION FACTOR . . . . lb steam per lb coal 6.766

10. PRESSURES AND TEMPERATURES: (corrected)

Barometric pressure	in. hg	28.22
Boiler drum pressure	psig	266
Superheater pressure	psig	255.7
Superheater temperature	F	509
Feedwater temperature	F	222.7
Fuel temperature	F	62
Dry bulb temperature	F	75.2
Wet bulb temperature	F	52.8

11. ENERGY BALANCE:

	btu per lb	percent
Gross efficiency	7,294	68.1
Loss due to CO	21.8	0.2
Loss due to unburned carbon	1,493	13.9
Loss due to dry flue gases	932.1	8.7
Loss due to moisture in the coal	90.8	0.9
Loss due to hydrogen in the coal	373	3.5
Loss due to water vapor in the air	5.3	0.1
Loss due to blowdown	54.6	0.4
Radiation and unaccounted for losses	451.4	4.2
Total	10,716.0	100.0

LOG OF RESULTS

RUN NO. 9

1. PROXIMATE ANALYSIS: (percent)

	"air-dried"	"combustible"	"as fired"
Air drying loss	7.12		
Moisture	0.5		7.6
Volatile matter	13.2	17.9	12.3
Ash	25.4		23.6
Fixed carbon	60.9	82.1	56.5

2. ULTIMATE ANALYSIS:

Carbon content	lb per lb coal	0.6192
Hydrogen content	lb per lb coal	0.0340
Higher heating value	btu per lb coal	10,841

3. REFUSE:

Weight of refuse	lb	12,851
Weight of carbon in the refuse	lb per lb coal	0.1221
Percent refuse	lb per lb coal	35.9
Percent carbon in refuse	lb per lb refuse	34.1

4. CARBON BURNED	lb per lb coal	0.4971
5. WEIGHT OF DRY FLUE GAS	lb per lb coal	11.32

6. AIR:

Theoretical air for complete combustion	lb per lb coal	8.29
Air supplied for combustion	lb per lb coal	11.17
Percent excess air		34.74

7. SPECIFIC VOLUME OF SUPERHEATED STEAM	cubic feet per lb	2.039

LOG OF RESULTS

RUN NO. 9

8. HOURLY QUANTITIES:

Coal fired	lb per hr	35,586
Steam generated	lb per hr	48,261
Blowdown	lb per hr	6,570

9. EVAPORATION FACTOR . . . . lb steam per lb coal 6.724

10. PRESSURES AND TEMPERATURES: (corrected)

Barometric pressure	in. hg	28.25
Boiler drum pressure	psig	262
Superheater pressure	psig	254
Superheater temperature	F	515
Feedwater temperature	F	223.4
Fuel temperature	F	57.3
Dry bulb temperature	F	75.4
Wet bulb temperature	F	52.5

11. ENERGY BALANCE:

	btu per lb	percent
Gross efficiency	7,238	66.8
Loss due to CO	0	0
Loss due to unburned carbon	1,728	15.9
Loss due to dry flue gases	1,020.4	9.4
Loss due to moisture in the coal	93.8	0.9
Loss due to hydrogen in the coal	378	3.5
Loss due to water vapor in the air	5.6	0.1
Loss due to blowdown	63.7	0.6
Radiation and unaccounted for losses	313.5	2.8
Total	10,841.0	100.0

LOG OF RESULTS

RUN NO. 10

1. PROXIMATE ANALYSIS: (percent)

	"air-dried"	"combustible"	"as fired"
Air drying loss	6.24		
Moisture	0.8		7.0
Volatile matter	13.7	18.2	12.8
Ash	24.1		22.6
Fixed carbon	61.4	81.8	57.6

2. ULTIMATE ANALYSIS:

Carbon content	lb per lb coal	0.6329
Hydrogen content	lb per lb coal	0.0348
Higher heating value	btu per lb coal	11,088

3. REFUSE:

Weight of refuse	lb	11,752
Weight of carbon in the refuse	lb per lb coal	0.1072
Percent refuse	lb per lb coal	33.4
Percent carbon in refuse	lb per lb refuse	32.2

4. CARBON BURNED	lb per lb coal	0.5257
5. WEIGHT OF DRY FLUE GAS	lb per lb coal	12.62

6. AIR:

Theoretical air for complete combustion	lb per lb coal	8.48
Air supplied for combustion	lb per lb coal	
Percent excess air		47.3

7. SPECIFIC VOLUME OF SUPERHEATED STEAM	cubic feet per lb	2.036

LOG OF RESULTS

RUN NO. 10

8. HOURLY QUANTITIES:

Coal fired	lb per hr	35,222.35
Steam generated	lb per hr	49,474
Blowdown	lb per hr	7,526

9. EVAPORATION FACTOR . . . . lb steam per lb coal 7.02

10. PRESSURES AND TEMPERATURES: (corrected)

Barometric pressure	in. hg	28.24
Boiler drum pressure	psig	263
Superheater pressure	psig	253
Superheater temperature	F	515.6
Feedwater temperature	F	224.4
Fuel temperature	F	58.6
Dry bulb temperature	F	72.2
Wet bulb temperature	F	51.4

11. ENERGY BALANCE:

	btu per lb	percent
Gross efficiency	7,551.4	68.1
Loss due to CO	0.0	0.0
Loss due to unburned carbon	1,515.5	13.7
Loss due to dry flue gases	1,125.0	10.2
Loss due to moisture in the coal	86.4	0.8
Loss due to hydrogen in the coal	386.5	3.5
Loss due to water vapor in the air	6.8	0.1
Loss due to blowdown	73.5	0.7
Loss due to unaccounted for losses	342.9	2.9
Total	11,088.0	100.0

COMPOSITE DATA SHEET

Test of Steam-Generating Unit No. 6

Virginia Polytechnic Institute Heating and Power Plant

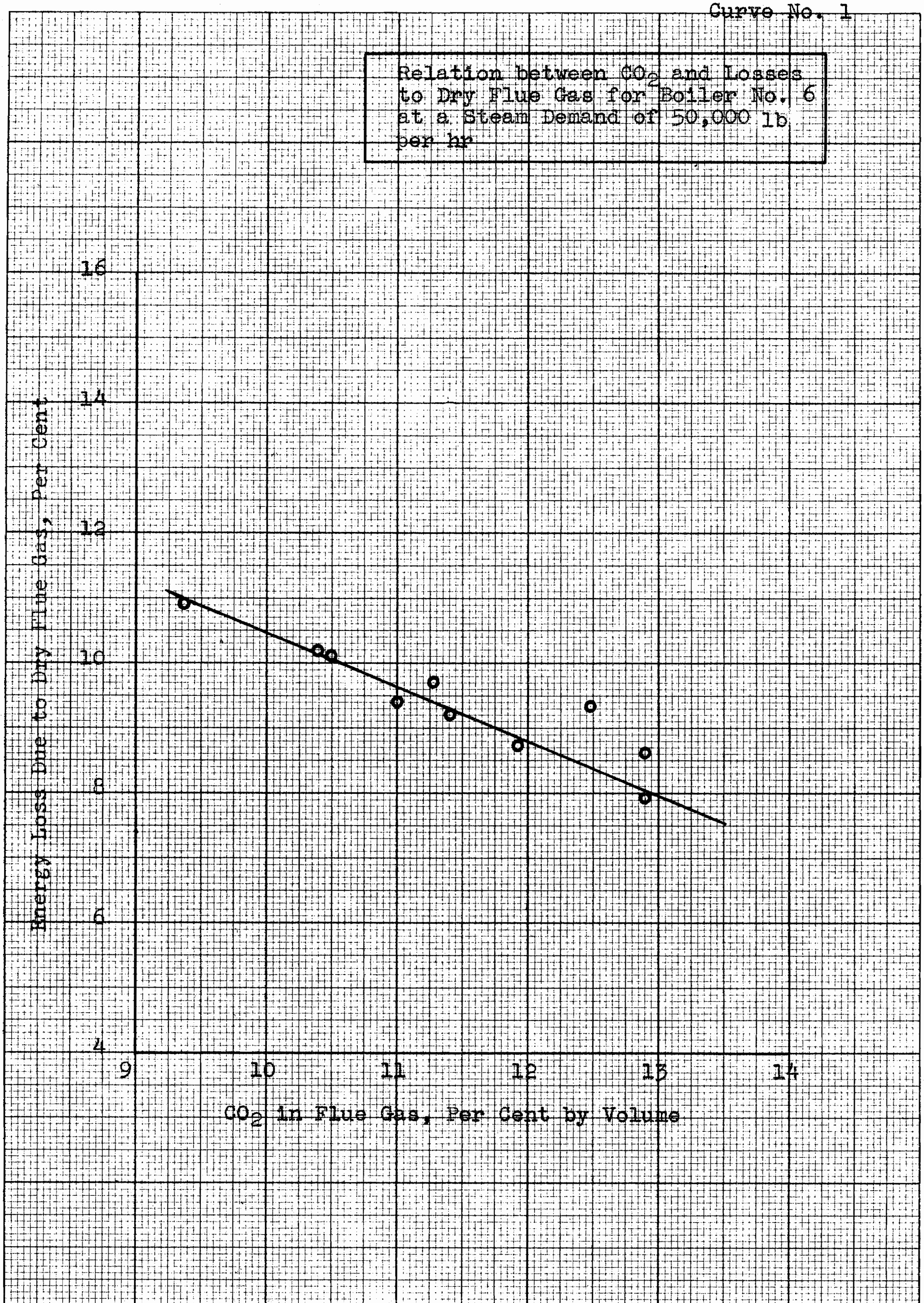
Run No.	1	2	3	4	5	6	7	8	9	10
Date, 1951	1-30	2-2	2-2	2-3	2-3	2-16	3-9	3-9	3-10	3-10
Duration of run, hr	5	5	5	5	5	5	5	5	5	5
Load										
Steam generated, lb per hr	49,751	50,232	49,101	50,804	50,700	46,520	51,480	49,790	48,261	49,474
Coal fired, lb per hr	7,355	7,058	7,122	6,772	6,685	6,852	6,943	7,358	7,177	7,044
Proximate Analysis (as fired)										
Moisture, percent	6.4	5.3	6.7	7.7	7.1	5.0	5.4	7.4	7.6	7.0
Voltile Matter, percent	12.4	12.8	12.8	12.5	13.1	13.6	12.8	12.9	12.3	12.8
Ash, percent	23.0	23.6	24.5	23.6	22.5	21.4	25.8	24.5	23.6	22.6
Fixed Carbon, percent	58.2	58.3	56.0	56.2	57.3	60.0	56.0	55.2	56.5	57.6
Heating Value, Btu per lb	11,130	11,202	10,830	10,820	11,082	11,585	10,830	10,716	10,841	11,088
Ultimate Analysis (as fired)										
Carbon, percent	63.54	63.96	61.78	61.76	63.22	66.1	61.78	61.9	61.92	63.29
Hydrogen, percent	3.41	3.48	3.41	3.34	3.48	4.95	3.4	3.38	3.4	3.48
Flue Gas, Boiler Outlet										
CO_2 Recorder, percent	9.67	10.3	11.5	12.75	13.45	---	14.3	13.3	12.52	12.4
CO_2 Orsat, percent	9.38	10.5	11.4	12.48	12.9	11.28	12.9	11.93	11	10.4
O_2 Orsat, percent	8.27	7.6	7.44	6.87	5.8	7.55	5.51	6.87	7.7	8.46
CO Orsat, percent	0.0	.05	.085	.015	.057	.03	.035	.05	0.0	0.00
N_2 Orsat, percent	82.35	81.85	81.08	81.4	81.24	81.14	81.57	81.15	81.3	81.2
Pressures and Drafts										
Barometer, in. hg	28.2	28.2	28.25	28.23	28.16	28.4	28.14	28.22	28.25	28.24
Drum, psig (corrected)	263	262.5	260	259	260	260.5	265.5	266	262	263
Supht., psig (corrected)	246	250	250	252.5	253	249	256	256	254	253
Air in Heater, in. water	3.77	2.76	2.38	2.12	1.82	2.68	2.33	2.2	2.72	2.9
Windbox, in. water	2.11	1.44	1.22	1.14	0.95	1.41	1.24	1.15	1.49	1.5
Furnace, in. water	0.22	0.26	0.25	0.18	0.2	0.23	0.23	0.3	0.22	0.24
Last Pass, in. water	1.5	1.43	1.29	1.17	1.02	1.35	1.3	1.38	1.4	1.53
Outlet Heater, in. water	3.0	2.68	2.37	2.0	1.97	2.8	2.36	2.34	2.57	2.75
I. D. Fan Outlet, in. water	6.0	5.05	4.4	3.77	3.46	5.45	4.45	4.53	4.96	5.38

COMPOSITE DATA SHEET

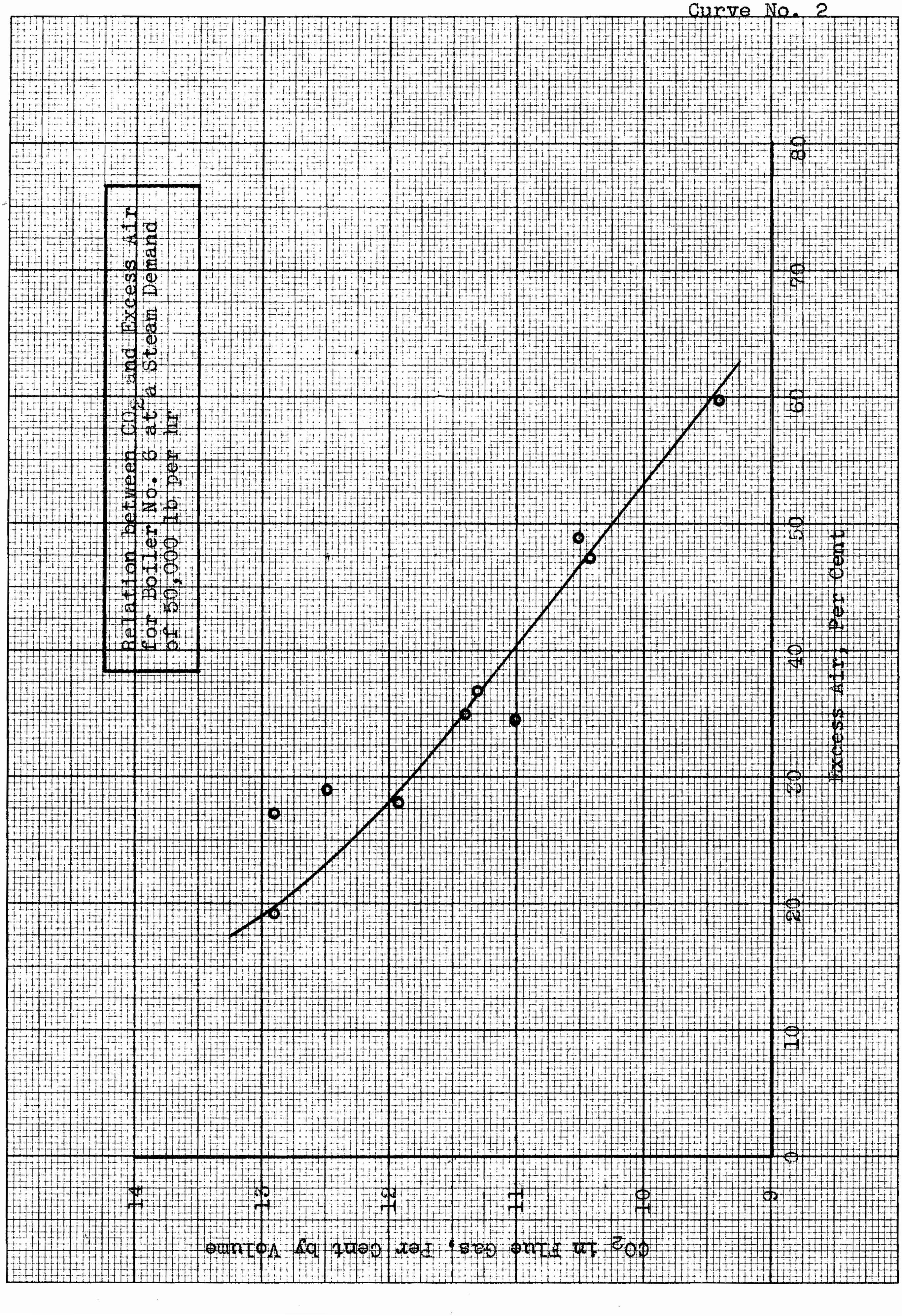
(continued)

Run No	1	2	3	4	5	6	7	8	9	10
Temperatures, F										
Gas to Heater, (recorder)	610	585	581	578	576.5	620	579	586	596	599
Gas from Heater, (recorder)	444	433	431.6	424.5	429	441	431.4	435.5	441	443
Air to Heater, (recorder)	70.5	65.5	72.5	70.8	74.4	62.1	79.3	77	74.1	70.5
Air from Heater, (recorder)	317	315	322.3	319	328.7	322	325	332	326.3	325.6
Inlet Supht. (thermo.)	404	403.8	403.8	404.6	404.6	402	403.5	402.5	404.6	404
Outlet Supht. (thermo.)	493	515	512.7	510.7	509.5	512	506	509	515	515.6
Feedwater (recorder)	228	230	229.9	233.3	233.5	227	225.2	222.7	223.4	224.4
Dry Bulb	68	60.3	68.3	66.3	70	61.7	76.1	75.2	75.4	72.2
Wet Bulb	52.6	48	52.2	51	54.5	47.8	53.4	52.8	52.5	51.4
Control Settings										
Fuel Feed	19.4	30.7	45.5	54.3	54	33	31	42	38.6	29.3
Inlet Damper	59.7	59	52.8	50	49	50	50	50	50	50
Master	9.9	7.9	7.7	7.3	7	8.5	7.6	7.4	8.6	8.4
Fuel Bed Thickness, in	3	3	3	3	3	2.5	3	3	3	3
Refuse, percent	37.3	34	33.8	31.4	29.2	31.8	36.2	36	35.9	33.4
Combustible in Refuse, percent	32.9	30.5	24.5	24.7	22.5	32.9	28.7	30.1	34.1	32.2
Evaporation per lb of coal, lbs	6.76	7.12	6.89	7.50	7.58	6.79	7.41	6.77	6.72	7.02
Energy Balance, percent										
Gross efficiency	64.5	68.1	68.2	73.9	72.9	62.9	73.3	68.1	66.8	68.1
Loss due to carbon in CO	0.0	0.2	0.4	0.1	0.2	0.1	0.1	0.2	0.0	0.0
Loss due to unburned carbon	16.1	13.1	12.1	10.1	8.6	12.8	13.6	13.9	15.9	13.7
Loss due to dry flue gases	10.9	10.1	9.2	9.3	8.6	9.7	7.9	8.7	9.4	10.2
Loss due to moisture in coal	0.7	0.6	0.8	0.9	0.8	0.5	0.6	0.9	0.9	0.8
Loss due to H_2 in coal	3.4	3.5	3.5	3.4	3.5	3.5	3.8	3.5	3.5	3.5
Loss due to water vapor in air	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Loss due to blowdown	0.5	0.3	0.3	1.2	1.3	0.8	0.6	0.4	0.6	0.7
Radiation and unaccounted	3.8	4.0	5.4	1.0	4.0	9.6	0.0	4.2	2.8	2.9
Total	100	100	100	100	100	100	100	100	100	100

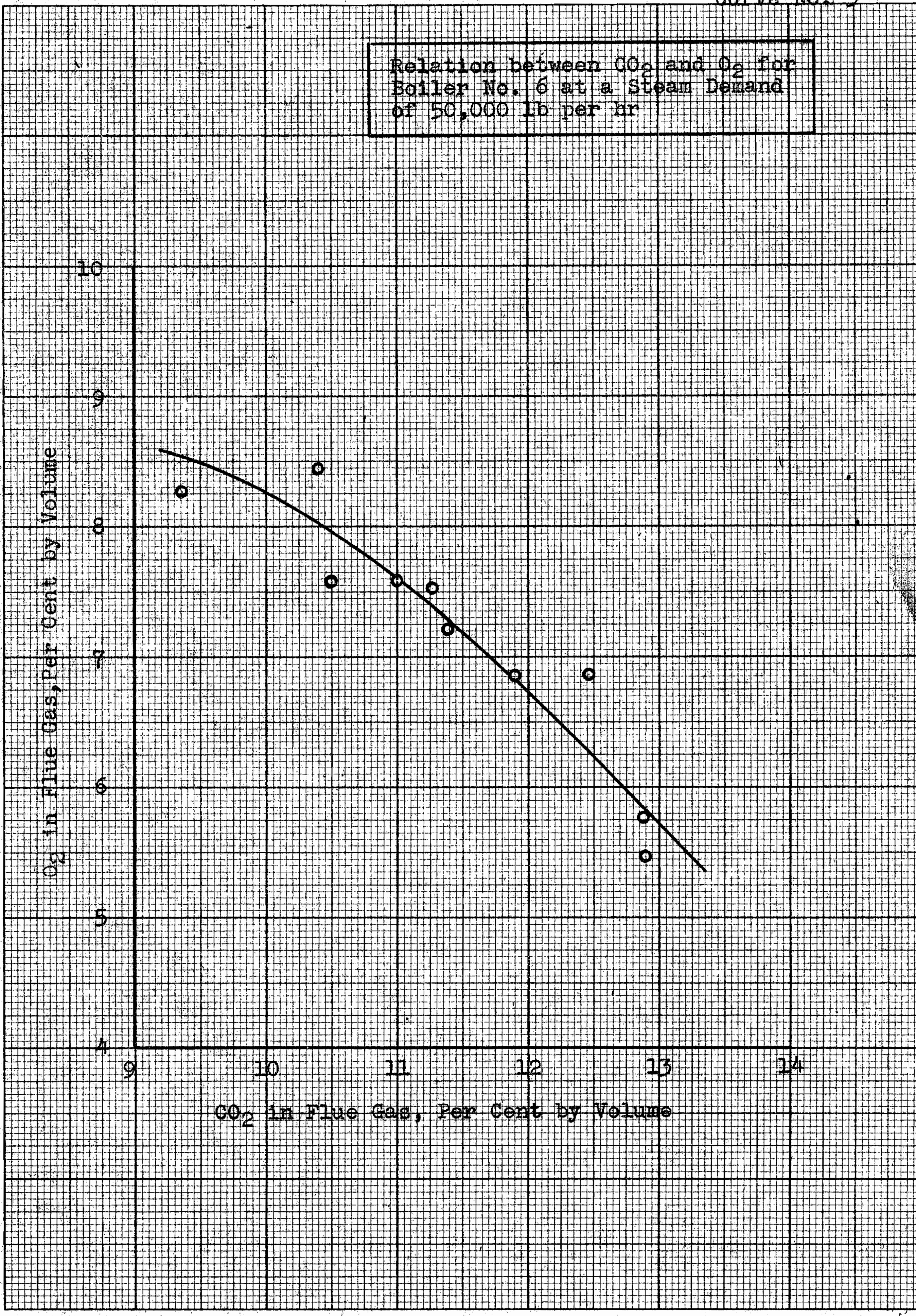
Curve No. 1


Relation between CO_2 and Losses to Dry Flue Gas for Boiler No. 6 at a Steam Demand of 50,000 lb per hr
Energy Loss Due to Dry Flue Gas, Per Cent
16
14
12
10
8
6
4
9
10
11
12
13
14
CO_2 in Flue Gas, Per Cent by Volume

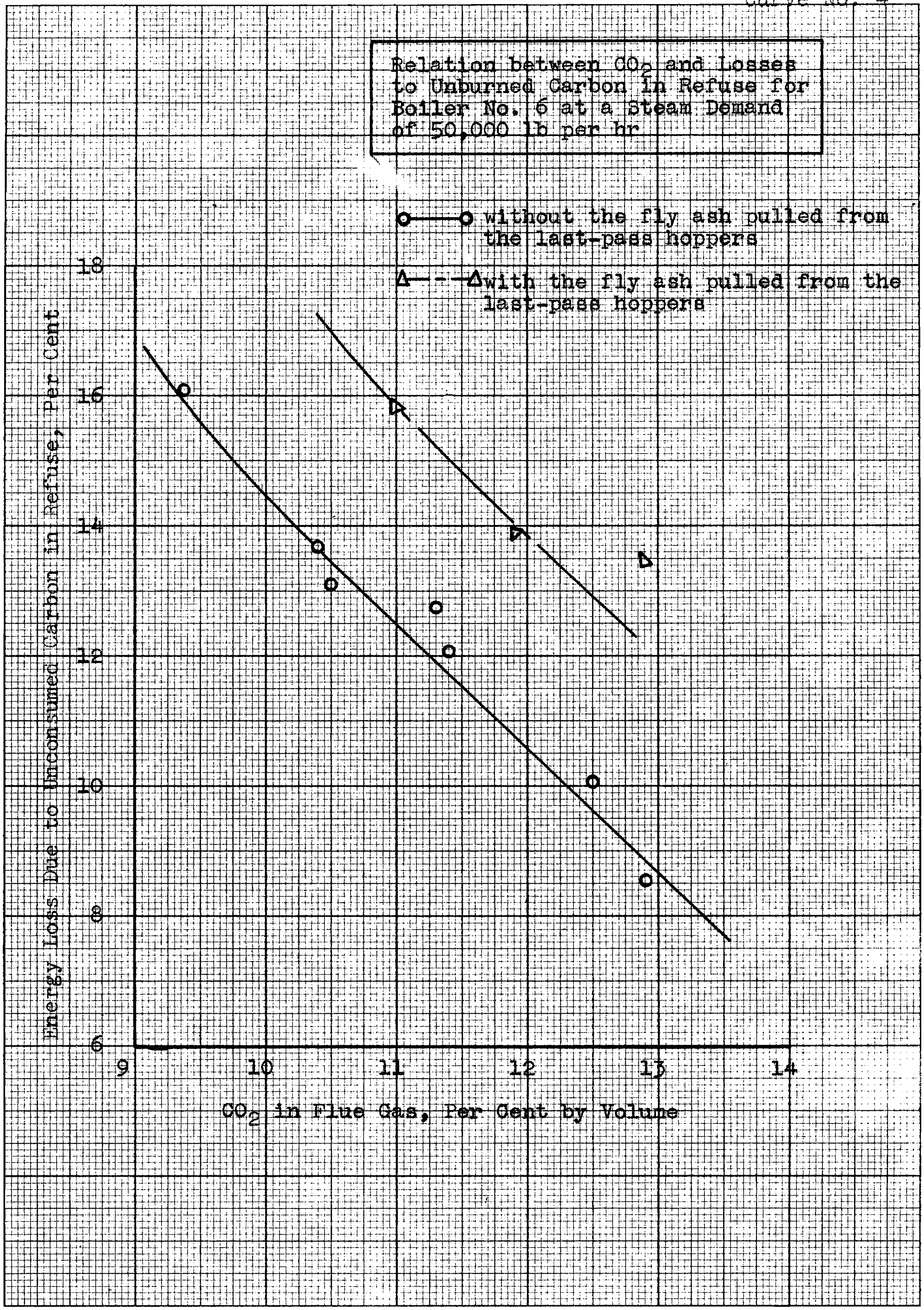
Curve No. 2


Relation between CO_2 and Excess Air
for Boiler No. 6 at a Steam Demand
of 50,000 lb per hr
Excess Air, Per Cent
CO_2 in Flue Gas, Per Cent by Volume
0
10
20
30
40
50
60
70
80
9
10
11
12
13
14

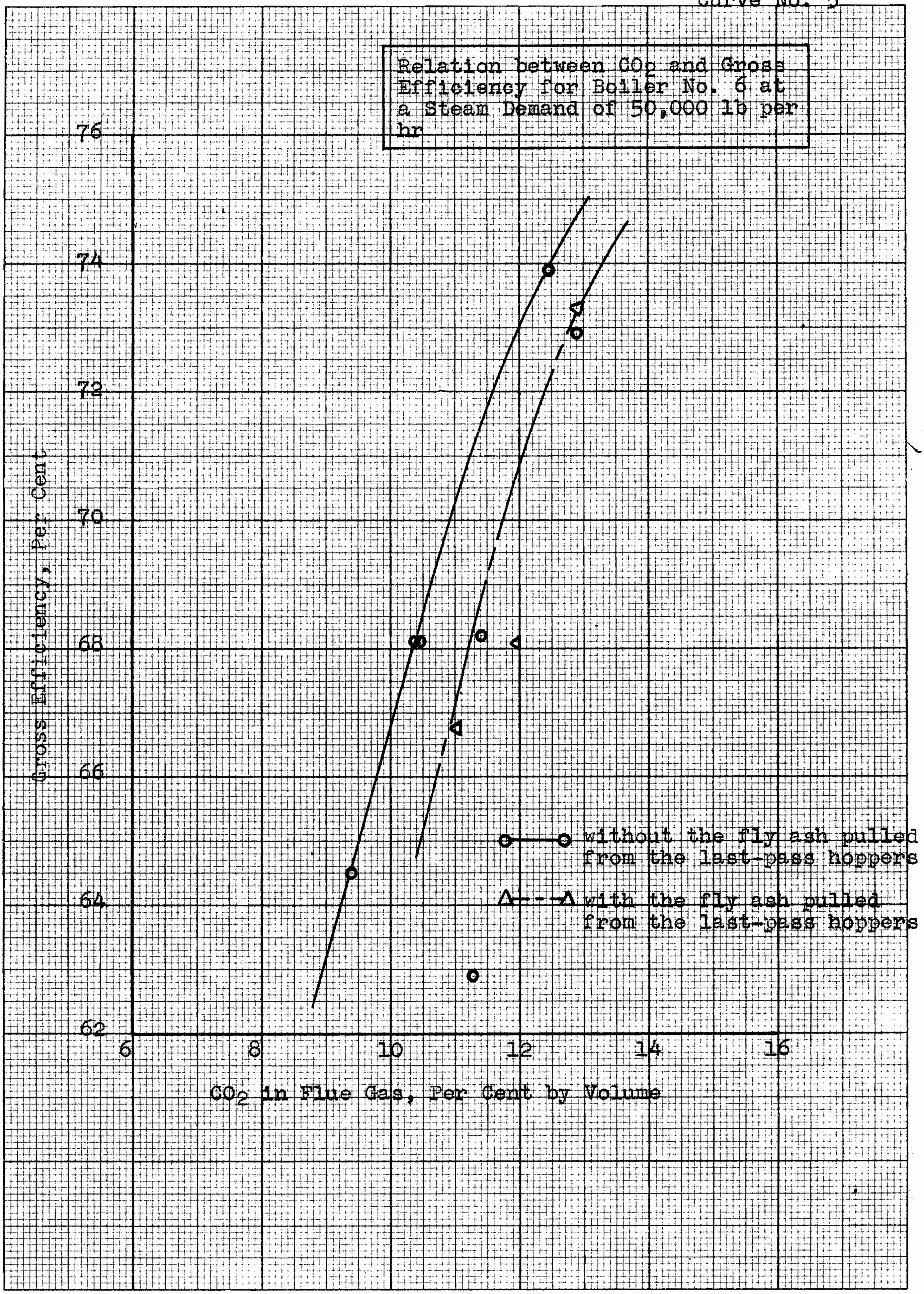
Curve No. 3


Relation between CO_2 and O_2 for Boiler No. 6 at a Steam Demand of 50,000 lb per hr
O_2 in Flue Gas, Per Cent by Volume
10
9
8
7
6
5
4
9
10
11
12
13
14
CO_2 in Flue Gas, Per Cent by Volume

Curve No. 4


Relation between CO_2 and Losses to Unburned Carbon in Refuse for Boiler No. 6 at a Steam Demand of 50,000 lb per hr
without the fly ash pulled from the last-pass hoppers
with the fly ash pulled from the last-pass hoppers
Energy Loss Due to Unconsumed Carbon in Refuse, Per Cent
18
16
14
12
10
8
6
9
10
11
12
13
14
CO_2 in Flue Gas, Per Cent by Volume

Curve No. 5


Relation between CO_2 and Gross Efficiency for Boiler No. 6 at a Steam Demand of 50,000 lb per hr
Gross Efficiency, Per Cent
76
74
72
70
68
66
64
62
6
8
10
12
14
16
CO_2 in Flue Gas, Per Cent by Volume
without the fly ash pulled from the last-pass hoppers
with the fly ash pulled from the last-pass hoppers

DISCUSSION OF RESULTS

One index to the effectiveness of the combustion of any fuel or any mixture of fuels is the percent by volume of CO_2 in the flue gas. The primary purposes of this thesis has been to determine what percentage of CO_2 would produce the most satisfactory combustion conditions in the Number Six Boiler at V. P. I. Heating and Power Plant when the fuel bed is maintained at a three inch level and a steam demand of 50,000 lb per hour is being supplied.

To obtain the desired results, tests were run on Number Six Boiler by varying the CO_2 from 9% to 13% in increments of one percent. These limiting values of CO_2 (9 and 13) were determined after the completion of part of the test runs. It was found that when the CO_2 dropped below 9%, it became difficult to maintain constantly the desired pressure of 250 psig and still supply a steam demand of 50,000 lb per hour. At a CO_2 value higher than the aforementioned operating conditions of pressure and steam demand, slag appeared on the walls of the boiler. Thus, the possibility of deterioration of the refactories forbid any further increase in CO_2 beyond 13%.

An examination of data resulting from the test in which the boiler was held at a low percentage of CO_2 showed an energy loss caused by the consequent increase of dry flue gases. As the percentage of CO_2 was raised in succeeding steps from 9% to 13%, this loss decreased. Such results are readily understandable. At low percentages of CO_2, the percentage of excess air is highest (when complete combustion is achieved); this consequently introduces a higher temperature in the exit gases and a higher weight of exit gases. Curve No. 1, which plots the loss attributed to dry flue gas against the CO_2, shows this variation graphically and corresponds generally to both actual and theoretical curves.

Curve No. 2, relating the percent CO_2 in the exit gases to the excess air, indicates an increase in the percent excess air as the percentage of CO_2 decreases. Since the addition of more air than is actually required for combustion merely dilutes the products of combustion, thus producing a lower percentage of CO_2 and a higher percentage of O_2, these results are easily understood. This line of reasoning is verified by Curve No. 3, which plots the percentage of O_2 against the percentage of CO_2. The wide size variation between the anthracite culm and the bituminous coal in the mixture used was responsible for differences in the quality of the fuel. The points recorded on Curves 2 and 3 which fail to correspond exactly to the desired curve are thus attributed to the segregation of the two fuels.

The effect of operating at decreasing percentages of CO_2 with an incurring energy loss, evidenced by an increase of carbon in the refuse, presented an unusual and interesting difference from the results obtained in most boiler operations. The ensuing portion of this discussion is concerned with test runs one through six and also test ten. (Test seven, eight, and nine will be discussed in the succeeding paragraph.) In most boilers, a decrease in the CO_2 (an increase in excess air) gives a lower energy loss due to the unconsumed carbon in the refuse; Boiler No. 6, however, showed a higher loss with a lower percentage of CO_2 than with a higher percentage. Complete combustion of the fuel with corresponding lower losses to unconsumed carbon in the refuse is expected with the higher percentages of excess air. In the case of Boiler No. 6, the lower percentages of CO_2, which gives the highest excess air, resulted in the cooling of the combustion space to a temperature below that required for complete combustion of the coal, leaving large particles of the coal on the traveling grate only partially burned. This was deduced from the condition of the refuse as it was discharged from the grate, and later verified by analysis of the refuse. At the lower percentages of CO_2 the top of the fuel bed was hot, but the lower section was cold with large black particles scattered throughout. As the CO_2 increased, the fuel bed became uniformly red as it was discharged from the grate.

The solid line in Curve No. 4 shows the relationship, in test one through six and test ten, between the energy loss to unconsumed carbon in the refuse and the percent CO_2.

In the case of test runs seven, eight, and nine, the fly ash was pulled out of the last-pass hoppers before and after each test run. This was not done to test the effect this would have on the operating characteristics of the boiler, but was used as a means to determine the reason why the calculated refuse did not equal the weighed refuse in the previous test.

When the fly ash was pulled from the last-pass hoppers before and after tests seven, eight and nine, the percentage loss due to unconsumed carbon in the refuse increased, but even so, the downward trend with an increase of CO_2 was still evident. This is shown by the broken line in Curve No. 4. Since the fly ash from these hoppers is recirculated or blown back into the boiler to be reburned, it is the belief of the authors that pulling the fly ash before and after each five hour test run removed a considerable amount of fly ash that would have been blown back into the boiler and burned. Thus, the added carbon in the fly ash increased the energy loss due to unconsumed carbon in the refuse. This is not a conclusion but only an observation made from the results of the three above-mentioned tests.

With an increase in the percent CO_2 in the flue gases, the boiler efficiency, as determined from the output and input of the boiler, showed a decided increase. This is the result of the energy losses caused by dry flue gases and unconsumed carbon in the refuse both decreasing with an increase in CO_2. The limiting factor thus becomes the temperature which the refactories can withstand without deterioration to a point where maintenance costs overbalance the increase in efficiency. In Curve No. 5, the boiler efficiency plotted against CO_2 is shown by the solid line for tests one through six and test ten. The broken line showing the variation of efficiency with CO_2 for test runs seven, eight, and nine where the fly ash was pulled from the last-pass hopper both before and after each test run. This supports the observation that pulling the fly ash from the last-pass hoppers increases the loss to carbon in the refuse, consequently reducing the efficiency. The low efficiency of test run six with its ensuing high radiation and unaccounted for losses can be attributed to a faulty functioning of the steam flow integrator. A careful check of the hourly readings on the steam flow integrator indicates that between the third and fourth hours, the integrator registered a drop in load while no drop was recorded by the load meter. Since the other points of the data supported the operating characteristics of the boiler, it was deemed desirable to consider this test with an explanation of the low efficiency.

Because of the increased flow of gas over the superheater, increasing the excess air raised the superheat temperature in all tests excepting the first run. The most feasible explanation for this case is that a coating of iron oxide had formed inside the superheater tubes. This became evident when a superheater tube erupted following the completion of the first test.

It seems advisable to note at this point the effect of the operation of the automatic combustion controls on the variation of CO_2 during the test runs. To operate the boiler at a low percentage of CO_2, it was necessary to set the fuel feed control so that a minimum amount of fuel was fed to the boiler with a maximum amount of excess air. This setting moved the master control to maximum increase; therefore any request for more fuel by the master control, in order to maintain superheat pressure, could not be met. This caused the pressure to vary at these conditions. On the other hand, with the high percentage of CO_2 a variation of the fuel, resulting in a desired decrease in the superheater pressure, would move the master control toward the maximum decrease. This in turn caused a positive pressure to build up momentarily in the boiler which consequently results in flue gases being blown out into the operating room. Since the completion of the test, it has been determined that a leak existed in the stabilizing line to the induced draft fan. This caused improper functioning of the fan and resulted in a positive pressure in the boiler. It is still the author's belief, however, that the controls are not sensitive enough and cause a continuious varying furnace pressure, though not to the extent that a positive pressure will exist.

In the first four tests, the CO_2 read on the Orsat checked within 0.5 of a percent with the CO_2 recorder, but in the last five, the recorder read 2% higher than the Orsat, the recorder being out in the sixth run.

CONCLUSION

The operating characteristics of a boiler prove that pressure can usually be maintained by the supply of fuel and air, regardless of the combustion efficiency; however, to achieve the desired efficiency the burning of the fuel must take place with a minimum amount of excess air.

Thus the criterion for boiler operation becomes percent CO_2 in the flue gas. With a CO_2 meter on the control board of the Number Six Boiler it became desirable to aquaint the boiler operators with the conditions in the boiler for a corresponding reading on the CO_2 meter.

The percent CO_2 in the flue gas of Number Six Boiler has four effects on the operating characteristics of the boiler when operating under a steam demand of 50,000 pounds per hour. First, it effects the energy loss due to dry exit gases; second, it effects the energy loss due to unconsumed carbon in the refuse; third, it effects slagging and possible deterioration of the refractory walls in the combustion space, and last, it effects the temperature of the refuse as it is discharged from the grate.

From a survey of the data obtained from the test runs a decrease in the energy loss due to dry flue gas is seen with an increase in the percentage of CO_2 in the exit gases. This indicates the desirability of operating the boiler at as high a CO_2 as possible in regard to losses occuring from dry flue gases. Similarly, the energy loss to unconsumed carbon in the refuse decreased with an increase in CO_2. Though this is contrary to results obtained in most boilers, the low CO_2, indicating a high excess air, resulted in the boiler being cooled below maximum combustion temperature; consequently, a high percentage of carbon in the refuse occured with the low CO_2. This too indicates the desirability to operate the boiler at a high percent CO_2.

The limiting factors on the maximum percent CO_2 at which the boiler can be operated, with a steam demand of 50,000 pounds per hour, occurred at 12.9 percent CO_2. At this condition the walls began to slag. This can be harmful to the walls, eventually causing their replacement, an economical loss which would outweigh the slight advantage of increased efficiency when operating at this percent CO_2 over a long period of time. The test runs were not long enough to determine the maximum effect slag would have on the boiler walls; nevertheless, it was noted during the test that slag running off the walls caused the fuel bed to become distorted and that the slagging has necessitated replacing parts of the front wall. Another economical loss would result from the increase temperature of the refuse discharged from the grate when operating at a higher CO_2. Since the refuse is manually removed from the ash pit to the vacuum ash removal system, and since there is a limit to the temperature the operator can withstand and still remove the ashes efficiently, the hotter refuse requires a longer time to be pulled from the ash pit. An additional load of 4,000 pounds of steam per hour, therefore, must be carried over the prolonged period.

The optimum percentage of CO_2 for a single boiler is that which will minimize the total losses due to dry flue gases and unconsumed carbon in the refuse and yet keep the refractory deterioration and temperature of the refuse as low as possible.

The desirable percentage of CO_2 to be maintained in Number Six Boiler for operation at a load of 50,000 pounds of steam per hour is 12 percent. This allows a maximum feasible boiler efficiency of 73 percent and corresponds to an excess air of 39 percent. It is not feasible to operate the boiler above 12 percent CO_2 because of the increase cost of maintenance due to the formation of slag on the walls and the increased time required to remove the refuse.

A CO_2 recorder is a desirable method of obtaining combustion efficiency when the same type of fuel is fired, but it requires periodical checks to maintain it in proper adjustment.

RECOMMENDATIONS

1. The Number Six Boiler at the Virginia Polytechnic Institute Heating and Power Plant, carrying a load of 50,000 pounds of steam per hour, should be at 12 percent CO_2.

2. An investigation should be made to determine the feasibility of crushing the coal to a uniform size for use in the Number Six Boiler

3. The air leaks between the front of the boiler and the operating floor should be sealed.

4. The CO_2 recorder should be periodically checked with an Orsat apparatus to maintain accuracy of the meter.

5. The result of producing a hotter combustion space in the Number Six Boiler by covering the lower portion of the water wall tubes with refractories, which would reflect the heat back into the combustion space, should be considered.

6. The controls on the I. D. Fan should be more sensitive so that the proper pressure will always be maintained in the Number Six Boiler.

BIBLIOGRAPHY

1. "Efficiency by Air Control," Power Engineering, Vol. 44, No. 12 (Dec., 1940), P. 796.

2. Luhrs, J. F., "Continuous Determination of Oxygen and Combustibles," Iron and Steel Engineer, Vol. 22, No. 5 (May, 1945).

3. Berkley, M., "Fuel and Steam Economy," The Petroleum Engineer, Vol. 19, No. 8 (May, 1948), pp. 221-227.

4. Barnard, Ellenwood, and Hirshfield, "Excess Air and CO_2 Content of Exit Gas," Heat Power Engineering, Part II, John Wiley and Sons, Inc., New York, 1935, pp. 415-421.

5. Barnard, Ellenwood, and Hirshfield, "The Burning of Coal on Grates and Stokers," Heat Power Engineering, Part II, Hohn Wiley and Sons, Inc., New York, 1935, pp. 458-473.

6. Kreisinger, Augustine, and Ovitz, "Combustion of Coal and Design of Furnaces," Bureau of Mines Bulletin, No. 135.

7. Bailey, E. G., "Limiting Factors in Reducing Excess Air," Mechanical Engineer, Vol. 48, No. 7 (July, 1926), pp. 703-709.

8. Lammers, H. B., Woodruff, E. B., "Combustion Analysis in Modern Boiler Unit," Edison Electric Institute Bulletin, Vol. 9, No. 8 (April, 1941), pp. 343-350.

9. "Recent Developments in Spreader-Stoker Firing," Engineering and Boiler House Review, Vol. 63, No. 4 (April, 1948), pp. 107-111.

VITA

Robert Louis Paret was born in Catonsville, Maryland on June 22, 1924 to parents of Pennsylvania background. When six years later his father's business took the family to Norfolk, Virginia, he was ready to enter school. It was there that he received his secondary education. In February of 1943 he graduated from Maury High School and prepared to answer a draft notice that same month.

The army took up his education where the public schools left off. There were courses at Coyne Electrical School in Chicago and then a brief sojourn at The 40 Millimeter Fire Control School located at Camp Davis, North Carolina. Soon thereafter he was shipped overseas where he saw action in the European Theater of War as a replacement to the 10th Armoured Division.

Discharged in February, 1946, Robert Paret left his duties as Staff Sergeant to return to Norfolk. There he filled in some five odd months by working for Virginia Electric and Power Company. In September, however, he packed up for four years at V.P.I. bent on a degree in Mechanical Engineering. The period proved rich in experience. Two summers' work as a junior engineer with North Carolina Pulp and Paper Company heightened his interest in the power and fuel aspect of his field.

A weekend trip to Randolph-Macon Womens College introduced him to a home town girl whom he married in

June, 1949. That same year he was elected to the honorary fraternity, in Mechanical Engineering, Pi Tau Sigma. Upon receiving his Bachelor of Science Degree in June,1950, he decided to stay on at V.P.I. for master's work in power and fuel engineering. This interest has secured for him a permanent position with North Carolina Pulp and Paper Company, the firm that he has already found stimulating.

Robert L. Purcell

William Walton Sellew, Jr., was born in Salem, Virginia, February 7, 1918. The family residence has not shifted throughout his formal education. Graduated from Andrew Lewis High School in 1936, he took a job as a machinery mechanic for the International Harvester Company located in Roanoke. Leaving this employment eighteen months later, he entered V. P. I. for four quarters of freshman work. His college career was interrupted when he went on the Norfolk and Western Railroad's payroll as a signalman helper.

With America's entrance into World War II, William Sellew enlisted in the Army Air Force. Shuttled from one service school to another, he graduated from army courses at the Airplane Mechanics School, Keesler Field, Mississippi, the Norden Bombsight Mechanics School and the Electronic Automatic Pilot School, both at Midland, Texas; and the Electronic Super-charge Control School at Minneapolis, Minnesota. During this service period, he married a Salem girl and later became the proud father of a sandy-haired baby girl. In November, 1945, he was discharged from his duties as a Technical Sergeant. Thereupon, he returned to Virginia and arranged for his re-entrance at V. P. I.

Leaving Blacksburg in 1949 with a Bachelor of Science Degree in Mechanical Engineering, he accepted a position with Ware Associates-Architects as a draftsman of heating and ventilating design and journeyed to Jackson, Mississippi.

Ten months later, the Sellews were back at V. P. I. ready to tackle further education. Upon receiving his Master of Science Degree in Power and Fuel Engineering, William Sellew will take his family to Charleston, West Virginia, where he will have a position with The Union Carbide and Carbon Corporation.

William W. Sellew, Jr.

SAMPLE CALCULATIONS

All calculations are on the "as fired basis. Calculation shown are for test run number three.

1. Approximate analysis of coal:

(1) "Air-dried" basis determined in the laboratory:

Air-dried loss	5.75%
Moisture	1.0 %
Volatile Matter..........................	13.6 %
Ash	26.0 %
Fixed Carbon (100-M-VM-A)	59.4 %

(2) "As fired" basis calculated from "air-dried" analysis:

$$\text{M. "as fired"} = \text{M. "air-dried"} \times \frac{(100-L)}{100} + L$$

$$= 1.0 \times \frac{(100-5.75)}{100} + 5.75 = 6.7\%$$

$$\text{V.M. "as-fired"} = \text{V.M. "air-dried"} \times \frac{(100-L)}{100}$$

$$= 13.6 \times (100-5.75) = 12.8\%$$

$$\text{Ash "as fired"} = \text{Ash "air-dried"} \times \frac{(100-L)}{100}$$

$$= 26.0 \times \frac{(100-5.75)}{100} = 24.5\%$$

$$\text{F.C. "as fired"} = \text{F.C. "air-dried"} \times \frac{(100-L)}{100}$$

$$= 59.4 \times \frac{(100-5.75)}{100} = 56.0\%$$

Where: L = Air-drying loss

All figures expressed in per cent

(3) "Combustible" basis calculated from "as fired" analysis:

$$\text{V.M. "combustible"} = \text{V.M. "as fired"} \times \frac{100}{(100-M-A)}$$

$$= 12.8 \times \frac{100}{(100-6.7-24.5)} = 18.6\%$$

$$\text{F.C. "combustible"} = \text{F.C. "as fired"} \times \frac{100}{100-M-A}$$

$$= 56.0 \times \frac{100}{100-6.7-24.5} = 81.4\%$$

Where: Combustible = Coal - Moisture - Ash

= Volatile Matter + Fixed Carbon = Unity

2. Properties of coal as determined from Evans' Emperical Relations:

(1) Total carbon in coal:

$$C = (0.943 - 0.242(Vc)\ )\ Cc$$

$$= (0.943 - 0.242(0.186)\ )\ 0.688 = 0.6178$$ lb carbon per coal

Where: C = fraction of carbon in coal, lb per lb coal

Cc = fraction of combustible in coal, lb per lb coal

Vc = fraction of volatile matter in combustible, lb per lb combustible

$0.943 - 0.242\ (Vc)_1$ = fraction of carbon in combustible, lb per lb combustible

(2) Total Hydrogen in coal:

$H = (0.0457 + 0.0206(Vc))Cc$

$= (0.0457 + .0206(0.186))\ 0.688 = 0.0341$ lb H2 per lb coal

Where: H = fraction of hydrogen in coal, lb per lb coal

Cc and Vc = same as calculation 2-(1)

$0.457 + 0.0206(Vc)$[1] = fraction of H_2 in combustible, lb per lb combustible

(3) Higher Heating Value of the coal:

$HHV = (16{,}160 - 2250(Vc))\ Cc$

$= (16{,}160 - 2250(0.186))\ 0.688 = 10{,}830$ Btu per lb coal

Where: HHV = higher heating value of coal, Btu per lb coal

Cc and Vc = same as calculation 2-(2)

$16{,}160 - 2250(Vc)$[1] = higher heating value of combustible, Btu per lb combustible

[1] "Emperical Relations for Coals of the United States" Evans, C.F., Table XXX, p.325, Heat-Power Engineering, Barnard, Ellenwood, Hirshfeld.

3. Net Weight of Refuse:

$$Wr = Wf \times \frac{Ac}{Ar}$$

$$= \frac{35{,}612 \times 0.245}{0.725} = 12{,}034 \text{ lb refuse}$$

Where: Wr = net weight of refuse, lb

Wf = net weight of fuel fired, lb

Ac = fraction of ash in the coal, lb ash per lb coal

Ar = fraction of ash in the refuse, lb ash per lb refuse

4. Per Cent Refuse:

$$\%R = \frac{Wf}{Wr} \times 100$$

$$= \frac{35{,}612}{12{,}034} \times 100 = 29.55\%$$

Where: %R = per cent refuse

Wf and Wr = same as calculation 3

5. Weight of Carbon in the Refuse:

$$Cr = \frac{\%R}{100} \times \frac{\%Cr}{100}$$

$$= 0.2955 \times 0.275 = 0.0929 \text{ lb Cr per lb coal}$$

Where: Cr = fraction of unconsumed carbon in the refuse, lb per lb coal

%R = per cent refuse, lb refuse per lb coal

%Cr = per cent carbon in refuse, lb carbon in refuse per lb refuse

6. Weight of Carbon Burned:

$Cb = C - Cr$

$= 0.6173 - 0.0929 = 0.5244$ lb carbon burned per lb coal

Where: Cb = fraction of carbon burned, lb per lb coal

C = fraction of total carbon, lb per lb coal

Cr = fraction of unconsumed carbon in the refuse, lb per lb coal

7. Weight of Dry Flue Gases:

$$Wg = Cb\ \frac{(11\ CO_2 + 8\ O_2 + 7(N_2 + CO))}{3(CO_2 + CO)}$$

$$= 0.5244\ \frac{(11(0.114) + 8(0.744) + 7(0.8116))}{3(0.1149)}$$

$= 11.46$ lb dry flue gases per lb coal

Where: Wg = weight of dry flue gases, lb per lb coal

Cb = fraction of carbon burned, lb per lb coal

CO_2, O_2, N_2 and CO = fractions by volume of these constituents in the exit gases

8. Weight of Air needed for Complete Combustion:

$A = 11.5(C) + 34.5(H)$

$= 11.5(0.6178) + 34.5(0.0341) = 8.28$ lb air per lb coal

Where: A = weight of air needed for complete combustion, lb per lb coal

C = fraction of total carbon in coal, lb per lb coal

H = fraction of hydrogen in coal, lb per lb coal

9. Weight of Air Supplied:

$$As = \frac{3.04\ N_2\ Cb}{(CO_2 + CO)}$$

$$= \frac{3.04\ (0.81075)\ (0.5244)}{(0.11485)} = 11.25 \text{ lb air per lb coal}$$

Where: As = weight of air supplied, lb per lb coal

Cb = fraction of carbon burned, lb per lb coal

CO_2, N_2 and CO = fraction by volume of these constituents in the exit gases

10. Per Cent Excess Air:

$$X = \frac{As - A}{A} \times 100$$

$$= \frac{11.25 - 8.28}{8.28} \times 100 = 34.9\%$$

Where: X = excess air, per cent

A = weight of air needed for complete combustion, lb per lb coal

As = weight of air supplied, lb per lb coal

11. Weight of Steam Generated:

$$Ws = \frac{M \times Csv \times Mf}{T}$$

$$= \frac{382.9 \times 0.9864 \times 650}{5} = 49{,}101 \text{ lb steam per hr}$$

Where: M = net meter reading, steam flow indicator

Csv = specific volume correction factor

= specific volume for steam flow meter calibration divided by specific volume of steam at superheater outlet

Mf = meter multiplying factor, 650 lb

Ws = steam generated, lb per hr

12. Evaporation Factor:

$$Wnf = \frac{Ws \times T}{Wf}$$

$$= \frac{49{,}101 \times 5}{35{,}612} = 6.894 \text{ lb steam per lb coal}$$

Where: Wnf = evaporation factor, lb steam per lb coal

Ws = weight of steam, lb per hr

Wf = net weight of fuel fired, lb

T = length of run, hr

13. Energy Balance:

(1) Energy absorbed by water and steam in unit:

$$E = Wnf\,(h_2 - h_1)$$

$$= 6.894\,(1268.8 - 198.2) = 7381 \text{ Btu per lb coal}$$

Where: E = energy absorbed by water and steam in unit (Gross Efficiency), Btu per lb coal

Wnf = evaporation factor, lb steam per lb coal

h_2 = enthalpy of steam leaving unit, Btu per lb steam

h_1 = enthalpy of feedwater entering unit, Btu per lb water

(2) Loss due to incomplete combustion:

$$L_{co} = \left(\frac{CO}{CO_2 + CO}\right) C_b \times 10{,}190$$

$$= \left(\frac{0.085}{0.114 + 0.085}\right) 0.5244 \times 10{,}190 = 40$$

= Btu per lb coal

Where: L_{co} = energy loss due to incomplete combustion, Btu per lb coal

C_b = fraction of carbon burned, lb per lb coal

CO_2 and CO = fraction by volume of these constituents in the exit gases

(3) Loss due to unconsumed carbon in refuse:

$$L_{cr} = C_r \times 14{,}150$$

$$= 0.0929 \times 14{,}150 = 1315 \text{ Btu per lb coal}$$

Where: L_{cr} = energy loss due to unconsumed carbon in the refuse, Btu per lb coal

C_r = fraction of carbon in refuse, lb per lb coal

(4) Loss due to dry flue gases:

$Lg = 0.24\ Wg\ (t_x - t_a)$

$= 0.24\ (11.46)\ (431.6 - 68.3) = 999$ Btu per lb coal

Where: Lg = energy loss due to dry flue gases, Btu per lb coal

Wg = same as in calculation 7

t_x = Temperature of gases leaving last heating surface, °F

t_a = temperature of air entering unit, °F

(5) Loss due to moisture in coal:

$$Lm = \frac{M}{100}\ (1089 + 0.46\ t_x - t_f)$$

$Lm = 0.067\ (1089 + 0.46(431.6) - 44.8) =$ 83 Btu per lb coal

Where: Lm = energy loss due to moisture in coal, Btu per lb coal

M = per cent moisture in coal "as fired", lb per lb coal

t_x = same as in calculation (4)

t_f = temperature of fuel "as fired", °F

(6) Loss due to H_2O formed from available H_2 :

$L_{H_2O} = 9\ H_2\ (1089 + 0.46\ t_x - t_f)$

$= 9\ (0.0341)\ (1089 + 0.46\ (431.6) - 44.8)$

$= 381$ Btu per lb coal

Where: L_{H_2O} = energy loss due to H_2O formed from available H2

H_2 = fraction of hydrogen in coal, lb per lb coal

t_x and t_f = same as in calculation 13-(5)

(7) Loss due to water vapor in the air:

Lwv = 0.46 (Wwv) (As) (tx-ta)

$= 0.46 \left(\frac{28}{7000}\right) (11.25)\ (431.6 - 68.3) =$

8 Btu per lb coal

Where: Lwv = energy loss to water vapor in the air, Btu per lb coal

Wwv = weight of water vapor, lb per lb dry air

As = weight of air supplied, lb per lb coal

t_x and t_a = same as in calculation 13-(4)

(8) Loss due to blowdown:

$Lbd = Wbd\ (h_{sw} - h_w)$

$= 0.1058\ (384.81 - 38.04) = 37$ Btu per lb coal

Where: Lbd = energy loss to blowdown, Btu per lb coal

Wbd = weight of blowdown, lb per lb coal

h_{sw} = enthalpy of saturated water at boiler drum pressure, Btu per lb water

h_w = enthalpy of saturated water at make water temperature, Btu per lb water

(9) Radiation and unaccounted for losses:

Lru = HHV – sum of items 13- (1) through 13 - (8)

$= 10{,}830 - (7381 + 40 + 1315 + 999 + 83 + 381 + 8 + 37)$

$= 586$ Btu per lb coal

Where: Lru = energy loss due to imperfect insulation and unaccounted for losses, Btu per lb coal

HHV = higher heating value of coal, Btu per lb coal