FINAL TECHNICAL REPORT
September 1, 1991 through August 31, 1992

Project Title:	Combustion Characterization of the Blend of Plant Coal and Recovered Coal Fines
ICCI Project Number:	91-1/3.1A-3P
Principal Investigator:	Shyam Singh, SS Energy Environmental International, Inc.
Other Investigators:	Dr. Alan Scaroni & Mr. Bruce Miller Combustion Laboratory, Penn State University
	Vas Choudhry Praxis Engineers, Inc.
Project Monitor:	Dr. Ken Ho, CRSC

ABSTRACT

The overall objective of this proposed research program was to determine the combustion characteristics of the blend derived from mixing a plant coal and recovered and clean coal fines from the pond. During this study, one plant coal and three blend samples were prepared as 100% plant coal, 90% plant coal/10% fines, 85% plant coal/15% fines, and 80% plant coal /20% fines with a particle size distribution of 70% passing through -200 mesh size. The plant coal and recovered coal fines were obtained from the Randolph Preparation Plant of Peabody Coal Co., Marissa, IL. These samples' combustion behavior will be examined in two different furnaces at Penn State Univeristy, i.e., a down-fired furnace and a drop-tube furnace. The down-fired furnace was used mainly to measure the emissions and ash deposition study, while the drop tube furnace was used to determine burning profile, combustion efficiency, etc.

The burning profile of the plant coal and the three blends was determined in a thermogravimetric analyzer. Results indicated slower burning of the blends due to low volatile matter and oxidized coal particles. The feedline blockage was eliminated by drying the coal samples at a moisture level of 10% or less by weight. Combustion emissions of these samples were determined in the down-fired combustor, while relative ignition temperatures were determined in the drop tube furnace. Chemical composition of ashes were analyzed to establish a correlation with their respective ash fusion temperatures.

Overall study of these samples suggested that the blended samples had combustion properties similar to the original plant coal. In other words, flames were stable under identical firing rates of approximately 200,000 Btu's/hr and 25% excess air. CO, NO_x and SO_x were similar to each other and within the experimental error. Combustion efficiency of 99^+% was achievable. Ash chemical analysis of each sample revealed that slagging and fouling should not be different from each other.

This project is funded by the U. S. Department of Energy (PETC) and by the Illinois Department of Energy and Natural Resources as part of their cost-shared programs.

EXECUTIVE SUMMARY

The overall objective of the research program is to determine the combustion behavior of plant coal and recovered coal fines blend (ignition temperature, flame stability, emissions and ash characteristics) in a laboratory scale furnace in which the time and temperature history of the burning particles are similar to the utility boiler furnace.

Plant coal and recovered coal fines were obtained from the Randolph Preparation Plant of Peabody Coal Co. in Marissa, IL. Test samples were prepared to the desired quality by Praxis Engineers. The proximate and ultimate analyses of all samples were determined by a commercial testing laboratory, located in Pennsylvania. Analyses indicated lower sulfur content in recovered cleaned coal fines than the original plant coal. Thus, blend coals had lower sulfur than the original plant coal. Particle size distribution indicated that recovered coal fines had a larger percentage of particles passing through 400 mesh.

Each sample was examined to determine the burning profiles representing the rate of weight change of particles as a function of temperature using a heating rate of 10°C/minute in an oxidizing atmosphere, in a thermogravimetric analyzer. These profiles were used for the relative combustion characteristics of the plant coal and blend. From these tests, it appeared that the blends will burn slower than the plant coal under identical operating conditions. This may be due to the lower volatile matter and oxidized coal particles.

Ignition temperatures of each sample were determined in a drop tube furnace and compared against the other coals of similar physical and chemical properties. Again, test results indicated no significant differences when compared with original plant coal.

Down fired combustor was calibrated and re-examined to ensure its functionability. Prior to any coal combustion study, the furnace was heated to 1900°F by a gaseous flame. Then each sample was fired for their combustion properties evaluation. As reported in the last quarterly report, one of the major concerns with burning these blends was related with the blockage of the feed line. This problem was solved by drying the blended fuel to below 10% moisture content by weight. These dried samples were then fired in the down-fired combustor at ~200,000 Btu/hr at 20-25% excess air to determine the flame properties, gaseous emissions, carbon conversion efficiency and ash properties. Maximum flame temperature of ~1400°C was attainable with all the samples. Emissions from the blends were similar to the original plant coal, suggesting no advantages or disadvantages from blending the fines with plant coal are expected during the combustion.

Ash fusion temperature samples and their chemical composition of ash analysis revealed no change in ash slagging and fouling properties.

OBJECTIVE

The objective of the proposed research project is to determine the combustion behavior of plant coal and recovered coal fines blend (ignition temperature, flame stability, ash behavior and unburned fuel composition) in a laboratory scale furnace in which the residence time and temperature history of the burning particles are similar to the utility boiler furnace. To understand the combustion phenomenon, the blend compositions will be varied by adding different percentages of coal fines to the plant coal by maintaining 75% of the particles passing through -200 mesh size, but the weight percentage of coal fines will not exceedd 20% in the total mixture. Praxis Engineers will guide the selection and appropriate composition of the fuel due to their experience and involvement in other similar projects. The overall combustion study will be done in the down-fired furnace and the drop tube furnace of the combustion laboratory at the Penn State University.

The objective of this study is to have three blends of plant coal mixed with recovered coal fines with approximately constant moisture content. The blends and the plant coal will be burned in the Penn State combustion laboratory furnaces at different firing rates to determine the ignition temperature, carbon burnout, ash behavior, SO_X, CO, NO_X, particulates, etc.

INTRODUCTION AND BACKGROUND

Use of recovered coal fines from a slurry effluent as a part of the blended fuel for utility will not be possible unless a systematic study is conducted to identify the variables that influence its economic advantage. The proposed research program is designed to understand the impact of the variables, i.e., the blend composition, moisture, etc. The proposed concept utilizes a mixture of certain percentage of recovered coal fines with the plant coal as a plant fines coal fuel. When this new fuel is prepared, the bulk properties of this fuel change and thus, the combustion characteristics change as well. It is not certain how this will affect the overall economics of the operation of a utility. Therefore, to systematically investigate this issue, a number of samples will be prepared and stored in a controlled manner to prevent contamination. These samples will then be analyzed using standard analytical tools. Simultaneously, a literature review of similar work done on other coal and blend will be conducted to establish the research methodology for the proposed program. In addition, a thermogravimetric analyzer will be used to determine the burning profile, while the down-fired combustor will be used to measure the emissions, flame properties and ash particles behavior.

EXPERIMENTAL PROCEDURE

Four samples (100% plant coal, 90% plant coal/10% recovered coal fines, 85% plant coal/15% recovered coal fines, 80% plant coal and 20% recovered coal fines) were prepared to meet the size distribution of 70% passing through 200 mesh. These samples were collected from the Randolph Preparaton Plant of Peabody Coal Co. in Marissa, IL. The test samples were prepared by Praxis Engineers. The physical and chemical properties of these samples were determined by a commercial testing laboratory located in Somerset, Pennsylvania. The details of the equipment and experimental procedures are described below.

Determination of Burning Profiles in a Thermogravimetric Analyzer

A burning profile is a plot of the rate at which a solid fuel sample changes weight as a function of temperature, when heated at a constant rate. The burning profiles were determined using a Perkin Elmer 7 Series Thermal Analysis System. A sample weight of 10 ±0.5 mg and a heating rate of 5 °C/min were used to prevent ignition and to minimize the temperature gradient between the furnace and the sample. The air flow rate used was 100 cm^3/min and was of regular compressed air grade. The weight change of the sample was monitored continuously until the sample attained a constant weight. Reproducibility of the burning profile using the chosen conditions was very good. The characteristic temperatures were reproducible to within ± 7°C.

Drop-Tube Reactor

Determination of the ignition temperatures of the was carried out in a vertical, electrically-heated drop-tube reactor (DTR) capable of simulating the heating rate, temperature profile, and particle residence time of a utility boiler. A schematic diagram of the reactor is shown in Figure 1. The drop-tube reactor has an alumina muffle tube which is 6.35 cm in internal diameter and 95.25 cm long with a maximum temperature zone of 50.8 cm. The tube was heated by 20 Silicon Carbide "glow bars" and can maintain a maximum temperature of 1550 °C. The preheater/injector system has two heating coils to heat the secondary air to a maximum temperature of 1100 °C prior to entering the main furnace. A Mullite flow straightener with 1.6 mm square cells was used to provide laminar flow of secondary air from the preheat/injector system. A thin stream of coal particles was introduced into the muffle tube along with a primary air stream of about 1 liter/min using a rotary coal feeder. The feeder was capable of feeding pulverized coal (80% through -200 mesh) at a feed rate of 0.33 ± 0.02 g/min. The coal feed rate was checked before the start and after the completion of a test. The mixture of coal and primary air was injected into the furnace through a water cooled injector probe. The secondary air, preheated to 800°C, was introduced at a rate of 3 liters/min. A total combustion air flow rate of 4 liters/min corresponds to about 20 - 30% excess air for a pulverized coal feed rate of 0.33 g/min used in the study.

Char was collected using a water-cooled probe placed at the furnace exit. A schematic diagram of the char collector probe is shown in Figure 2. The char /fly ash was collected on a filter and was analyzed for carbon conversion using an ash tracer technique. The govering equation used is:

$$\Delta W = 100\left[1 - \frac{Ao(100-A')}{A'(100-Ao)}\right]$$

where, ΔW = weight loss calculated on a dry-ash-free basis (% burnout)
A'= ASTM ash of the dry char
Ao= ASTM ash of the dry coal

The assumption involved in using this equation is that the mineral matter in the coal does not undergo transformations which would change the quantity of ash produced upon ashing the chars. The carbon conversion of each sample was determined twice and the mean difference between the duplicate tests was ± 1.3%. The procedure was repeated at temperatures from 400 to 700 °C at 50°C intervals. Carbon conversion at various temperatures was plotted as a function of temperature. The temperature at which the carbon conversion (on a dry basis) exceeds the dry ash- free volatile matter of the parent coal is defined as the ignition temperature of the coal.

Description of the Down-Fired Combustor

A schematic diagram of the down-fired combustor used in the study is shown in Figure 3. The total combustor height is 10.2 ft. The main radiant section of the combustor is modular and consists of four 18 inch tall and 16 inch diameter circular refractory sections. A divergent refractory cone, commonly called a quarl, is positioned on top of the circular refractory sections. The quarl is 32.5 inches high. The pulverized fuel burner is located on top of the quarl. The divergent cone top has a half-angle of approximately ten degrees and is used to minimize recirculation and swirl in the combustor. Below the four circular refractory sections is a constrictor segment and a flue gas exit section. The flue gas passes through the convective section and enters a spray chamber to decrease the gas temperature prior to existing the system via the induced draft fan and the stack.

A series of 3-inch sampling ports is located the length of the combustor. Sample ports are numbered 1 through 10 starting at the top. Gas samples were obtained at port 7. On-line gas analyzers for oxygen, carbon monoxide, carbon dioxide, sulfur dioxide, and oxides of nitrogen were used to monitor the gas composition. Wall temperatures were monitored with type-S thermocouples at eight locations along the length of the combustor.

Operating Procedure

Before the pulverized coal was fired, the combustor was preheated for 4-5 hours firing natural gas at a thermal input of 385,000 Btu/h. After heating the combustor to a suitable temperature (approximately 1300°C) and achieving a steady-state wall temperature profile, pulverized coal was slowly introduced while reducing the natural gas support. A typical steady-state wall temperature profile when firing natural gas is shown in Figure 4. Steady-state was assumed when the variation in wall temperature at any location was less than 1°C/min. The pulverized coal feed rate was controlled with an Accurate model 302 dry material feeder. The coal feed rate was adjusted to a thermal input of 200,000 Btu/h (as fired) for all the tests in this study which yields a volumetric heat release rate of 20,000 Btu/h/cu.ft. A new steady-state wall temperature profile was established in approximately an hour after the fuel switching was completed and the natural gas burner was completely shut off.

Data and Sample Collection Procedure

The tests were continued for at least 20 minutes after the new equilibrium was reached. The wall temperature at various locations was recorded every ten minutes in order to determine the temperature profile and thereby obtain information on the heat release patterns of the various coals. A gas sample was extracted from port 7 and the composition was analyzed using a bank of on-line analyzers. The data (O_2, CO_2, CO, SO_2, NO_x concentrations in the flue gas) were manually recorded every two minutes. Particulates were sampled at the same height in the combustor but from a port located 180° from the gas sampling port using a water cooled char/ash collection probe. Particulate samples were collected twice for 10 minute periods to obtain enough sample to analyze for carbon burnout (combustion efficiency) and to check reproducibility.

Technical Work Completed

Analysis of the Coals

The proximate analysis of the Plant Coal and blends of Plant Coal and Recovered Coal (in three different proportions) is given in Table 1. The values given in the table are average of triplicate analyses. The calorific values of the samples are also listed in Table 1 and were determined just prior (on the same day) to firing the fuels in the down-fired combustor. Table 2 lists the ash fusion temperatures of the Plant Coal and the blends. The results show that the differences between the Plant Coal and the blends are minor and would not be predicted to cause potential problems.

Fuel Handling Characteristics

Although the differences between the Plant Coal and the blends are minor, the moisture content of the Plant Coal and blends of Plant Coal and Recovered Coal (as received basis) was sufficiently high to cause handing problems in the coal feeding systems. During initial combustion tests in the down-fired combustor, coal agglomerated at the end of the screw and slugs of coal dropped into the entrainer, which caused fluctuations in the gas composition in the combustor resulting in unstable operation. After experiencing these coal feeding problems, the samples were air-dried to reduce the moisture content to about 4-5%. Subsequent to air-drying no handling problems were encountered. The feeding rates of the air-dried coal samples were within ± 0.1 lb/min of the required feed rate over a test period.

Burning Profiles

The burning profiles of 100% Plant Coal and blends of 90, 85 and 80% Plant Coal with 10, 15 and 20% Recovered Coal, respectively, were determined in a thermogravimetric analyzer (TGA).

Typically, a burning profile can be divided into several stages, which are represented by various characteristic temperatures. The ' Initial Temperature' (IT) is the temperature at which the sample weight loss exceeds 0.1%/min. The ' Peak Temperature' (PT) is the temperature at which the burning rate is the maximum. The ' Burnout Temperature' (BT) represents the temperature at which the rate of weight loss is less than 1%/min.

In general, the height of the oxidation peak is proportional to the intensity of the reaction and the area under the peak is approximately proportional to the total heat liberated.

Samples with high weight loss at low temperatures are easier to ignite and burn. Such fuels are also expected to burn more completely in the lower part of a boiler furnace releasing most of their heat in this region. The initial temperature has been correlated with carbon burnout in a drop- tube reactor.

The burning profiles of the Plant Coal and the blends of the Plant Coal and Recovered Coal are shown in Figures 5-8. Figures a and b on each Figure show the reproducibility of the test. The characteristic temperatures are summarized in Table 3. These are average values of at least three determinations on each sample. The reproducibility of the characteristic temperatures is ± 7°C. The burning profile of the Plant Coal shows a single peak with a narrow range between the Initial and the Burnout Temperatures, indicating that most of the burning would take place in a short residence time in a combustion chamber. The burning profiles of the blends of plant and Recovered Coal show multiple peaks indicating that there are various components in the coals that react at different temperatures. As the percent Recovered Coal in the blend increases, an initial peak indicative of oxidized material appears. This peak may be due to the decomposition of various oxygen-containing functional groups which release CO_2 and H_2O upon heating. This peak may not, therefore, indicate the presence of exothermic reactions which release heat. The burnout temperatures of the blends are higher than that for the Plant Coal indicating that longer residence times are needed for combustion of the Recovered Coal. The difference between the burnout temperature and the initial temperature also increased as the percent Recovered Coal in the blend increased (broader peaks) indicating that the release of heat occurs over a longer period of time. This indicates that combustion chambers designed for short residence times may not be suitable for achieving complete burnout of the blends.

In summary, the burning profile data indicated that the Recovered Coal seems to be oxidized, hence there is a difference in the burning profile when this coal is blended with the Plant Coal. The burning of the blends occurs over a longer period of time than that for the Plant Coal.

Determination of Relative Ignition Behavior

Since the ignition temperature in a practical flame is not well defined, a method which simulates some of the conditions in the practical situation should give a fair ranking of coals in terms of ignitability. As previously indicated, a drop-tube reactor was used to determine the relative ignition temperature of the fresh and the crop coals. The ignition temperature of a coal is also a function of particle size. Various particles exist in a standard pulverized grind with particle sizes ranging from 1-100 µm likely to ignite at various temperatures. Therefore, in the current study an average relative ignition behavior was determined. The carbon conversion was obtained by operating the DTR at various temperatures ranging from 400 to 700°C and the relative average ignition temperature was arbitrarily defined as the temperature at which the carbon conversion exceeded the dry-ash-free proximate volatile matter. The relative ignition temperatures were determined by interpolating between the weight loss values obtained at 50 °C intervals.

The relative ignition temperatures as determined in the DTR are given in Table 4. Relative ignition temperatures ranged from 672 to 708°C. These temperatures indicate that the differences between the Plant Coal and its blends with Recovered Coal are not significant enough to alter the combustion performance.

Combustion Behavior in a Pilot-Scale Down-Fired Combustor

The combustion behavior of the Plant Coal and its blends with Recovered Coal was evaluated using the wall temperature profiles and carbon burnouts obtained in the down-fired combustor. The firing rate used was 200,000 Btu/h and the coal feed rate was adjusted to the same thermal input for all the samples. Any temperature variation in the combustor when the coal sample is changed can be attributed to the change in heat release pattern (reactivity). The flue gas composition was monitored to evaluate the differences in the emissions levels of SO_2 and NO_x.

The wall temperature profile before fuel switching is shown in Figure 4. The profile at steady state operation after switching to the Plant Coal is shown in Figure 9. Figure 9 shows the wall temperature at various axial locations in the combustor measured at 10 minute intervals. The variation in wall temperature at any given location during the 30-minute test period was minimal, indicating that the combustor achieved steady state. The wall temperature profiles for the Plant Coal when blended with Recovered Coal in the proportion of 90, 85, and 80% are given in Figures 10-12. A comparison of the average wall temperature profile for the Plant Coal and its blends with the Recovered Coal is given in Figure 13. The comparison indicates that the gradient of the profile is similar for all the samples. The slight shift in the profile towards lower temperatures for the blends of 90% Plant Coal and 10% Recovered Coal and 85% Plant Coal and 15% Recovered Coal is possibly due to a slight change in the excess air levels. Figure 13 indicates that the heat release rates and patterns (reactivity) of the samples are similar. These profiles confirm the earlier observations that the differences in combustion behavior between the Plant Coal and blends with Recovered Coal are minimal. The carbon burnout (combustion efficiency) obtained for the Plant Coal and blends with Recovered Coal is given in Table 5. The combustion efficiency obtained in the combustor for the Plant Coal and the blends was between 99.4 and 99.8%, indicating no significant difference when the Plant Coal was blended with Recovered Coal under the conditions used in the study.

Variations in oxygen and carbon dioxide concentrations and in carbon monoxide, sulfur dioxide and oxides of nitrogen during the test period when firing 100% Plant Coal are shown in Figures 14 and 15, respectively. Similar plots are given for other blends in Figures 16-21. Table 5 shows the gas composition data averaged over the test period for the Plant Coal and blends. Figures 23 and 24 compare the average concentrations of O_2, CO_2, and CO, SO_2 and NO_x, respectively for various coal blends. The differences in the sulfur emissions values are insignificant because the sulfur contents of the parent coal (3.52% on dry basis) and the Recovered Coal (2.96% on dry basis) are similar and the Recovered Coal is only blended in small proportions.

Conclusions and Recommendations

The high moisture content of the Recovered Coal caused coal feeding problems which was eliminated by air-drying the coal samples. The burning profile data indicated that the Recovered Coal appears to be oxidized and hence, there is a difference in the burning profile when this coal is blended with the Plant Coal. The difference between the burnout temperature and the initial temperature increased as the percent Recovered Coal in the blend increased (broader peaks) indicating that the release of heat release occurs over a longer period of time and that combustion chamber designed for short residence times may not be suitable for achieving complete burnout of the blends. Howefver, the combustion efficiency data obtained from the down-fired combustor at higher temperatures indicated that the residence time in the down-fired combustor was sufficient to achieve the similar combustion efficiency for the Plant Coal and the blends. The relative ignition temperatures, as determined in a drop-tube reactor, corroborated the observations. Hence, it can be concluded that the differences in the combustion behavior of the Plant Coal and the blends of Plant Coal and Recovered Coal (up to 80% Plant Coal and 20% Recovered Coal) was not significantly different the combustion behavior under the conditions used in the study. The ash fusion temperatures show that the differences between the Plant Coal and the blends are minor and would not be predicted to cause potential problems.

Table 1. Proximate Analysis of the Samples (as received, wt%)

Coal	Moisture	Volatile Matter	Fixed Carbon	Ash	Calorific Value(air-dried samples)
100% Plant Coal	11.9	33.4	43.9	10.8	11,903
90% Plant Coal and 10% Recovered Coal	13.2	32.9	43.7	10.2	11,932
85% Plant Coal and 15% Recovered Coal	13.4	32.5	44.0	10.1	12,012
80% Plant Coal and 20% Recovered Coal	13.7	32.2	44.3	9.9	11,824

Table 2. Ash Fusion Temperatures (°F)

	Reducing Conditions				Oxidizing Conditions			
Coal	IT	ST	HT	FT	IT	ST	HT	FT
100% Plant Coal	2076	2109	2147	2270	2284	2327	2409	2547
90% Plant Coal and 10% Recovered Coal	2075	2109	2146	2240	2280	2319	2405	2550
85% Plant Coal and 15% Recovered Coal	2071	2099	2138	2222	2275	2313	2374	2472
80% Plant Coal and 20% Recovered Coal	2059	2098	2154	2220	2278	2308	2397	2443

IT = Initial Deformation Temperature
ST= Softening Temperature
HT= Hemispherical Temperature
FT= Flow Temperature

Table 3. Summary of Burning Profiles

Coal	Initial Temperature (°C)	Peak Temperature (°C)	Burnout Temperature (°C)	Peak Rate of Weight Change(%/min)
Plant Coal	307.6	453.9	560.7	16.5
90% Plant Coal and 10% Recovered Coal	315.6	480.4	636.5	20.8
85% Plant Coal and 15% Recovered Coal	306.6	464.2	630.7	21.7
80% Plant Coal and 20% Recovered Coal	308.9	468.5	636.2	20.0

Table 4. Relative Ignition Temperatures

Coal	Relative Ignition Temperature (°C)
100% Plant Coal	686
90% Plant Coal and 10% Recovered Coal	677
85% Plant Coal and 15% Recovered Coal	672
80% Plant Coal and 20% Recovered Coal	708

Table 5. Summary of the Combustion Performance

Coal	Firing Rate (Btu/h)	Combustion Efficiency (%)	O2 (%)	CO (ppm)	CO2 (%)	SO2 (ppm)	NOx (ppm)	SO2 @ 3% O2 (ppm)	NOx @3% O2 (ppm)
100% Plant Coal	199,970	99.86	5.52	121	13.18	1926.8	629.4	2241.2	732.0
90% Plant Coal	199,383	99.71	4.78	0	13.65	1902.4	812.4	2111.1	901.5
85% Plant Coal	200,480	99.84	4.78	0	13.78	1840	827.7	2041.9	918.5
80% Plant Coal	201,126	99.43	5.26	158	13.5	1848	612.5	2113.3	700.4

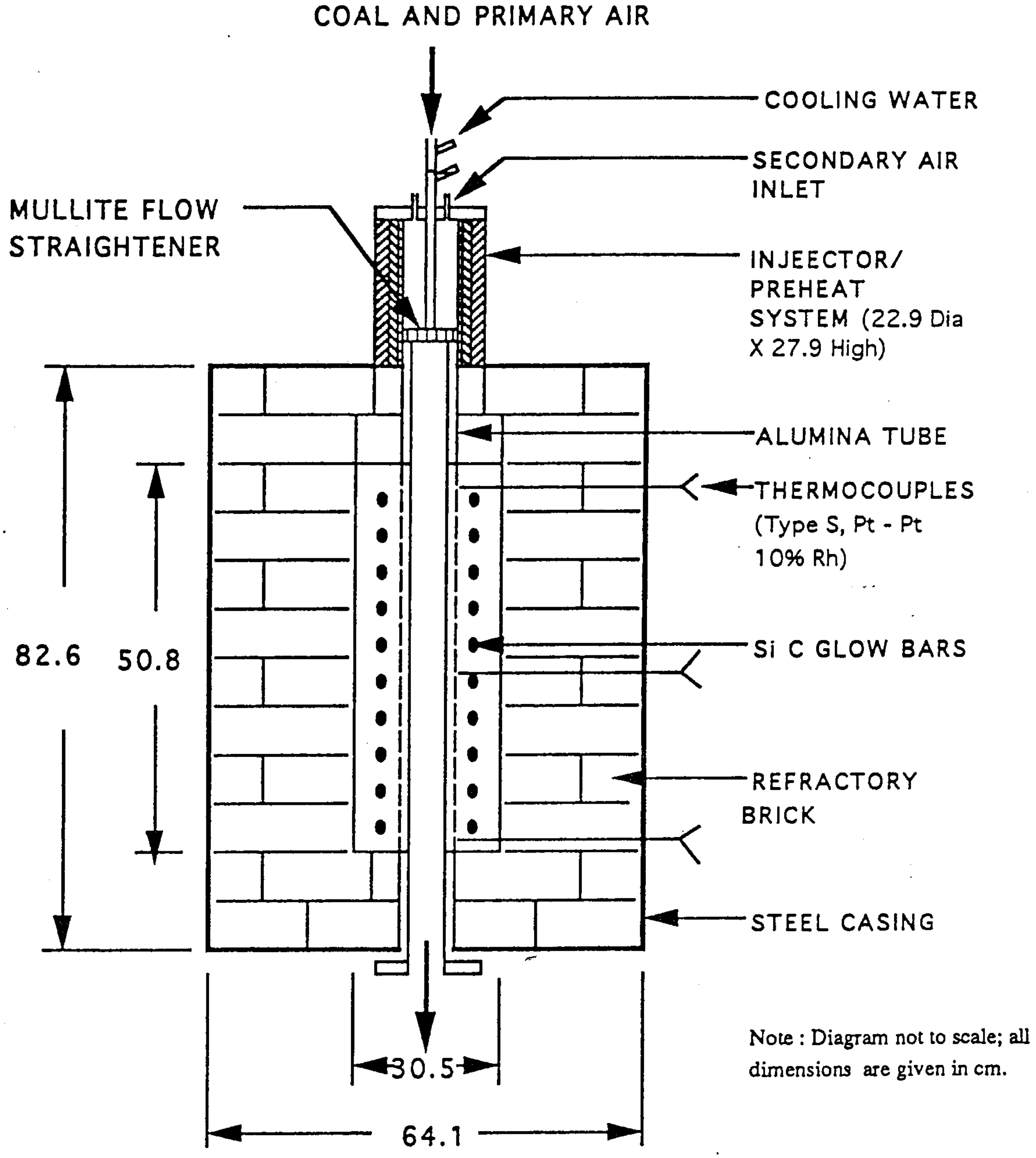
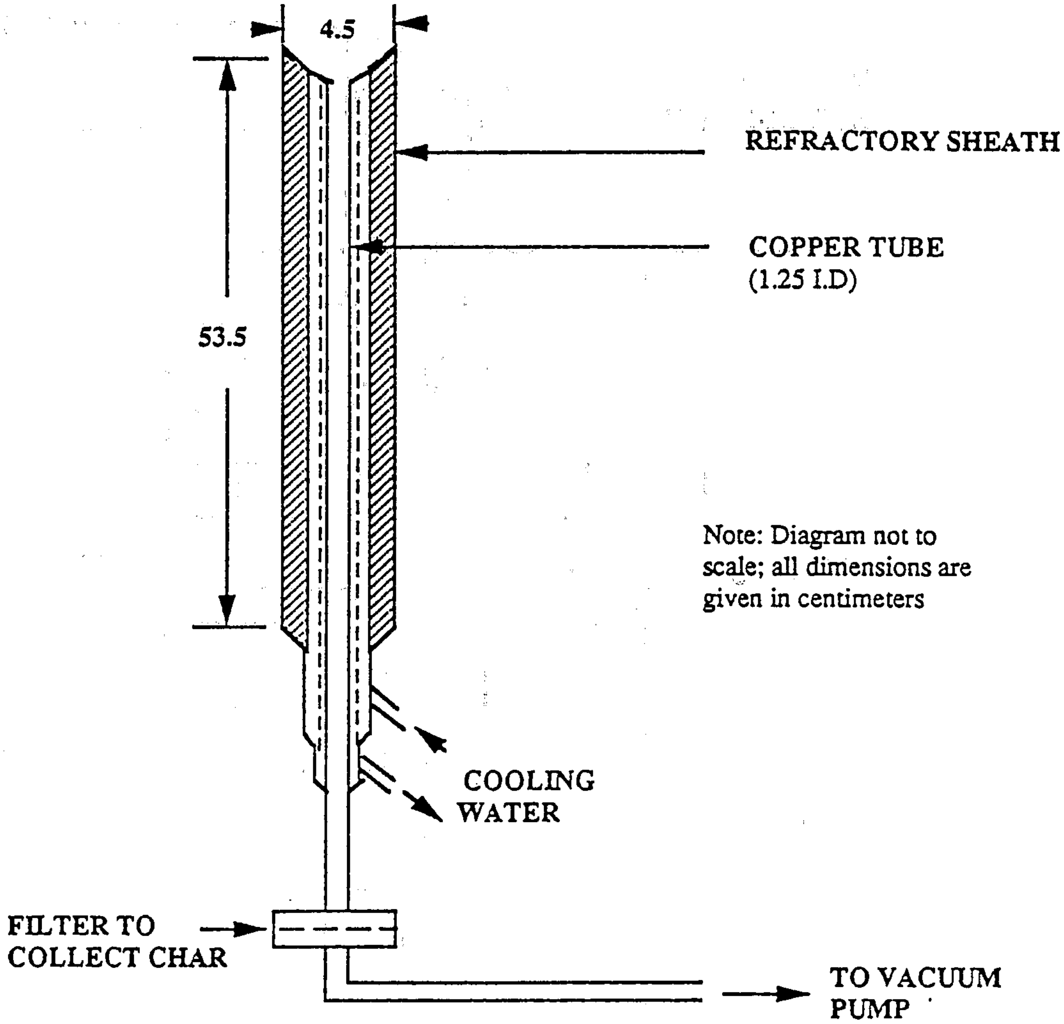


Figure 1. Schematic Diagram of Drop-Tube Reactor



Note: Diagram not to scale; all dimensions are given in centimeters

Figure 2. Schematic Diagram of Char Collection Probe

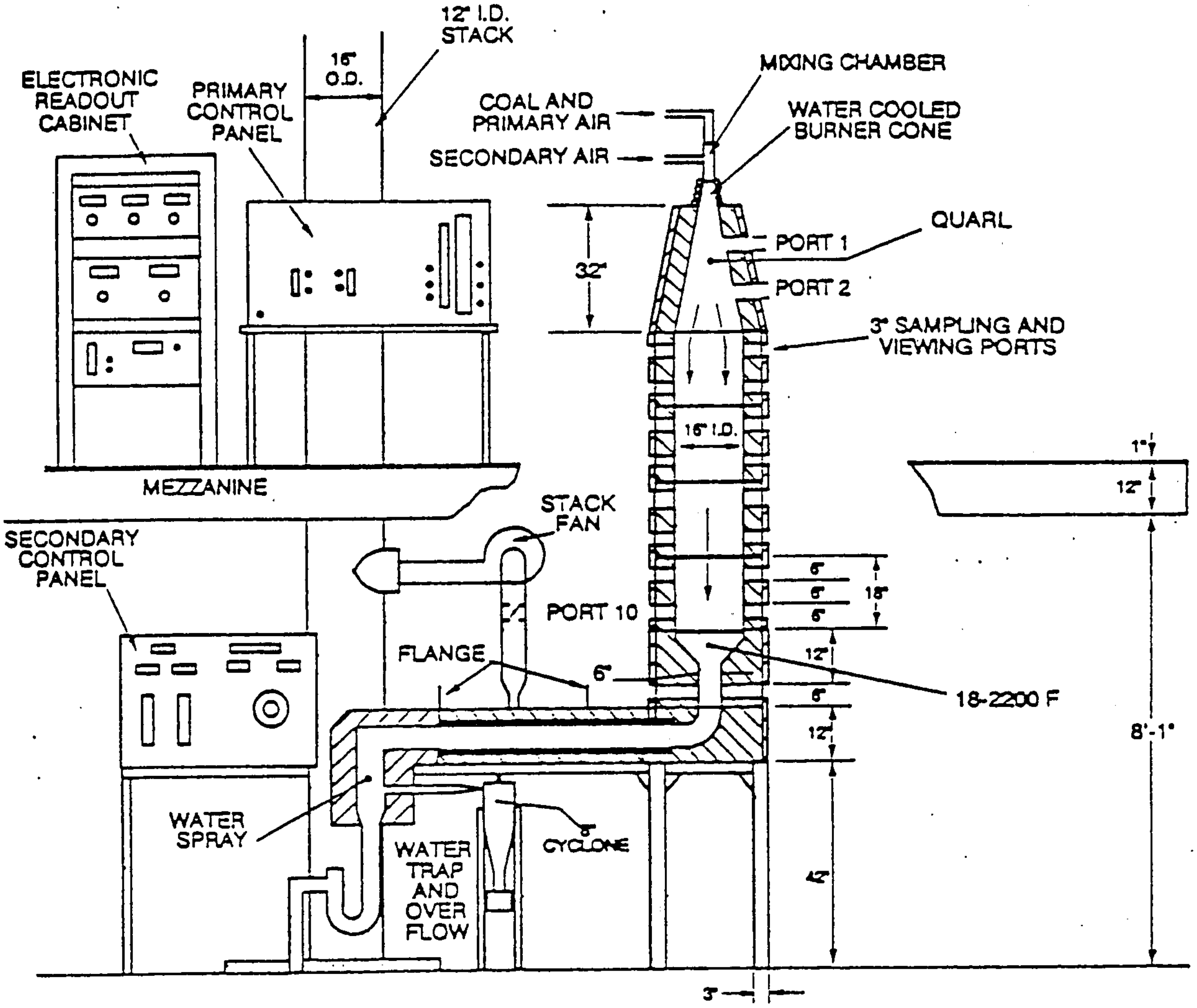


Figure 3. Schematic Diagram of the Down-Fired Combustor

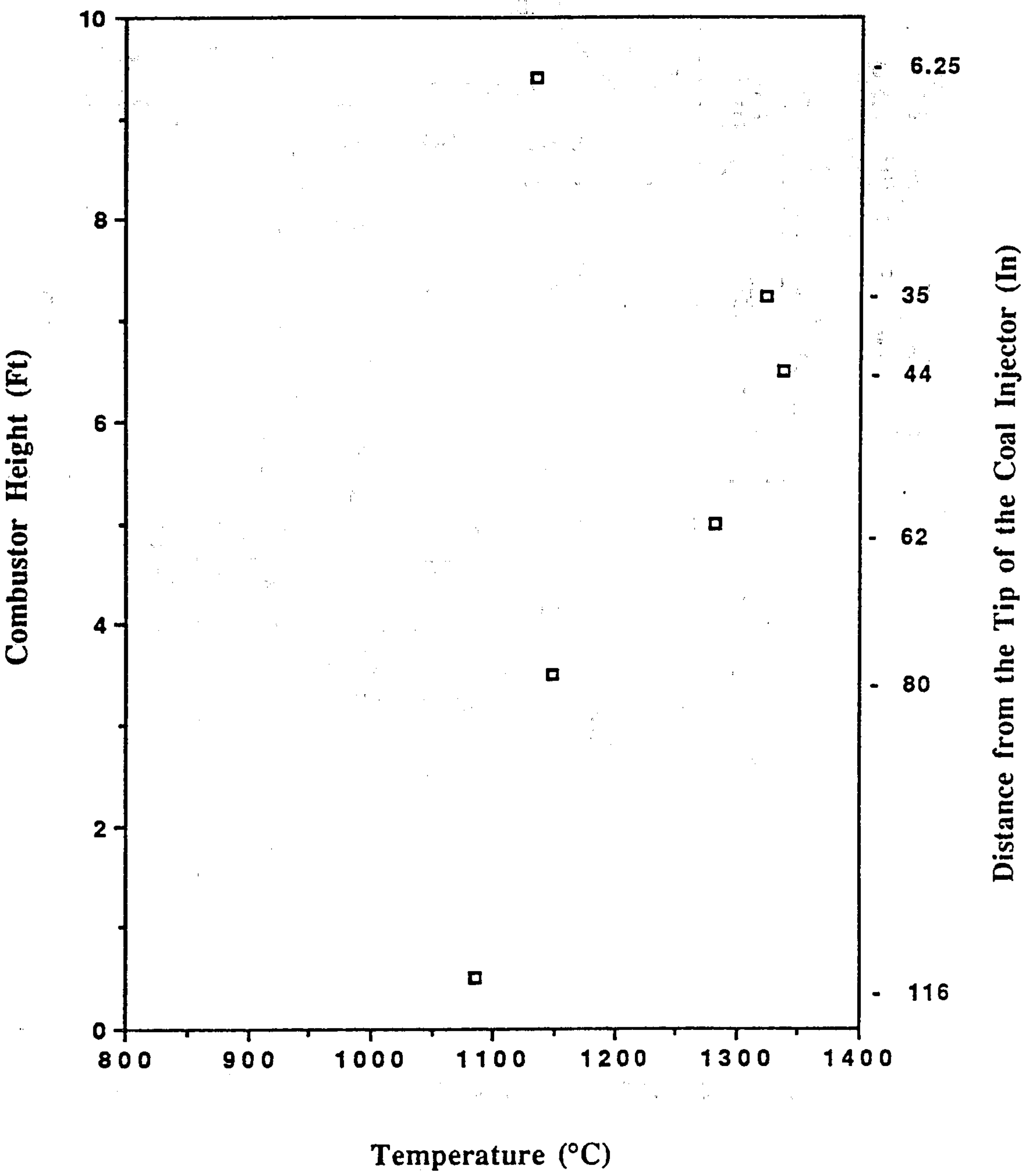


Figure 4. Steady-State Wall Temperature Profile When Firing Natural Gas to Preheat the Combustor

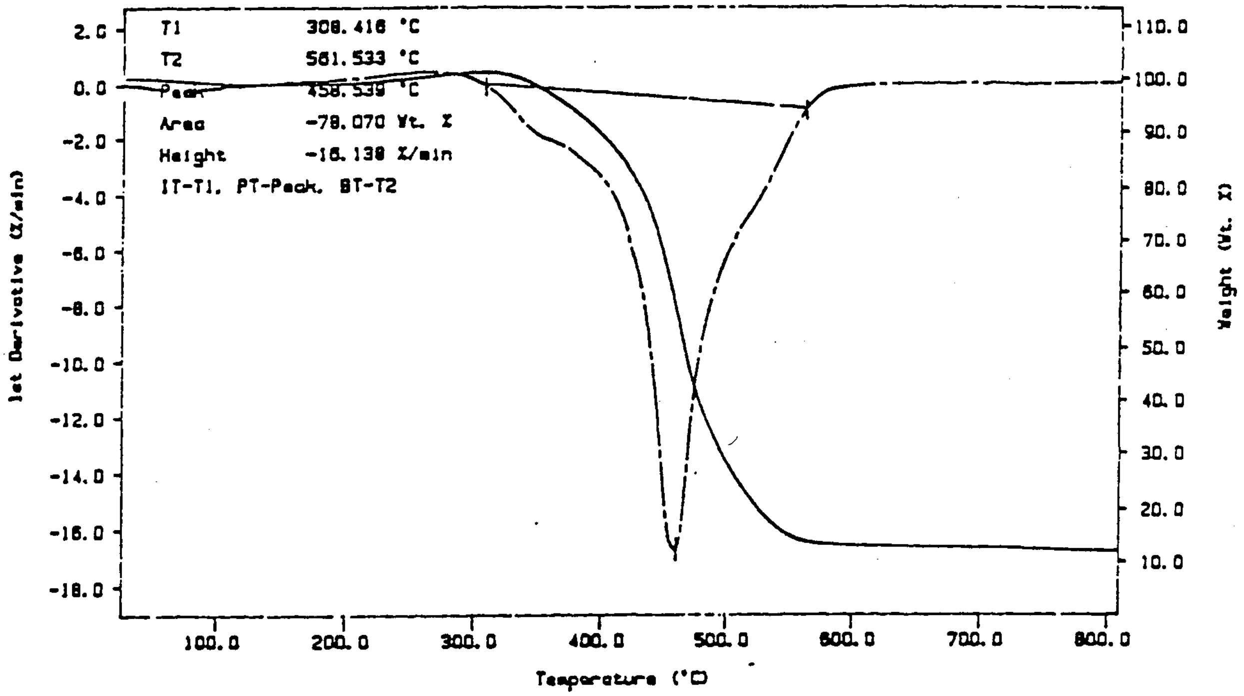


Figure 5. Burning Profile for the 100% Plant Coal.

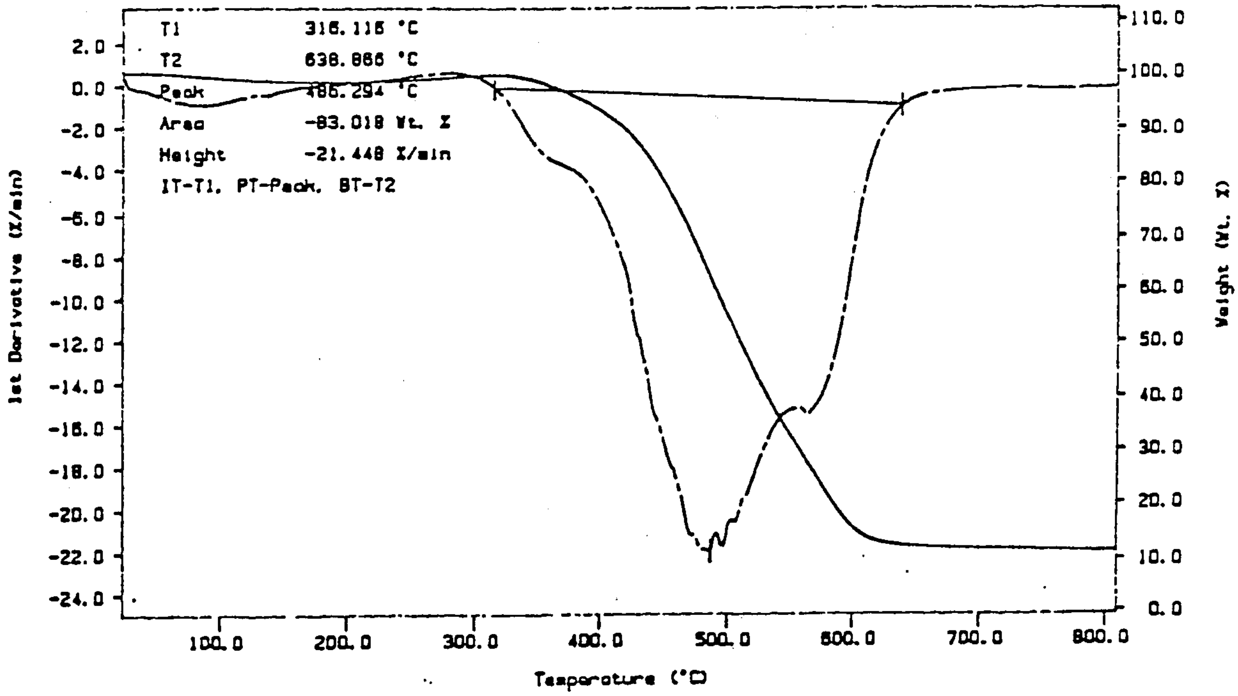


Figure 6. Burning Profile for the Blend of 90% Plant Coal and 10%

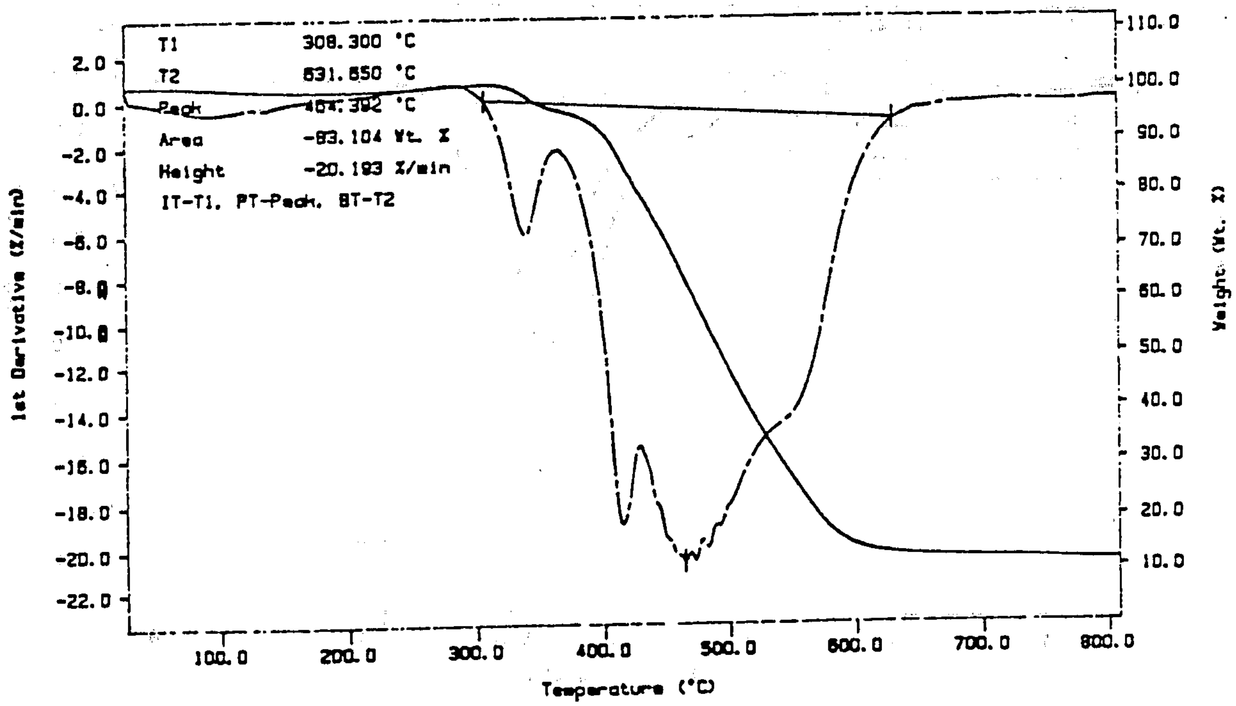


Figure 7. Burning Profile for the Blend of 85% Plant Coal and 15%

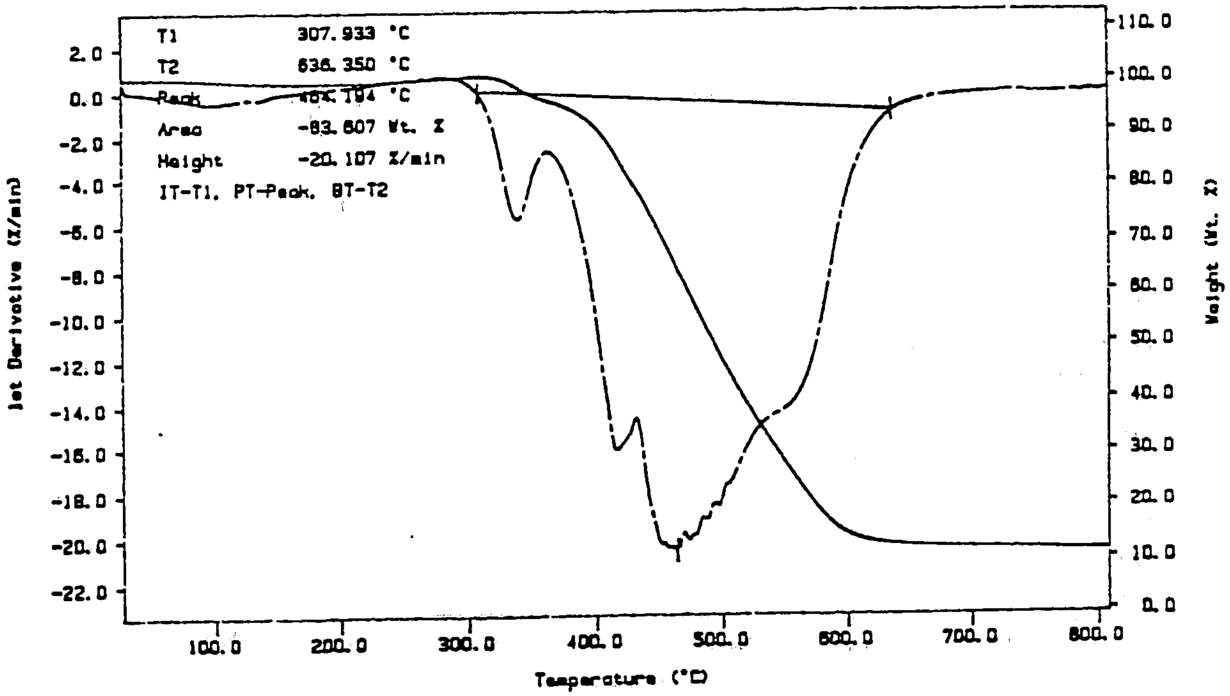


Figure 8. Burning Profile for the Blend of 80% Plant Coal and 20%

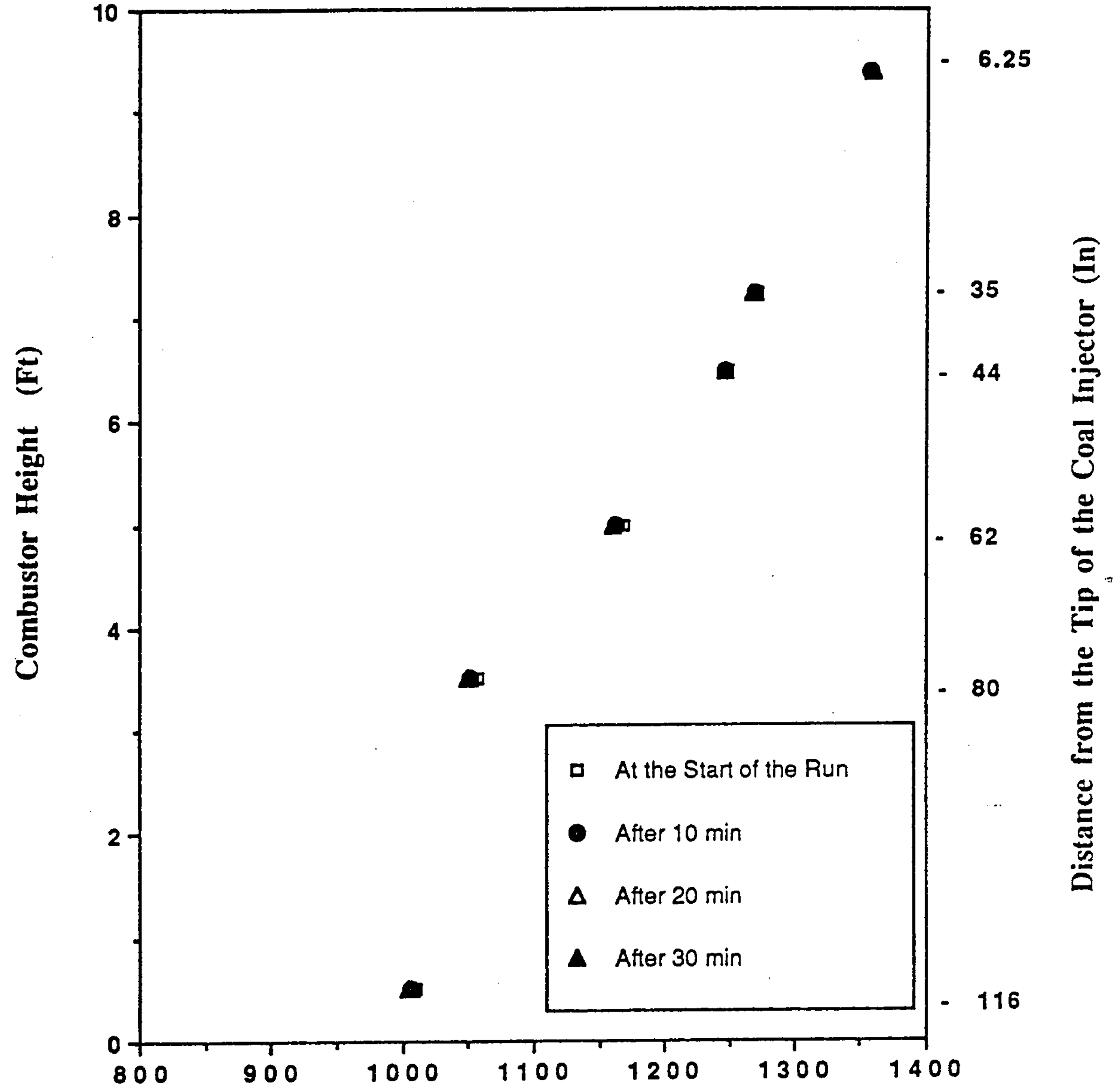


Figure 9. Changes in the Wall Temperature Profile when Firing 100% Plant Coal

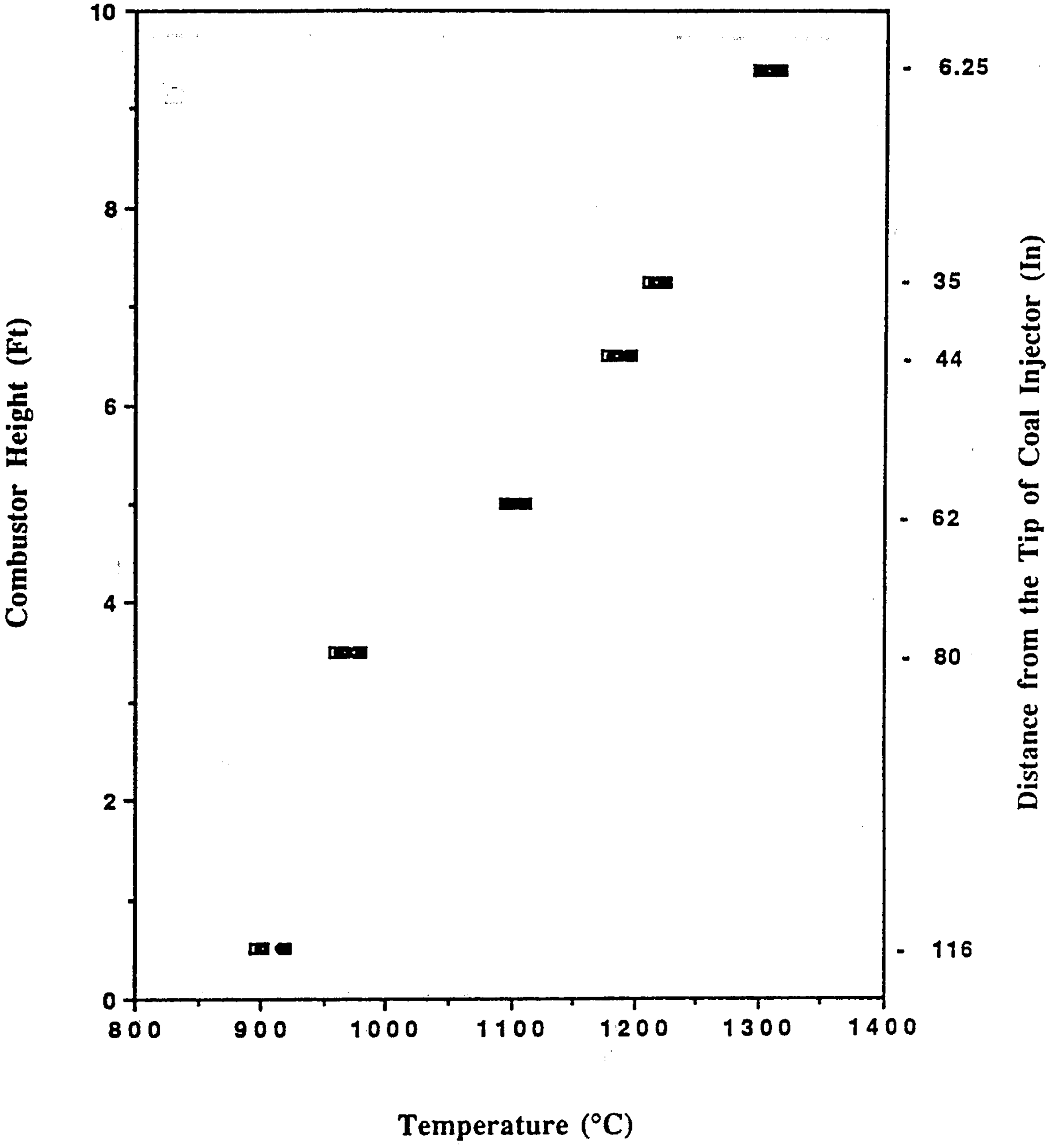


Figure 10. Changes in the Wall Temperature Profile when Firing the Blend of 90% Plant Coal and 10% Recovered Coal

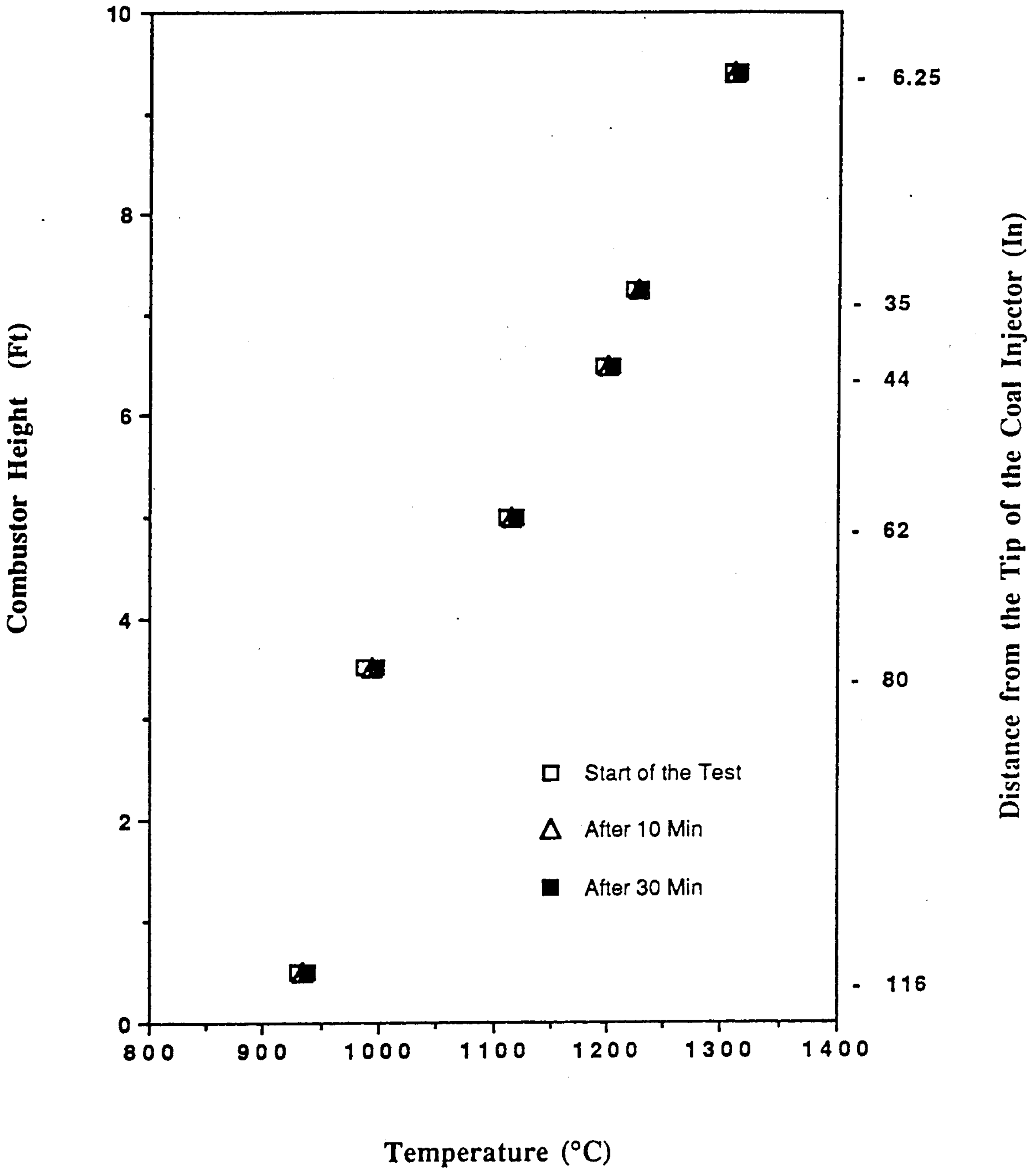


Figure 11. Changes in the Wall Temperature Profile When Firing the Blend of 85% Plant Coal and 15% Recovered Coal

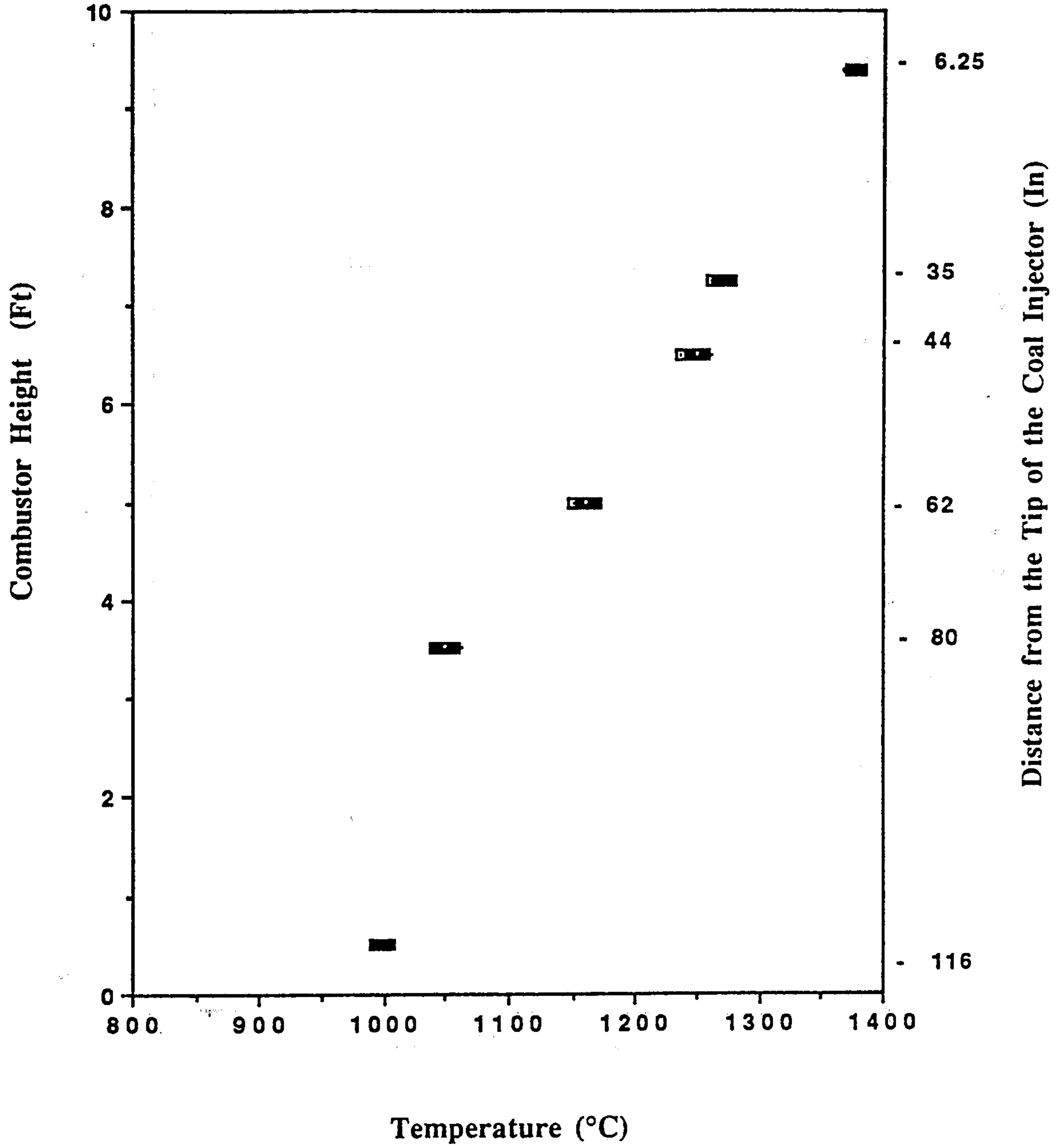


Figure 12. Changes in the Wall Temperature Profile when Firing the Blend of 80% Plant Coal and 20% Recovered Coal

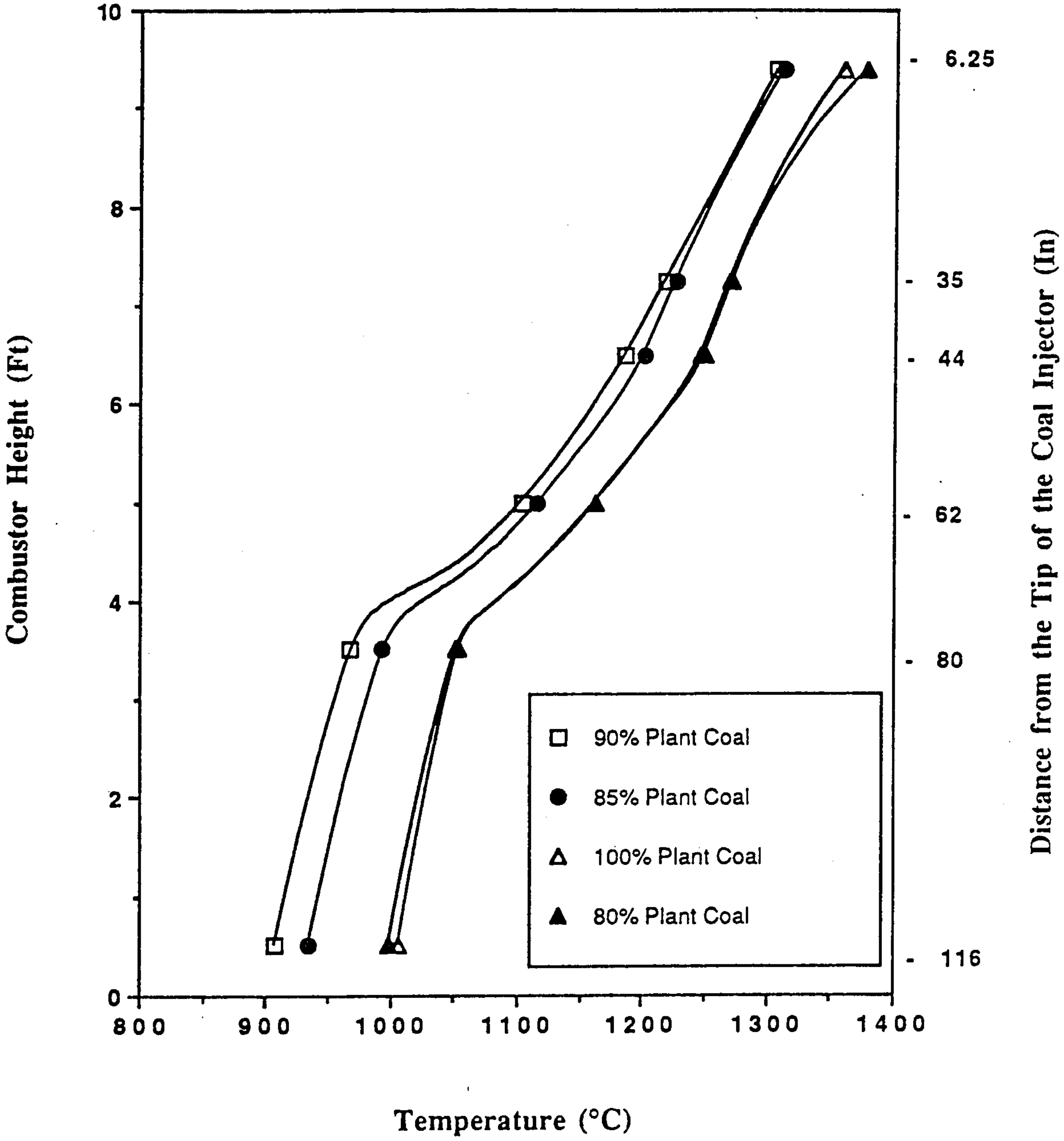


Figure 13. Comparison of Temperature Profiles in the Combustor while Firing Plant Coal and Blends of Plant Coal and Recovered Coal

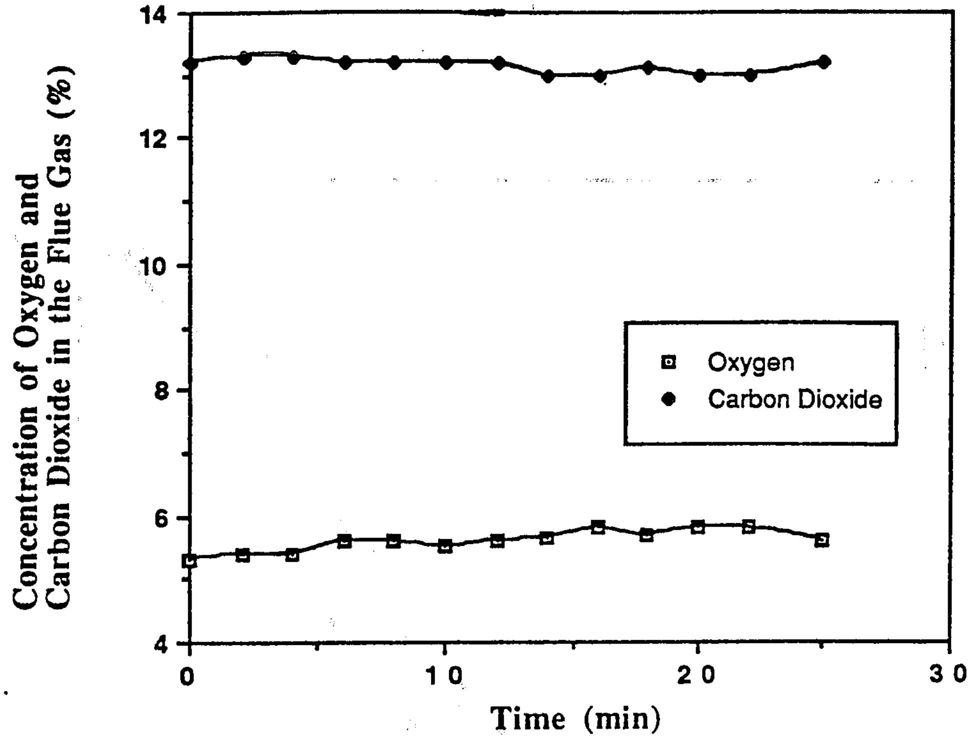


Figure 14. Variation in the Concentration of Oxygen and Carbon Dioxide in the Flue Gas when Firing 100% Plant Coal

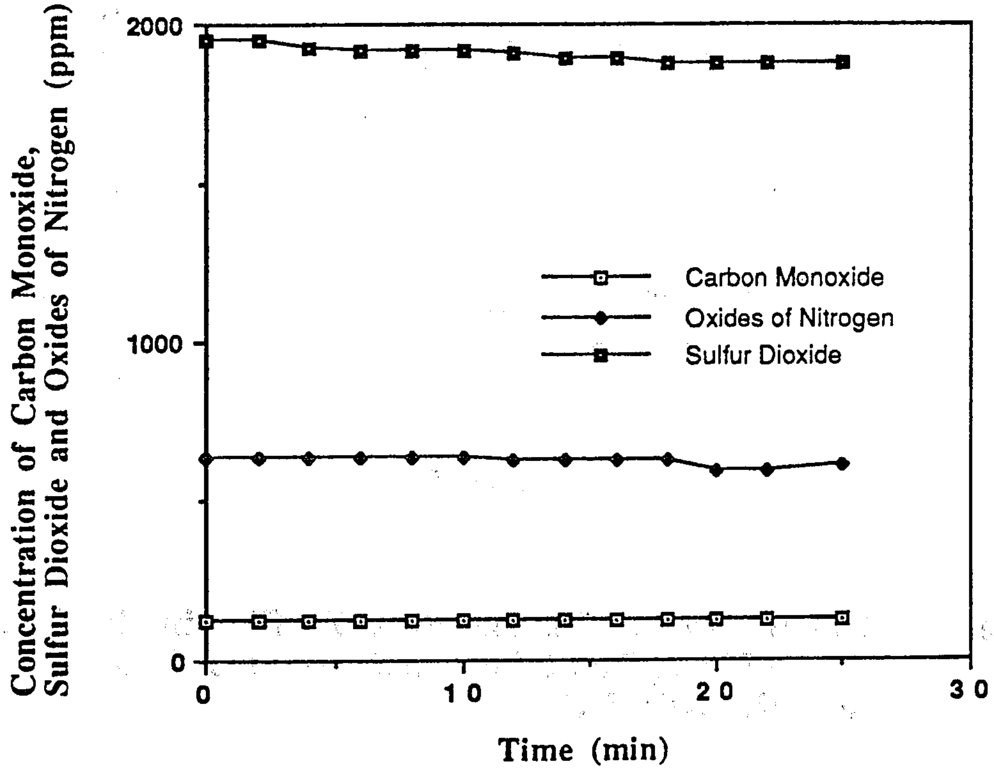


Figure 15. Variation in the Concentration of Carbon Monoxide, Sulfur Dioxide and Oxides of Nitrogen during the test when Firing 100% Plant Coal

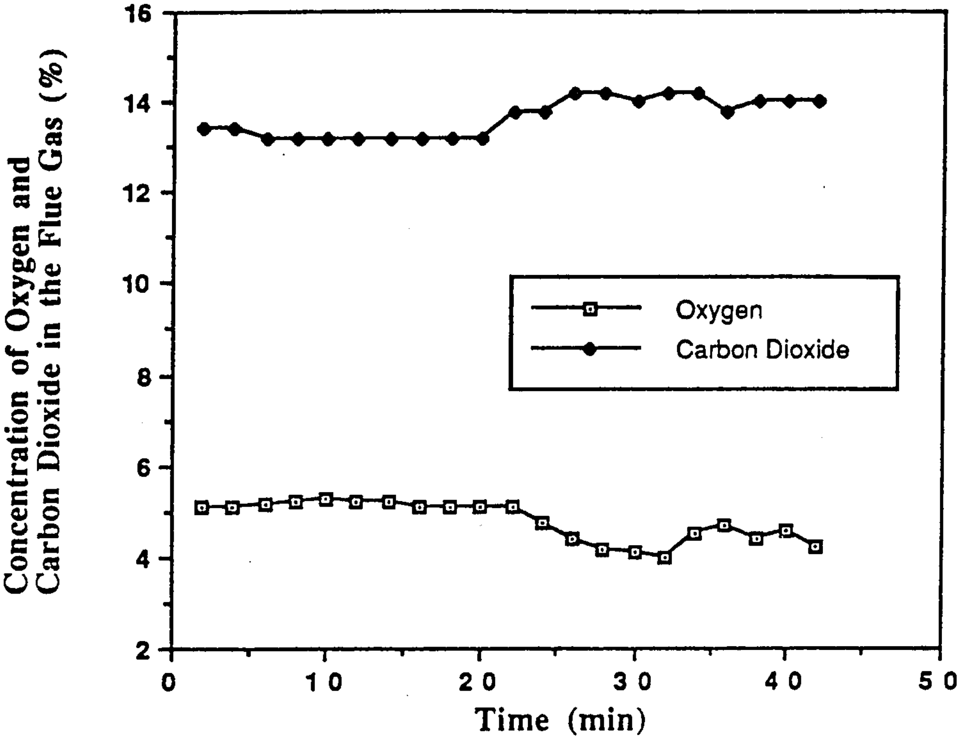


Figure 16. Variation in the Concentration of Oxygen and Carbon Dioxide in the Flue Gas During the Test Period when Firing the Blend of 90% Plant Coal and 10% Recovered Coal

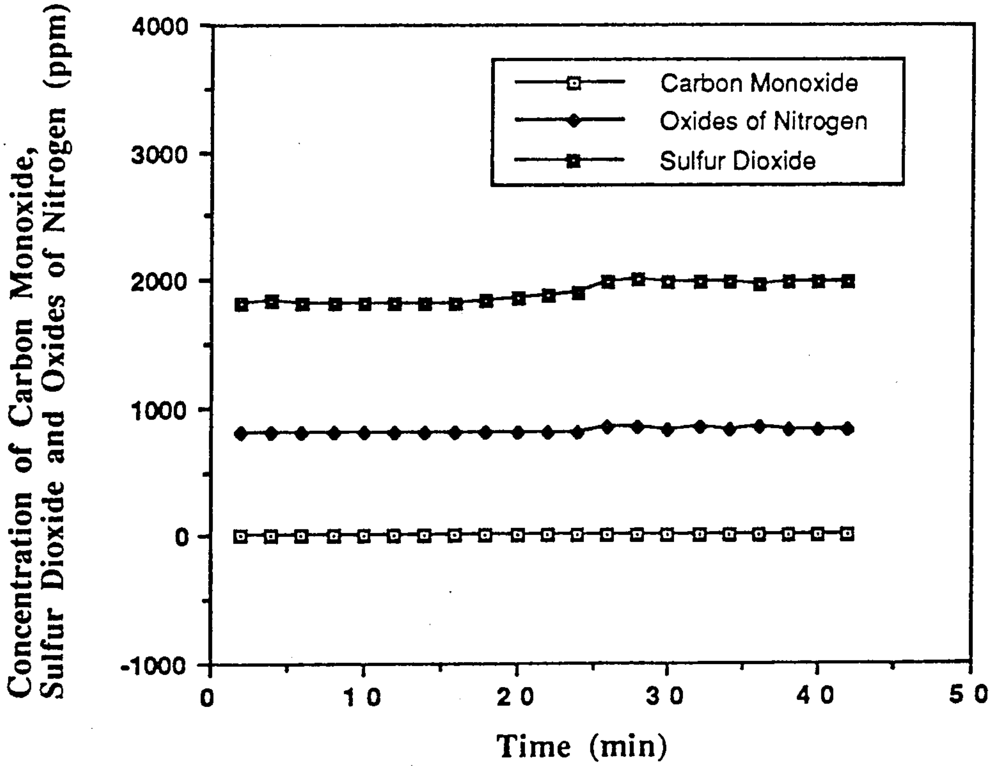


Figure 17. Variation in the Concentration of Carbon Monoxide, Sulfur Dioxide and Oxides of Nitrogen During the Test Period when Firing the Blend of 90% Plant Coal and 10% Recovered Coal

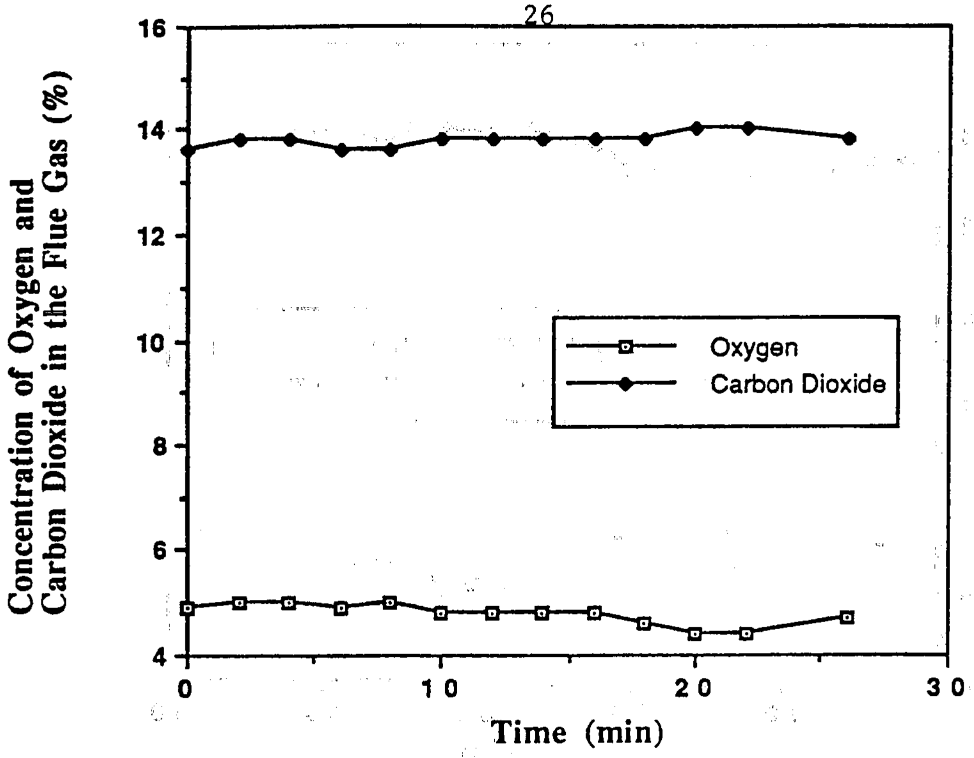


Figure 18. Variation in the Concentration of Oxygen and Carbon Dioxide in the Flue Gas when Firing the Blend of 85% Plant Coal and 15% Recovered Coal

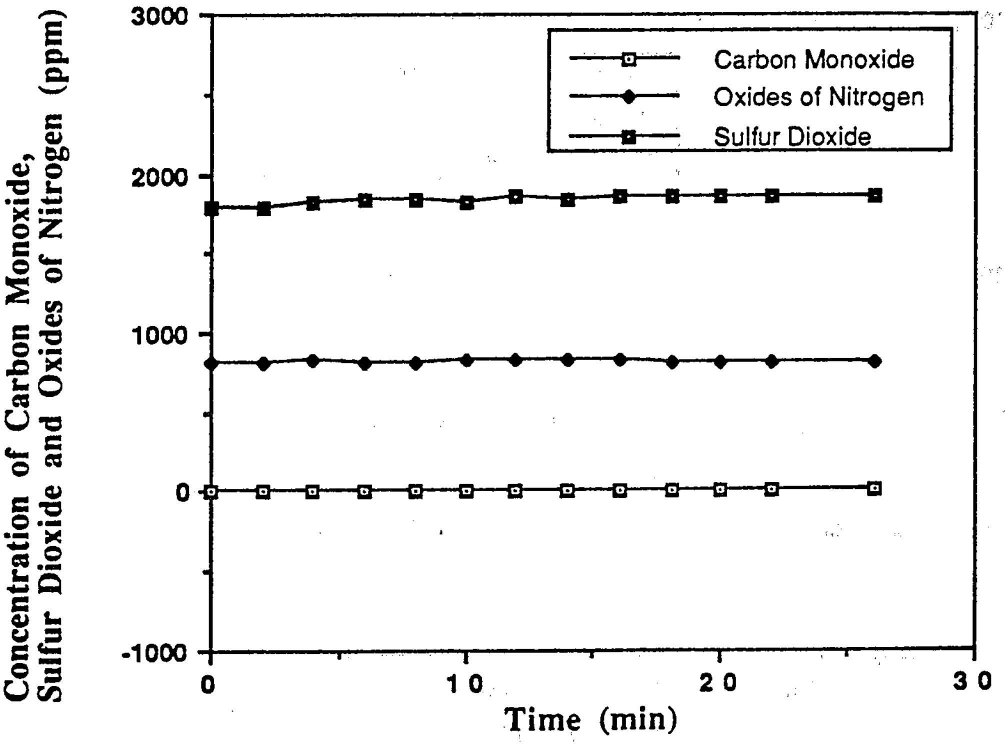


Figure 19. Variation in the Concentration of Carbon Monoxide, Sulfur Dioxide and Oxides of Nitrogen During the Test Period when Firing the Blend of 85% Plant Coal and 15% Recovered Coal

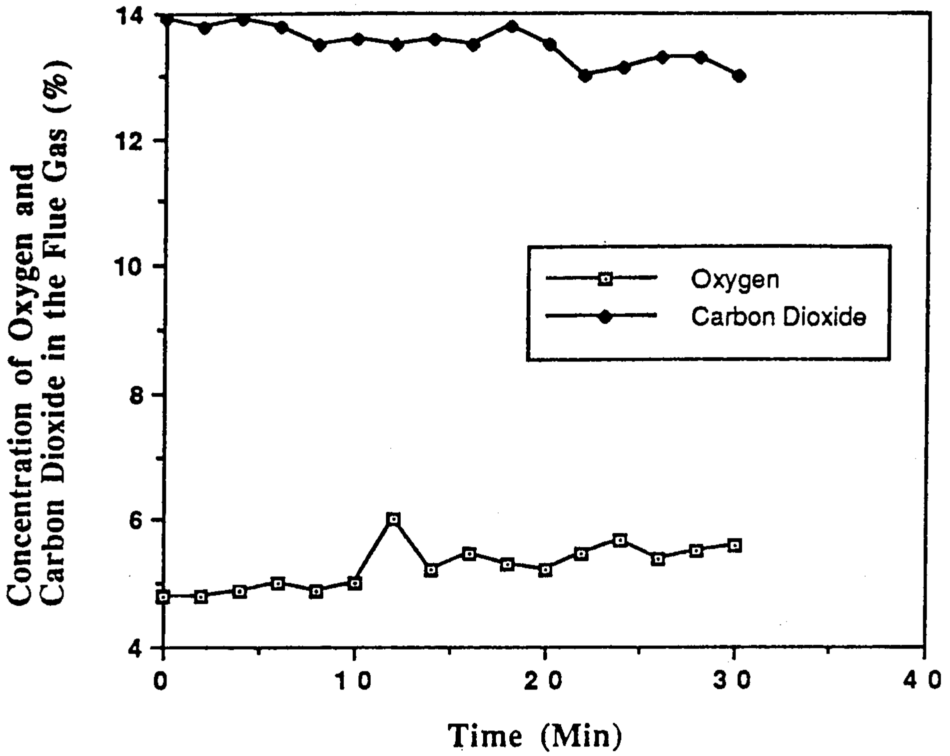


Figure 20. Variation in the Concentration of Oxygen and Carbon Dioxide in the Flue Gas During the Test Period when Firing the Blend of 85% Plant Coal and 15% Recovered Coal

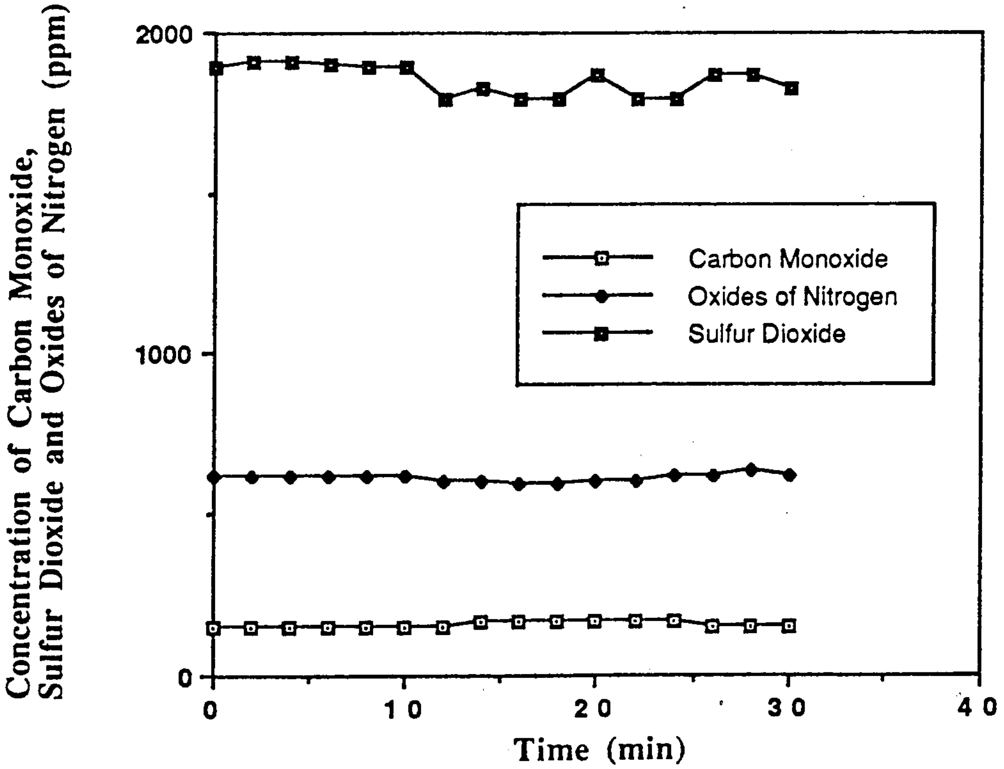


Figure 21. Concentration of Carbon Monoxide, Sulfur Dioxide and Oxides of Nitrogen During the Test Period when Firing the Blend of 85% Plant Coal and 15% Recovered Coal

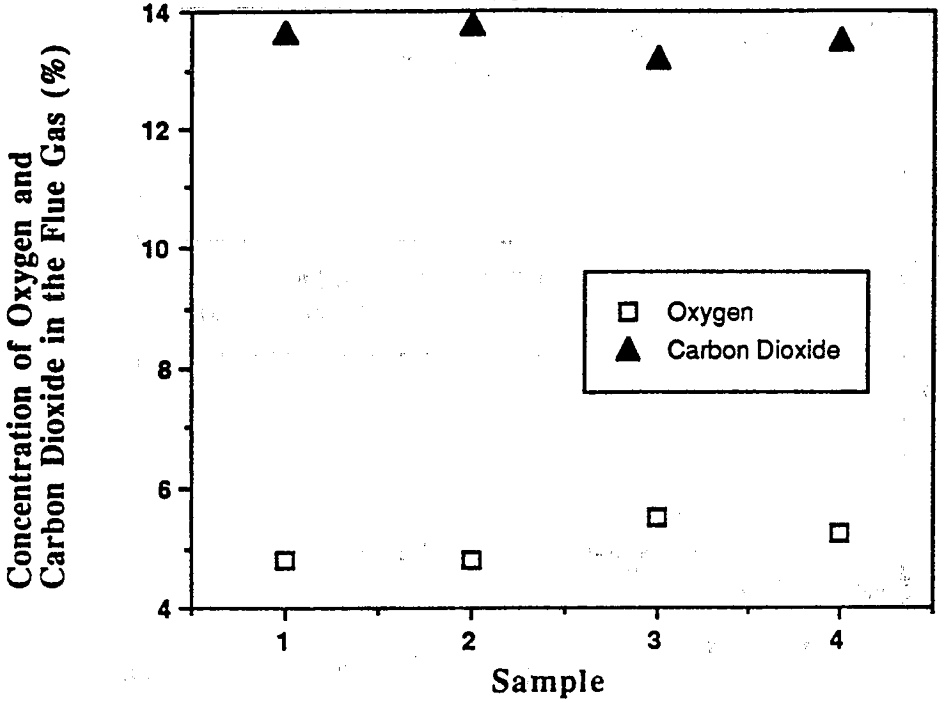


Figure 22. Comparison of the Average Oxygen and Carbon Dioxide Concentrations in the Flue Gas During Combustion of Various Blends of Plant Coal and Recovered Coal:
1) 90% Plant Coal 2) 85% Plant Coal
3) 100% Plant Coal 3) 80% Plant Coal

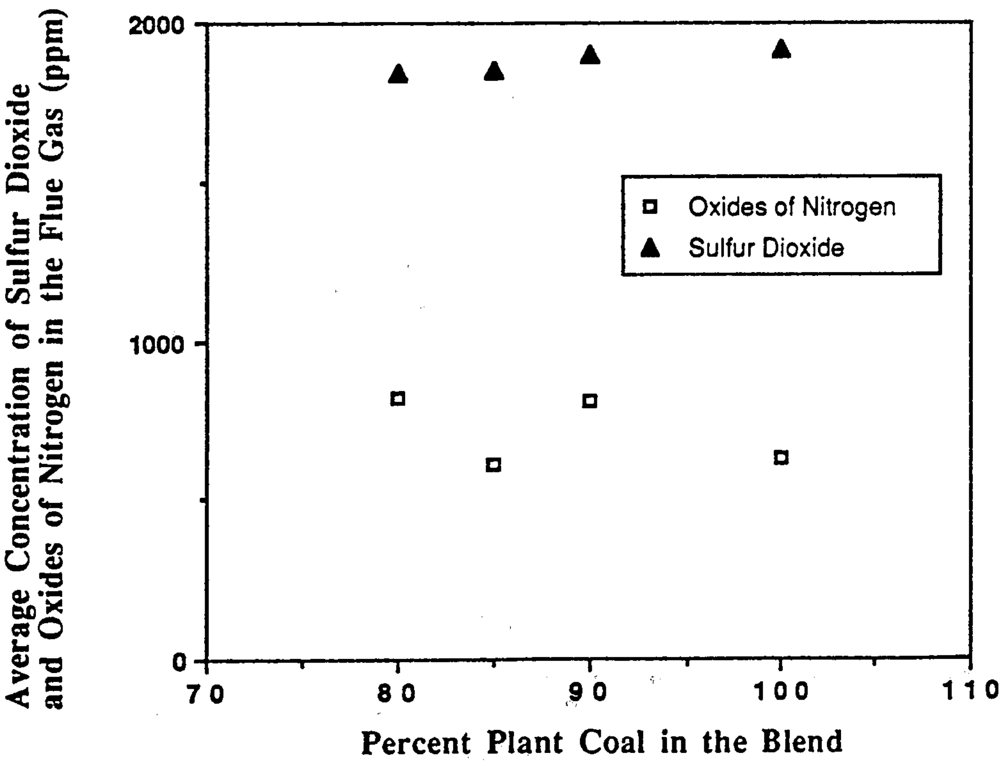


Figure 23. Variation in the Average Concentration of Sulfur Dioxide and Oxides of Nitrogen in the Flue Gas as a Function of Percent Plant Coal in the Blend

PROJECT MANAGEMENT REPORT
September 1, 1991 through August 31, 1992

Project Title: Combustion Characterization of the Blend of Plant Coal and Recovered Coal Fines

Principal Investigator: Shyam Singh, SS Energy
Environmental International, Inc.

Other Investigators: Dr. Alan Scaroni & Mr. Bruce Miller
Combustion Laboratory, Penn State Univ.

Vas Choudhry
Praxis Engineers, Inc.

Project Monitor: Dr. Ken Ho, CRSC

COMMENTS

No problems were encountered during this quarter in either the technical or financial aspects of the project. Although a few adjustments made in the original budget keeping, the aggregate amount remained unchanged.

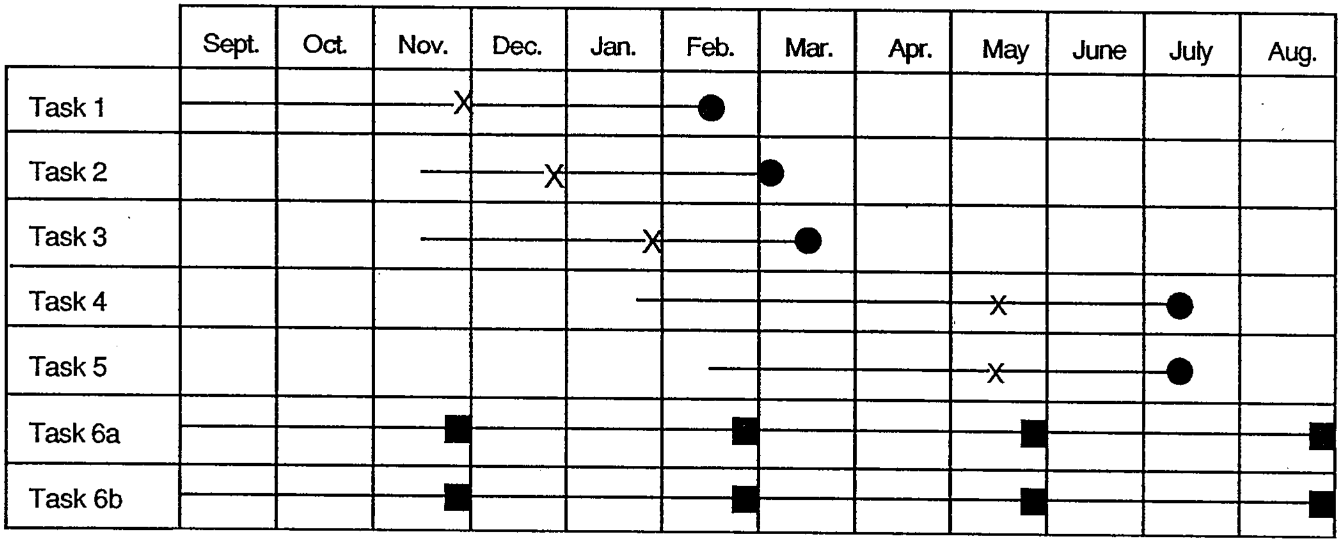
This project is funded by the U. S. Department of Energy (PETC) and by the Illinois Department of Energy and Natural Resources as part of their cost-shared programs.

Projected and Estimated Expenditures by Quarter

Quarter*	Types of Cost	Direct Labor	Materials & Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Cost	Total
Sept. 1, 1991 to Nov. 30, 1991	Projected	5,000.00	200.00	2,800.00		10,580.00	6,994.00	$25,574.00
	Estimated	551.00	-	-	-	2,940.00	-	$3,500.00
Sept. 1, 1991 to Feb. 29, 1992	Projected	14,000	700	3,800		15,580	11,994	$46,074.00
	Estimated	7,943.52	0.00	142.90		19,089.00	6,668.16	$33,843.64
Sept. 1, 1991 to May 31, 1992	Projected	29,000	1,200	5,800		18,080	26,994	$81,074.00
	Estimated	22,748.52	0	956.80		25,788.38	16,103.70	$65,597.40
Sept. 1, 1991 to Aug. 31, 1992	Projected	41,731	1,200	6,800		19,580	30,154	$99,465.00
	Estimated	36,493.04	0	2,607.15		35,730.55	24,606.95	$99,437.69

*Cumulative by quarter

Schedule of Project Milestones



Task 1	Procurement and preparation of test samples
Task 2	Characterization of recovered coal fines, plant coal and blend
Task 3	Test facility calibration
Task 4	Combustion characteristics of blends and plant coal
Task 5	Data analysis and its interpretation
Task 6a	Technical Report preparation
Task 6b	Project Management Report preparation

COSTS BY QUARTER

Combustion Characterization of the Blend of Plant Coal and Recovered Coal Fines