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Compilation of Sandia Coal Char Combustion Data and Kinetic Analyses

Milestone Report

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Prepared by
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**COMPILATION OF SANDIA COAL
CHAR COMBUSTION DATA
AND
KINETIC ANALYSES
MILESTONE REPORT**

June 1992

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MASTER

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1. NOMENCLATURE

A	global pre-exponential factor, $\text{g C cm}^{-2} \text{s}^{-1} \text{atm}^{-n}$
A_c	empirical parameter in correlations for the combustion product ratio
A_p	particle external surface area, cm^2
$c_{p,g}$	constant pressure heat capacity of gas-phase, $\text{cal mole}^{-1} \text{K}^{-1}$
$c_{p,p}$	constant pressure heat capacity of particle, $\text{cal g}^{-1} \text{K}^{-1}$
$c_{p,k}$	constant pressure heat capacity of gas-phase species k , $\text{cal g}^{-1} \text{K}^{-1}$
C_s	oxygen concentration at the particle surface, mole cm^{-3}
D_{ox}	oxygen diffusion coefficient, $\text{cm}^2 \text{s}^{-1}$
d_c	mean particle diameter of the initial (unreacted) coal samples
d_p	particle diameter, cm
d_o	mean particle diameter of samples extracted from the reactor at 6.35 cm above the burner surface (corresponding to the approximate end of devolatilization and beginning of char combustion)
d_{25}, d_{50}, d_{75}	25 th , 50 th (median) and 75 th percentile from the optically-determined particle diameter distributions
E	global activation energy, cal mole^{-1}
E_c	empirical parameter in correlations for the combustion product ratio
f_i	fraction of the initial amount of element i remaining in the char
g	acceleration due to gravity, $\text{cm}^2 \text{s}^{-1}$
ΔH	overall heat of reaction at the particle surface, cal (g C)^{-1}
ΔH_1	heat of reaction for $\text{C} + 1/2 \text{O}_2 = \text{CO}$, $\text{cal (mole carbon monoxide)}^{-1}$
ΔH_2	heat of reaction for $\text{C} + \text{O}_2 = \text{CO}_2$, $\text{cal (mole carbon dioxide)}^{-1}$
k_d	mass transfer coefficient, $\text{g C cm}^{-2} \text{s}^{-1}$
k_s	global chemical reaction rate coefficient, $\text{g C cm}^{-2} \text{s}^{-1} \text{atm}^{-n}$
$k_{s,i}$	intrinsic chemical reaction rate constant, $(\text{mole O}_2)^{(1-m)} (\text{cm}^3 \text{fluid})^m \text{s}^{-1} (\text{cm}^2 \text{surface})^{-1}$
m	particle mass, g , or true reaction order
m_c	mass of raw coal, g
M_C	molecular weight of carbon, $\text{g C (mole carbon)}^{-1}$
n	global reaction order
Nu	Nusselt number
P	total pressure, atm
P_g	ambient oxygen partial pressure, atm
P_s	oxygen partial pressure at the particle surface, atm
q	overall particle burning rate per unit external surface area, $\text{g C cm}^{-2} \text{s}^{-1}$
q_i	intrinsic chemical reaction rate, $(\text{mole O}_2) \text{s}^{-1} (\text{cm}^2\text{-surface})^{-1}$
R, R'	gas constant, $\text{cal mole}^{-1} \text{K}^{-1}, \text{atm cm}^3 \text{mole}^{-1} \text{K}^{-1}$
Sh	Sherwood number
T_g	gas-phase temperature, K
T_m	arithmetic mean of gas and particle temperature, K
T_p	particle temperature, K
T_{pm}	median particle temperature in a particle population
T_w	reactor wall temperature, K
v_g	gas velocity, cm s^{-1}
v_p	particle velocity, cm s^{-1}
x_i	weight fraction of element i in the char

$x_{i,o}$	weight fraction of element i in the raw coal
X	fractional or percentage combustion conversion, daf basis
X_a	weight fraction of ash in the char
$X_{a,o}$	weight fraction of ash in the raw coal
z	axial height above reactor inlet, cm

Greek Symbols

α	particle burning mode parameter (see Eq. 5.20)
γ	change in volume during reaction referred to unit volume of oxygen
ϵ_p	particle emissivity
κ	parameter defined in Eq. (5.9)
η	effectiveness factor: ratio of the observed reaction rate to the theoretical rate in the absence of internal mass and heat transfer limitations
λ	gas-phase mixture thermal conductivity, cal cm ⁻¹ s ⁻¹ K ⁻¹
μ	gas-phase mixture viscosity, g cm ⁻¹ s ⁻¹
ν_o	stoichiometric oxygen coefficient for reaction at the particle surface, mole O ₂ (mole carbon) ⁻¹
ρ	particle (or apparent) density, g cm ⁻³
ρ_b	density of tapped particle bed, g cm ⁻³
$\rho_{c,o}$	mass of carbonaceous material/char particle volume, g cm ⁻³
σ	Stefan-Boltzmann constant, cal cm ⁻² K ⁻⁴ s ⁻¹
τ_{50}	coal char global reactivity index: the characteristic time for 50% carbon conversion (volatile-free basis) in a chosen gas environment.
θ	interparticle void fraction or "packing factor" in particle beds; also particle porosity
χ	ratio of the actual particle burning rate to its maximum, diffusion-limited rate
ψ	fraction of carbon converted to CO ₂ at the particle surface
ω	linear swelling factor, d_o/d_c

2. EXECUTIVE SUMMARY

An experimental project was undertaken to characterize the physical and chemical processes that govern the combustion of pulverized coal chars. The experimental endeavor establishes a database on the reactivities of coal chars as a function of coal type, particle size, particle temperature, gas temperature, and gas and composition. The project also provides a better understanding of the mechanism of char oxidation, and yields quantitative information on the release rates of nitrogen- and sulfur-containing species during char combustion. An accurate predictive engineering model of the overall char combustion process under technologically relevant conditions is a primary product of this experimental effort. This document summarizes the experimental effort, the approach used to analyze the data, and individual compilations of data and kinetic analyses for each of the parent coals investigated.

A milestone report in similar format is also available on a multi-year experimental effort within Task 1 of the Sandia Coal Combustion Science Program entitled "Compilation of Sandia Coal Devolatilization Data, Milestone Report" (Fletcher and Hardesty, 1992).

Materials

During the course of this project, data have been acquired on the combustion characteristics of chars from the ten United States coals listed in Table 2.1, ranging in rank from lignite to low-volatile bituminous.

Table 2.1
Suite of Coals Investigated

Seam Name	State of Origin	PSOC number	Rank*
Lower Wilcox	TX	1443D	lignite
Blue #1	NM	1445D	subbituminous
Pittsburgh #8	PA	1451D	hva-bituminous
Dietz	MT	1488D	subbituminous
Illinois #6	IL	1493D	hvb-bituminous
Hiawatha	UT	1502D	hvc-bituminous
Beulah Zap	ND	1507D	lignite
Pocahontas #3	WV	1508D	lv-bituminous
Lower Kittanning	PA	1516D	lv-bituminous
Smith Roland	WY	1520D	subbituminous

* reported rank. There are slight variations between reported rank, apparent rank as received by the Pennsylvania State Coal Bank, and apparent rank as received by Sandia National Laboratories.

Experimental Approach

Figure 2.1 depicts the optically-accessible laminar flow reactor used in these experiments to generate gaseous environments simulating those found in the upper furnace region of pulverized coal fired boilers. The reactor is equipped with a unique particle-sizing pyrometer that permits *in situ* measurements of the sizes, temperatures, and velocities of individual particles at various residence times. It is also equipped with an isokinetic solids-sampling probe that permits the extraction of particles from the reactor for off-line physical and chemical analyses.

Figure 2.1 Schematic of the CCL atmospheric laminar flow reactor

The overall extents of conversion, particle densities, and specific surface areas are determined from the bulk extracted samples. Chemical analysis of the extracted samples yields, in addition, C, H, O, N, and S contents, total ash content and an elemental analysis of the ash (Ti, Al, Si, Fe, K, Na, and Ca contents). This information provides answers to fundamental questions concerning the oxidation mechanism, modes of particle burning, effects of mineral matter on the combustion characteristics of the char, and the rate and location of release of nitrogen and sulfur-containing pollutant precursors during char combustion.

Theoretical Approach

The data obtained were used to develop and validate an accurate model of the overall char combustion process. A model of gas-particle transport processes was used to determine char combustion rates from the optical measurements of single-particle sizes, temperatures, and velocities. Combustion rates were also determined by an independent inorganic tracer technique based on chemical analysis of extracted samples.

The kinetics of char combustion are described by the global expression:

$$q = k_s P_s^n \quad (2.1)$$

where k_s is a temperature-dependent rate coefficient, n is the global, or apparent, reaction order, and P_s is the partial pressure of oxygen at the particle surface. The temperature dependence of the global rate coefficient k_s is described by a correlation in Arrhenius form:

$$k_s = A \exp(-E/RT_p) \quad (2.2)$$

where A is the global preexponential factor and E is the global activation energy.

Both CO and CO₂ were shown in this study to be primary products of the heterogeneous oxidation reactions depending upon reaction conditions. At the high particle temperatures obtained in this study (1500 - 2000 K) CO is the dominant primary product, although there is evidence of some CO₂ formation at the lower particle temperatures in this range (Mitchell, 1988, 1990b). The kinetic analyses assume the CO to CO₂ product ratio to be correlated by:

$$\frac{\text{moles CO}}{\text{moles CO}_2} = A_c \exp(-E_c / R T_p) \quad (2.3)$$

The empirical parameters A_c and E_c are estimated for each coal char by comparing combustion rates determined by the optical and extractive techniques.

Summary of Kinetic Results

Included in the document are individual compilations of the data and kinetic analyses performed for each coal. The data include sets of optical measurements of single-particle temperatures, sizes, and velocities in various gas environments, along with time-resolved measurements of particle density and elemental composition and, for selected chars, internal surface areas measured by vapor

adsorption techniques. For each of the ten coals, a set of eight combustion parameters is reported that provides a complete quantitative description of the combustion kinetics of that coal char under technologically relevant conditions. The sets of combustion parameters are summarized in Table 2.2.

The combustion parameters were used to compute combustion rates, q , and characteristic burning times, τ_{50} , in a selected standard environment containing 6 mole-% oxygen and having a gas temperature of 1600 K. Fig. 2.2 presents a comparison of the standard combustion rates and times for each of the ten coals. A pronounced trend is evident in the data set; char reactivity decreases with increasing rank of the parent coal. Burning rates vary by a factor of about 7 between the Beulah lignite (PSOC-1507) and the Pocahontas #3 low-volatile bituminous coal (PSOC-1508). The characteristic burning time, τ_{50} , which reflects both reactivity and char physical properties, varies by a factor of about 10.

Figure 2.2 Instantaneous burning rates, q , and the char reactivity index, τ_{50} for 100 μm particles of the PETC suite of coals reacting in a selected standard combustion environment (6 mole-% oxygen, 1500 K gas temperature, cold walls). Combustion rates, q , in g-carbon/cm²-sec x 100; char reactivity index, τ_{50} , in seconds.

Table 2.2 Char Combustion Parameters and Selected Properties for the Suite of Coals Investigated

Seam Name, PETC Designation	Reported Rank (ASTM)	%Vol Matter (dmmf)	Calorific Val, mmf eq moist (kJ/gm)	Elemen Carbon Content (wt %)	Preexp Factor, A (g-carb/cm ² -s-atm ^{0.5})	Activation Energy E (kcal/mol)	Product [†] Ratio Correlation	Physical mode of burning α	Combustion swelling factor ω	Parameters initial carbon density (g/cc) ρ_c	Standard ^{††} burning rate q (g/cm ² -s)	Characteristic ^{†††} burnout time τ_{50} (sec)
Pocahontas #3 PSOC-1508D	low vol bitum	16.21	35.74	89.0	114	30.0	1	0.3	1.21	0.63	1.2×10^{-3}	0.63
Low Kittanning PSOC-1516D	low vol bitum	18.55	34.84	82.8	10.5	20.5	2	0.0	1.27	48	2.1×10^{-3}	0.29
Pittsburgh #8 PSOC-1451D	hva bitum	38.81	34.18	82.6	29	24	3	0.1	1.1	0.40	2.4×10^{-3}	0.19
Hiawatha PSOC-1502D	hvc bitum	44.24	29.39	79.6	—*	—*	1	0.1	1.16	0.44	6.5×10^{-3}	0.070
Illinois #6 PSOC-1493D	hvc bitum	42.91	29.18	78.2	22.4	22.5	4	0.45*	1.06*	0.39*	3.3×10^{-3}	0.11
Blue #1 PSOC-1445D	hvc bitum	47.86	27.81	77.9	3.8	15.3	1	0.25	1.16	0.26	4.5×10^{-3}	0.064
Dietz PSOC-1488D	Subbit	43.88	23.13	74.4	—*	—*	5	0.25	1.04	0.41	6.7×10^{-3}	0.061
Smith-Roland PSOC-1520D	Subbit	61.96	21.48	66.4	—*	—*	2	0.3	0.85	0.62	7.2×10^{-3}	0.069
Lower Wilcox PSOC-1443D	Lignite A	78.22	17.88	67.9	44	21.9	5	0.12	0.92	0.68	5.6×10^{-3}	0.11
Beulah PSOC-1507D	Lignite A	45.73	17.26	63.0	—*	—*	2	0.2	0.92	0.63	7.2×10^{-3}	0.078

* Combustion rates of chars from these coals are limited by the rate of diffusion of oxygen from the bulk gas to the particle surface (Zone 3 combustion) under the experimental conditions

** Values for 75 - 106 μ m size fraction (All others are for 106 - 125 μ m size fraction)

† CO/CO₂ product ratio under the experimental conditions correlated by the empirical relation (moles-CO)/(moles-CO₂) = $A_c \exp(-E_c/RT_p)$ Correlation type 1 $A_c = 3 \cdot 10^8$, $E_c = 60$ kcal/mol, 2 CO only, 3 $A_c = 4 \cdot 10^4$, $E_c = 30$ kcal/mol, 4 $A_c = 2.5 \cdot 10^8$, $E_c = 60$ kcal/mol, 5 $A_c = 5 \cdot 10^8$, $E_c = 60$ kcal/mol These values are to be regarded as empirical parameters useful only for the prediction of char combustion rates in the range of gas environments investigated

†† Burning rates in 6 mole-% oxygen at 1500 K gas temperature with radiation to cold walls (g-carbon/s-cm²-external surface)

††† Characteristic time for 50 wt-% carbon conversion of char (volatile matter free basis) in 6 mole-% oxygen at 1500 K gas temperature with radiation to cold walls Values computed for each coal from A , E , n , A_c , E_c , α , ω , and ρ_{co}

A unified treatment of the kinetic parameters (A , E , and n) is found in Hurt and Mitchell (1992). This treatment culminates in a generalized reactivity correlation based on coal carbon content, allowing the prediction of char combustion rates under conditions relevant to pulverized coal-fired combustors. In Fig. 2.3, extracted from Hurt and Mitchell (1992), the combustion rates for the ten PETC suite coals are compared to the predictions of this generalized correlation.

Figure 2.3 Comparison of char oxidation rates for chars from the PETC/Sandia coal suite in a selected environment having a gas temperature of 1500 K and containing 6 mole-% oxygen. Points: values predicted by the individual sets of kinetic parameters determined for each char. Curves: Values predicted by the Sandia coal char oxidation kinetic correlation.

A unified presentation and discussion of the physical combustion parameters (α , ω , and ρ_{co}) and the characteristic burning times (τ_{50}) can be found in Hurt and Hardesty (1992) and will be available later in the open literature. A unified presentation and discussion of the data base on elemental nitrogen release rates is currently in preparation. Together, this data base and the associated correlations will allow accurate predictions of char combustion rates, particle

temperatures, and char properties in a wide range of environments for all commercially important U.S. coals. The predictive capability will facilitate the design, optimization, and retrofit of current and future pulverized-coal technologies.

References for Executive Summary

Fletcher, T. H. and Hardesty, D. R. "Compilation of Sandia Coal Devolatilization Data, Milestone Report" Sandia National Laboratories Technical Report, SAND 92-8209, May 1992.

Hurt, R. H. and Mitchell R. E., "Unified High-Temperature Char Combustion Kinetics for a Suite of Coals of Various Rank" paper presented at the *24th International Symposium on Combustion*, Sydney, Australia (1992)

Hurt, R. H. and Hardesty, D. R. in *Coal Combustion Science--Quarterly Progress Report*, Hardesty, D. R. (ed.), Sandia National Laboratories Technical Report, SAND 92-8210, June 1992.

3. INTRODUCTION

The Department of Energy's Pittsburgh Energy Technology Center (PETC) began a research effort to improve the understanding of coal combustion mechanisms, and thus to allow accurate prediction of the effects of coal properties on combustion performance. This research project constitutes an integral part of their research effort to understand the chemical and physical sub-processes that govern the char oxidation phase of coal combustion. Accurate characterization of char particle temperatures, burning rates, modes of burning, and nitrogen and sulfur release rates are essential to the accurate prediction of carbon burnout, pollutant formation rates, and heat transfer rates in industrial and utility boilers. It is anticipated that the knowledge and information obtained during the course of this project will be incorporated into existing comprehensive combustion codes used for the design of commercial-scale combustors. The results of this work are therefore directly applicable to the design of advanced combustors and are useful in evaluating strategies for pollutant abatement.

The experiments were designed to characterize the combustion behavior of a suite of ten strategic U.S. coals selected by PETC. In the experiments, the sizes, temperatures, and velocities of individual char particles of the raw coals burning in a laminar flow reactor were measured at selected residence times. Samples of partially reacted chars were extracted from the reactor at various residence times, and the chemical and physical properties of the chars determined as a function of conversion. The combined set of optical *in situ* and off-line measurements are used to determine sets of combustion parameters (one set for each coal) that quantitatively describe the combustion behavior of this suite of coals.

Overall Objective

The overall objective of this project is to characterize the physical and chemical processes that govern the combustion of pulverized-coal chars. A specific objective was to determine combustion kinetic parameters that quantitatively describe the char combustion process as a function of coal type, particle size and temperature, and gas temperature and composition. Gas environments were chosen that simulate those present in pulverized-coal fired combustors. It was also an objective of this study to determine the release rates of C, H, N, O, and S from the solid char and to characterize the evolution and transformations of the mineral matter during char combustion.

During the course of this project, data have been acquired on the combustion characteristics of chars from ten United States coals, ranging in rank from lignite to low-volatile bituminous. These coals are listed in Table 3.1. The coals were obtained from the bank of coals at Pennsylvania State University. The letter D following the PSOC designation refers to this particular set of coal from the Pennsylvania State University Coal Bank, which were supplied to Sandia by PETC after grinding and size-classification. A laminar flow reactor was used that allows optical measurements on coal-char particles to be made during combustion in controlled gaseous environments. The reactor is equipped with a particle-sizing pyrometer that permits *in situ* measurements of the sizes, temperatures, and velocities of individual particles at various residence times. It is also equipped with an isokinetic solids-sampling probe that permits the extraction of particles from the reactor for off-line physical and chemical analyses. In particular, the extents of burnoff, the apparent densities, and specific surface areas are determined from the bulk extracted samples. Chemical

analysis of the extracted samples yields, in addition, C, H, O, N, and S contents, total ash content and information on ash chemistry (Ti, Al, Si, Fe, K, Na, and Ca contents).

The experimental endeavor establishes a unique, self-consistent database on the reactivities of U.S. coal-chars. The information learned provides answers to fundamental questions concerning the oxidation mechanism, modes of particle burning, effects of mineral matter on the combustion characteristics of the char, and nitrogen and sulfur release rates during char burnoff. The complete sets of combustion parameters for the PETC coal suite are currently being used to develop a predictive correlation of char reactivity valid for the entire spectrum of commercially important coals burning under technologically-relevant conditions (see Hurt and Mitchell, 1992).

Background

The combustion rates of coal char particles are determined by the combined effects of external mass transfer, oxygen diffusion through the porous carbon particle, and the intrinsic chemical reactivity of the carbon surfaces. The extent to which each of these effects influences the overall particle burning rates depends upon the temperature and composition of the gaseous environment, and the sizes and temperatures of the particles. In typical pulverized coal combustor environments, the burning rates of particles in the 50 to 200 μm size-range are limited by the combined effects of external (gas-to-particle) mass transfer, pore diffusion and the material's intrinsic chemical reactivity. Depending on the specific environment and on the reactivity of the coal char in question, combustion may occur in the so-called Zone II regime (where rates are determined by surface reaction and pore diffusion), in Zone III (where rates are determined by external mass transfer) or in the transition from Zone II to III (where all three factors significantly influence the combustion rate).

The overall particle burning rate is generally expressed in terms of a mass transfer coefficient, k_d , which accounts for the transport of oxygen to the outer surface of the particle, and an apparent chemical reaction rate coefficient, k_s , which accounts for the combined effects of pore diffusion and the intrinsic chemical reactivity of the carbonaceous solid. The mass transfer coefficient depends upon the temperature in the boundary layer surrounding the particle, the particle size, and the product formed at the particle surface. It is readily determined from the analysis of flow across the particle boundary layer.

The apparent chemical reaction rate coefficient depends upon the particle temperature and is expressed in Arrhenius form. The Arrhenius parameters, A (preexponential factor), E (activation energy), and n (reaction order) are properties of a given coal and must therefore be determined, for each coal, by experiment. The kinetic parameters A , E , and n are determined from the combined data set consisting of optical measurements (particle sizes, temperatures, and velocities), and off-line analysis of bulk extracted samples.

Table 3.1
Suite of Coals Investigated

Seam Name	State of Origin	PSOC number	Rank*
Lower Wilcox	TX	1443D	lignite
Blue #1	NM	1445D	subbituminous
Pittsburgh #8	PA	1451D	hva-bituminous
Dietz	MT	1488D	subbituminous
Illinois #6	IL	1493D	hvb-bituminous
Hiawatha	UT	1502D	hvc-bituminous
Beulah Zap	ND	1507D	lignite
Pocahontas #3	WV	1508D	lv-bituminous
Lower Kittanning	PA	1516D	lv-bituminous
Smith Roland	WY	1520D	subbituminous

* reported rank. There are slight variations between reported rank, apparent rank as received by the Pennsylvania State Coal Bank, and apparent rank as received by Sandia National Laboratories.

4. EXPERIMENTAL APPROACH

A laminar entrained flow reactor was employed that provides optical access to coal char particles burning in carefully-controlled gaseous environments. The reactor is equipped with a particle-sizing pyrometer (Tichenor, et al., 1984) that permits the *in situ* measurement of the sizes, temperatures, and velocities of individual particles at various residence times. It is also equipped with an isokinetic solids-sampling probe that permits the extraction of particles from the reactor for off-line physical and chemical analyses. In particular, the extents of burnoff (via ash tracer techniques), the apparent densities (via bulk density and mercury porosimetry measurements), and specific surface areas (via gas adsorption measurements) were determined, and analyses were made for the C, H, O, N, and S elemental contents and total ash content of the chars. The ash was further analyzed to determine its Ti, Al, Si, Fe, K, Na, and Ca contents. Use of Al, Si, Ti, and total ash as tracers allows four independent techniques for determining combustion conversion of each char sample.

The data are used to develop and validate a model describing single-particle burning in gaseous environments characteristic of practical pulverized coal combustors. Data reduction yields overall burning rates of individual particles and parameters that describe the mode of particle burning, *i.e.*, the evolution of particle size and density during combustion. The data for several selected coals also permit intrinsic chemical reactivity parameters to be determined (as described by Mitchell, 1988b) using expressions for the particle Thiele modulus and effectiveness factor (Satterfield, 1970).

Experimental Apparatus

The combustion tests were performed in the Char Combustion Laboratory (CCL) in the Combustion Research Facility at Sandia National Laboratories in Livermore, California. The CCL is designed to accurately characterize the burning behavior of the char particles of pulverized coals in the 50 to 250 μm size-range. The laboratory houses a transparent, laminar, entrained flow reactor that provides a well-characterized, optically-accessible combustion environment. The reactor is equipped with a particle-sizing pyrometer that allows the sizes, velocities, and temperatures of individual particles to be measured. The reactor is also equipped with an isokinetic, helium quench, solids sampling probe that allows partially reacted char samples to be extracted from the reactor at selected heights above the reactor inlet (corresponding to different residence times and extents of burnoff). Analyses of the extracted samples yield the fraction of the initial mass of coal remaining and data on the physical and chemical properties of the char. The flow reactor, particle sizing-pyrometer, and solids sampling probe are described in more detail below.

Laminar flow reactor and coal feeder

The vertical, 5 x 5 cm square, transparent, entrained flow reactor used to investigate the combustion behavior of individual coal char particles has been described in detail previously (Hardesty *et al.*, 1978). It has been used to observe devolatilizing coal particles (McLean *et al.*, 1981a) and particles in their early stages of burning (McLean *et al.*, 1981b, Mitchell and McLean,

1982). A schematic of the atmospheric, laminar flow reactor is shown in Fig. 4.1. Metered flow rates of fuel (hydrogen and/or methane) and oxidizer (oxygen and nitrogen mixtures) are fed through their respective inlets at the base of a diffusion flamelet burner. Upon ignition, an array of diffusion flamelets are stabilized on the rectangular honeycomb burner surface. A rectangular quartz chimney, 46 cm in length, fits over the honeycomb surface and defines the reactor boundaries. The quartz walls allow optical access in the two coordinate directions perpendicular to the reactor centerline. The entire burner assembly is mounted on an x-y-z-positioner so that all regions of the reactor volume above the honeycomb surface can be brought into the focal volume of the optical system.

Figure 4.1 Schematic of the CCL atmospheric laminar flow reactor

By adjusting the flow rates of the gases fed to the reactor, various gas compositions and axial gas temperature profiles in the reactor can be selected. Gas temperatures are measured using platinum-vs-platinum/13% rhodium thermocouples. Allowance for radiative heat loss from the bead permits the gas temperature at the bead location to be calculated. Gas temperatures just above the flame zone can be varied from about 1400 to nearly 2000 K. An axial temperature gradient of -8 to -10 K/cm exists along the centerline downstream of the flame zone due to heat losses at the wall. At each axial distance above the burner surface, a uniform temperature region (nominally, 2.5 x 2.5 cm in area) exists about the reactor centerline. The temperature decreases radially from this uniform value as the reactor walls are approached.

The composition of the reactor environment in the post-flame region is uniform. The burned gases consist primarily of oxygen, water vapor, carbon dioxide and nitrogen. Oxygen levels can be varied from the parts-per-million range up to about forty mole-percent. Oxygen concentrations are calculated from the measured flow rates of the feed streams assuming that the burned gases are in chemical equilibrium. In selected environments, the calculated levels were confirmed by measurement using a gas sampling probe and a solid-state oxygen analyzer.

Gas velocities along the reactor centerline are influenced by thermal expansion effects and by the effects of the boundary layers that form along each of the reactor walls. The boundary layer thicknesses increase as the height above the reactor inlet increases, thereby causing the gas velocities along the centerline to increase with height. The gas velocity in the central core of the reactor is expressed as:

$$\sqrt{\frac{v_g}{T_g}} = c_1 + \frac{\sqrt{c_2 w}}{2} + \frac{c_2 w}{8\sqrt{c_1}} \quad (4.1)$$

where

$$w = z T_g^{0.68} \quad (4.2)$$

This equation is the solution of the conservation equation governing steady, one-dimensional flow through a square conduit when it is assumed that the boundary layer along each wall of the conduit develops in the same way as that which develops along a flat plate, and that the fraction of the total mass flow within the boundary layer at any cross-section of the conduit is proportional to the boundary layer thickness. The exponent on T_g in the defining equation for w is a consequence of employing an expression for the gas viscosity that varies with temperature in this manner. The size and velocity measurements obtained with spherical, non-friable graphite particles are used to determine the constants c_1 and c_2 (Niksa, *et al.*, 1984; Mitchell, 1987a). With the graphite particles, any errors in the measurements associated with non-sphericity effects are negligible and any heat effects due to devolatilization and combustion of volatiles are avoided.

A schematic of the particle feeder is shown in Fig. 4.2. Pulverized coal particles are loaded into a gas-tight syringe, and the plunger is advanced by a stepping motor. As particles fall off the end of the syringe, they are entrained by the carrier gas and fed to the flow reactor. The syringe-type feeder provides a steady flow of particles to the reactor at a rate up to about one gram per hour. Most of the particles loaded into the syringe reach the reactor with little attrition. Particles are

injected along the reactor centerline and burn as they flow in the post-flame gases. Table 4.1 lists the ranges of the independent parameters associated with the laminar flow reactor and coal feeder.

Table 4.1
Range of Operating Conditions
Achievable in the CCL Laminar Flow Reactor

Independent Parameter	Achievable Range
Gas temperature	1000 - 2000 K
O ₂ partial pressure	~0 - 0.4 atm
CO ₂ partial pressure	~0 - 0.2 atm
Particle size	50 - 250 μ m
Particle residence time	up to 0.2 s
Particle loading	up to 1 g/h
Particle heating rate	10 ⁴ - 10 ⁵ K/s

Gas environments employed in the combustion experiments

The kinetic data presented in this report derive from measurements made in two gas environments, containing 6 and 12 mole-% oxygen, respectively. In the course of the development of this kinetic technique, experiments have also been performed in environments containing 1, 3, 24, and 36 mole-% oxygen. A detailed description of the two flow reactor combustion environments is given in Table 4.2.

Particle-sizing pyrometer

The transparent walls of the flow reactor permit luminous emission from burning particles to be monitored by a particle-sizing pyrometry system that was developed during the course of this project (Tichenor *et al.* 1984). Particle size, temperature, and velocity are obtained using an image-plane, coded-aperture technique (Tichenor and Wang, 1982). Figure 4.3 depicts the optical configuration. Incandescent particles moving in the laminar flow reactor pass through the image of a coded-aperture focused onto the reactor centerline. The coded-aperture consists of a 100-micron-width slit (the trigger slit) positioned just prior to a pair of slits of different widths (the sizing-slits). The width of the smaller sizing-slit (36 microns) defines the lower size-measurement limit and the width of the larger sizing-slit (1 mm) defines the upper limit. A pair of f/4 cemented, achromatic lenses having 150 mm focal lengths are used to form a 1:1 image of the particles on the coded-aperture. The transmitted light is separated into two wavelength bands (centered at 500 and 800 nm with bandwidths of 50 and 90 nm, respectively) and detected using Hamamatsu R928 photomultiplier tubes thermo-electrically cooled to 250 K. The signals are low-pass filtered at 25

Table 4.2
Description of the
6 Mole-% Oxygen Environment

POST-FLAME GAS COMPOSITION

0.0592, 0.024, 0.177 (OXYGEN, CO₂ AND H₂O MOLE FRACTIONS; REMAINDER N₂)

MASS FLOW TO THE REACTOR

1.032 g/s

NUMBER OF TEMPERATURE MEASUREMENTS IN AXIAL PROFILE

10

AXIAL GAS TEMPERATURE PROFILE

height above burner surface	Temperature (K)
0.	300.
1.27	1659.
2.54	1685.
3.81	1689.
6.35	1682.
12.7	1642.
19.05	1593.
25.4	1536.
31.75	1480.
38.1	1425.

VALUES OF PARAMETERS IN VELOCITY CORRELATION, VV1, VV2

GAS VELOCITY PARAMETERS, VV1, VV2: 0.32920 1.4582E-5 (*THIS SET IS USED*)
 (DETERMINED USING PSOC-1445)

GAS VELOCITY PARAMETERS, VV1, VV2: 0.34462 1.6738E-5 (*FOR REFERENCE ONLY*)
 (DETERMINED USING SPHEROCARB WITH RHO = 0.6 G/CC)

GAS VELOCITY PARAMETERS, VV1, VV2: 0.333587 1.6525E-5 (*FOR REFERENCE ONLY*)
 (DETERMINED USING SPHEROCARB WITH RHO = 0.5 G/CC)

THE GAS VELOCITY ALONG THE VELOCITY CENTERLINE IS CORRELATED BY

$$\text{SQRT}(\text{VG}/\text{TG}) = \text{VV1} + 0.5 * \text{SQRT}(\text{VV2} * \text{W}) + \text{VV2} * \text{W} / 8. / \text{SQRT}(\text{VV1})$$

 WHERE $\text{W} = \text{Z} * \text{TG}^{**0.6756}$

Table 4.3
Description of the
12 Mole-% Oxygen Environment

POST-FLAME GAS COMPOSITION

0.119, 0.024, 0.177 (OXYGEN, CO₂ AND H₂O MOLE FRACTIONS; REMAINDER N₂)

MASS FLOW TO THE REACTOR

1.041 g/s

NUMBER OF TEMPERATURE MEASUREMENTS IN AXIAL PROFILE

10

AXIAL TEMPERATURE PROFILE

height above burner surface	Temperature (K)
0.	300.
1.27	1675.
2.54	1700.
3.81	1702.
6.35	1692.
12.7	1645.
19.05	1591.
25.4	1532.
31.75	1474.
38.1	1418.

VALUES OF PARAMETERS IN VELOCITY CORRELATION, VV1, VV2

0.3107 1.5599E-5 GAS VELOCITY PARAMETERS, VV1, VV2: (*THIS SET IS USED*)
 (DETERMINED USING PSOC-1445)

GAS VELOCITY PARAMETERS, VV1, VV2: 0.33128 1.9557E-5 (*FOR REFERENCE ONLY*)
 (DETERMINED USING SPHEROCARB WITH RHO = 0.6 G/CC,)

GAS VELOCITY PARAMETERS, VV1, VV2: 0.32266 1.9274E-5 (*FOR REFERENCE ONLY*)
 (DETERMINED USING SPHEROCARB WITH RHO = 0.5 G/CC)

GAS VELOCITY PARAMETERS, VV1, VV2: 0.33968 1.9850E-5 (*FOR REFERENCE ONLY*)
 (DETERMINED USING SPHEROCARB WITH RHO = 0.7 G/CC)

THE GAS VELOCITY ALONG THE VELOCITY CENTERLINE IS CORRELATED BY

$$\text{SQRT}(V_G/T_G) = VV1 + 0.5 \cdot \text{SQRT}(VV2 \cdot W) + VV2 \cdot W / 8. / \text{SQRT}(VV1)$$

$$\text{WHERE } W = Z \cdot T_G^{**0.6756}$$

Figure 4.2 Schematic of Pulverized Particle Feeder

Figure 4.3 Schematic of Particle-Sizing Pyrometer

kHz, which is suitable for particle velocities up to about 4 m/s. The filtered outputs are processed through MVP 4-decade logarithmic amplifiers. A pair of triple-pulse signals (one waveform for each wavelength band) is generated for each particle that passes through the sampling volume.

The sampling volume is defined by the image of the trigger slit and the waist of a 5 mW He-Ne laser beam directed 90 degrees to the image-plane. Light passing through the trigger slit is separated from light passing through the sizing-slits and detected through a narrow band filter centered at the laser wavelength. The laser beam is confined to the depth of field of the imaging system so that only those particles in focus will scatter the trigger beam and produce an output in the trigger detector. Signals are analyzed only if they are validated by a trigger pulse, thereby eliminating errors that could be incurred due to focussing and/or edge effects. The waveforms of validated signals are digitized using a Nicolet 12-bit digitizing oscilloscope and stored on a computer for off-line analysis. The system is controlled by a PDP-11/34 minicomputer.

Particle size is encoded in the transmitted light. The ratio of the peak photocurrents in each sizing-slit is a monotonic function of the particle diameter, d_p . The sizing technique is calibrated using back-lighted pinholes having diameters of 50, 100, and 200 μm and spherical carbon particles (Spherocarb) of known sizes. Particle velocity is obtained by measuring the transit time across the larger sizing-slit of the coded-aperture. Calibration is not required since the dimensions of the slit and the optical magnifications are known.

The ratio of peak photocurrents in the two wavelength bands in the larger sizing-slit of the coded-aperture is used to determine particle temperature. The principle employed is based on the theory of two-color pyrometry and hence, relies on the assumption that char particles behave as graybody emitters. Mitchell and McLean (1982) have shown that over the wavelength range 500 to 850 nm, radiant emission from burning coal char particles is characteristic of emission from graybodies. A tungsten strip lamp is used to determine the system-dependent temperature calibration constant. The spectral emissivity data of Latyev *et al.*, (1970) are used for the monochromatic emissivity of tungsten at the wavelengths employed. The lamp is periodically calibrated by comparing its intensity against that of a blackbody at known temperature. System calibration procedures and the precision in the measurements are discussed by Tichenor *et al.*, (1984). Accuracy in the measurements obtained using this particle-sizing pyrometer are discussed by Niksa *et al.*, (1984). Results have indicated that the instrument developed is capable of determining the diameters of spherical particles to within ten microns and the surface temperatures of particles to within 25 K for those particles having diameters greater than 70 μm and surface temperatures greater than about 1200 K.

Solids sampling probe

Solid samples are extracted from the laminar flow reactor using a water-cooled isokinetic, solids sampling probe. The probe is shown schematically in Fig. 4.4. An outer jacket for cooling water protects two concentric tubes from the hot reactor environment. The probe is constructed of stainless steel tubing. The outer diameter of the cooling jacket is 1.9 cm and

Figure 4.4 Schematic of Solids Sampling Probe Assembly

the diameter of the central tube is 0.5 cm. The quench fluid (helium) flows downward through the annulus of the concentric tubes and mixes with the incoming sample stream at the probe inlet. The quench fluid and sample stream (consisting of hot reactor gases and solids) are drawn upward through the central tube by a vacuum pump. The solids are collected on filter paper (having 1 μm size openings) in the filter housing and the gases are vented through the vacuum pump. The particles are removed from the filter paper, weighed, and stored in sealed sample bottles.

The flowrate of water in the cooling jacket is adjusted to maintain no more than a 30 K increase in the water temperature. The quench fluid flowrate is adjusted such that the gas temperature in the central tube, 3 mm from the tip, is less than about 900 K during isokinetic sampling (i.e. when the velocity of the gas entering the probe is equal to the gas velocity at that point in the reactor when the probe is absent). Gas cooling rates are greater than 10^6 K/s. Particle cooling rates are estimated to be about an order of magnitude lower. Such cooling rates are sufficient to quench gas and particle combustion rates. The extracted particles are effectively at the conditions they attained in the absence of the sampling probe.

Experimental Procedures

Samples of the ten coals in Table 3.1 were pulverized and sieved under nitrogen to obtain two narrow size fractions for study, 75 - 106 μm and 106 - 125 μm in particle diameter. The size classified samples were stored under Ar prior to initiation of combustion studies. The coal particle feeder used in the experiments requires a free flowing powder to achieve uniform single-particle feeding. It was necessary to dry several of the coal samples at 100 $^{\circ}\text{C}$ for one hour prior to combustion studies to remove moisture and achieve uniform feeding. The remaining samples were injected into the combustion chamber untreated.

The size-graded pulverized coal samples are injected into gaseous environments with known oxygen contents and axial gas temperature and velocity profiles. The particles are injected through a 0.19 cm nozzle at the feed gas temperature and velocity along the reactor centerline. Particle heating rates are calculated to be 10^4 - 10^5 K/s. The coal loading is low enough to ensure that the gas phase is not appreciably altered by combustion of the coal volatiles or the char particles. Combustion tests were performed in two gas environments, containing 6 and 12 mole-% oxygen respectively. For each coal, the complete battery of tests was carried out on coal samples of initial size 106 -125 μm . For selected coals additional tests were performed on a 75 - 106 μm size fraction.

At successive heights above the reactor inlet, the particle-sizing pyrometer is used to obtain the sizes, temperatures, and velocities of individual particles. The residence times to the selected heights are calculated from the particle velocities. At the same heights at which the *in situ* sizes, temperatures, and velocities measurements are made, the solids sampling probe is used to extract samples of partially reacted chars from the reactor. At each measurement height, a known weight of coal is injected and all particles that reach the height are collected. The ratio of the weight of the particles collected (m) to the weight of coal injected (m_o) gives the fraction of the initial mass of coal remaining in the solid phase (m/m_o) at the measurement height. Typically 500 mg of sample are collected at each location. This amount is sufficient for particle density measurements, and organic and inorganic elemental analysis. For surface area measurements an additional 500 mg of

sample is collected. The apparent densities and specific surface areas of the extracted samples are determined, as well as elemental carbon, hydrogen, nitrogen, oxygen, and sulfur contents and total ash. The ash is further analyzed to determine its titanium, aluminum, silicon, iron, potassium, sodium, and calcium contents. Ash tracer techniques provide additional estimates of m/m_o at the various measurement heights.

Table 4.4
Statistical Analysis of Burning Char Particles
of Beulah Zap Coal

COAL TYPE: BEULAH ZAP LIGNITE, 106 - 125 μm
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642 K
 SAMPLING HEIGHT: 12.7 cm

Size (μm)	Num	Temp (K)	rms(T) (K)	Vel (m/s)	rms(V) (m/s)	Emiss	rms(E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	0	0	0	0.00	0.00	0.00	0.00
100.	3	1733	8	2.59	0.03	1.13	0.14
110.	36	1745	44	2.56	0.05	0.76	0.17
120.	62	1747	26	2.57	0.03	0.62	0.17
130.	64	1747	20	2.56	0.03	0.58	0.13
140.	65	1740	27	2.55	0.13	0.54	0.13
150.	26	1739	15	2.57	0.04	0.53	0.17
160.	10	1731	36	2.44	0.30	0.45	0.06
170.	6	1703	53	2.55	0.05	0.43	0.11
180.	4	1743	22	2.59	0.01	0.38	0.14
190.	1	1736	0	2.60	0.00	0.37	0.00
200.	1	1726	0	2.47	0.00	0.44	0.00
210.	1	1738	0	2.57	0.00	0.48	0.00
220.	0	0	0	0.00	0.00	0.00	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	1	1799	0	1.53	0.00	0.18	0.00

NUMBER OF PARTICLES = 280

Particle size, temperature, and velocity

At each selected height above the reactor inlet, optical measurements are made on 200 to 300 particles. The waveforms of validated signals are analyzed to determine size, temperature, and velocity of each individual particle observed. A typical data set is summarized in Table 4.4, which shows the statistical analysis of data obtained for the char particles of Beulah Zap lignite burning in a 6 mole-% oxygen environment 12.7 cm above the reactor inlet. Raw coal particles in the 106 to 125 μm size-range were injected into the flow reactor, and the extent of burnoff at this particular measurement height is approximately 73% on a dry, ash-free basis. The first column of the table gives the center diameter of each ten-micron size-bin into which the measured particle sizes were grouped. The adjacent column gives the number of particles that fall within the ten-micron size-range. The mean values and standard deviations of the distributions of particle temperatures and velocities in each size-bin are shown in the next columns. The last two columns show the means and standard deviations of the distributions of particle emissivities in each size-bin.

The particle emissivity is calculated by using the peak photocurrent in the wide sizing slit of the coded-aperture in Wien's equation, modified for non-black emitters. The wavelength-dependent calibration constant is determined using a calibrated tungsten lamp, as described in the paper by Tichenor *et al.* (1984). We assume that the char particles are spherical.

Since the particle emissivities are calculated from absolute signal levels and not from signal ratios (as are the values calculated for the particle sizes and temperatures), they are more sensitive to errors in calibration and to adverse optical effects due to misalignment and monochromatic aberrations. In addition, any errors incurred in determining the size and temperature of the particle are reflected in the value determined for its emissivity. Tests with Spherocharb (spherical, ash-free graphite particles) indicate that errors associated with adverse optical effects due to misalignment and monochromatic aberrations are small. The calculated emissivities of Spherocharb particles are generally in the range 0.75 to 0.95, in agreement with the expected value of 0.85 for graphite particles. Waters *et al.*, (1988a) show that when a prolate spheroid with a length-to-width ratio of 1.5 crosses the sizing-slits of the pyrometer, it exhibits an orientation-dependent shape-correction factor (the ratio of the sphere-equivalent diameter to measured particle diameter) between 0.76 and 1.14. Such factors yield calculated particle emissivities of 1.3 and 0.58, respectively, times the true values. Thus, irregularly-shaped particles are expected to have calculated emissivities that range from 0.58 to 1.3 times their true values. The value calculated for emissivity is not used therefore as a measure of the true emissivity of the particle, but instead serves as an indicator of the consistency of the data.

The measured temperature distribution associated with the data shown in Table 4.2 is shown in Fig. 4.5. Almost 80% of the particles have temperatures within 25 K of 1750 K. A few particles have temperatures as high as 1800 K; some particles have temperatures near the theoretical non-burning limit. Variations in the temperatures of char particles are expected due to: (a) variations in the size and morphology of particles; (b) differences in surface area and pore structure; (c) differences in intrinsic carbon surface reactivity among the various components of the coal; (d) catalysis by mineral matter; Mitchell (1990a) shows that particle-to-particle variations in ash-content are important factors in causing variations in the temperatures of particles of nominally the

same size. At long residence times, low particle temperatures reflect high-ash particles in their final stages of burning and high particle temperatures reflect average- to low-ash particles in their middle to relatively late stages of burnoff. The low-temperature, high-ash particles near burnout may have emissivities significantly lower than those typical of carbon-rich char particles.

Figure 4.5 The distribution of the temperatures of the char particles of Beulah Zap lignite (PSOC-1507) burning in 6 mole-% oxygen in the flow reactor.

Particle density

Mercury intrusion porosimetry was used to determine the densities of coal particles. The term particle density refers here to the density of the porous coal or char, as distinguished from the true density of the (nonporous) carbon material. In the experimental procedure, prior to analysis, each coal sample was heated under vacuum (10^{-5} Torr) at 473 K for several hours to remove gaseous or liquid contaminants from the surface. Porosimetry analysis was performed using an Autopore 9200, with 40 intrusion points and 31 extrusion points. Maximum pressure attained was 60,000 psi corresponding to a minimum pore diameter of approximately 30 Angstroms. Figure 4.6 shows

intrusion data obtained at low manifold pressures for Pittsburgh #8 coal particles in the 75 - 106 μm size-range. At a manifold pressure of 7.9 psia, openings larger than 22 μm are filled.

Since pores in unreacted coal particles are much smaller than this, at pressures below 7.9 psia the mercury intruded into the penetrometer is filling openings between particles, (*i.e.*, interparticle voids are being filled). The relatively large amount of mercury intruded at 7.9 psia (as evidenced by the peak in the differential volume curve) suggests that the openings between particles are nominally 20 μm . For manifold pressures between 30 and 60 psia, little mercury is intruded into the penetrometer. Hence, in agreement with the results of Gan *et al.* (1972), the mercury intrusion porosimetry data indicate that the void volume surrounding raw coal particles is essentially filled at a pressure of 60 psia. At this manifold pressure, mercury penetrates all openings larger than 3 μm . Below say, 45 psia, only the interparticle voids are filled and above 60 psia, mercury is forced into particle pores. Thus, the volume of mercury intruded up to 60 psia is used to calculate the apparent density of raw, unreacted coal particles.

Figure 4.6 Low-Pressure Mercury Intrusion Porosimetry data for Pittsburgh #8 Coal Particles

With coal chars, the blowholes in the outer particle surfaces can be as large as the openings between particles. Mercury fills the interparticle volumes and penetrate the outer surfaces of particles at the same manifold pressures, thereby making it impossible to determine the volume

displaced by particles. The volume of mercury intruded up to 60 psia would give inaccurate measures of the apparent densities of coal char.

In order to determine the apparent density of a coal char, a sample of the char was introduced into a tube graduated in microliters. The outside of the tube was tapped until the particles were well-settled. The volume occupied by the particles was noted. The char in the tube was then weighed. Data were obtained for different amounts of char added to the tube. The same procedure was performed with the raw coal. Figure 4.7 shows results obtained for Pittsburgh #8 coal particles and its partially reacted chars extracted at successive heights in the flow reactor (and hence, at increasing extents of burnoff). The lines in the figure represent least squares fits to the data obtained at each sampling height, and the slope of each line gives the bulk density, ρ_b , the weight of material per unit volume of tube filled. The linearity confirms the uniformity in the packing of the tube. The particle (or apparent) density of the material, ρ , equals $\rho_b / (1 - \theta)$, where θ is the interparticle porosity in the tapped bed, or "packing factor". Assuming that the interparticle porosities for coals and coal chars are the same, the ratio of the slope of the line for the char to that of the coal equals the ratio of the apparent density of the char to that of the parent coal. Thus, using mercury porosimetry to determine the apparent density of the coal, the apparent densities of its partially reacted chars can be determined from the ratios of slopes.

The procedure was validated by determining the ratios of slopes for several raw coals and comparing these ratios to the ratios of apparent densities determined using mercury porosimetry. Excellent agreement was obtained. Particles in the 75 to 106 μm and 106 to 125 μm size-ranges yielded a packing factor of 0.42. This value is in agreement with the value 0.45 used by Field (1969) in similar tests in which the bulk density of a bed of particles, vibrated to a minimum volume in a tube, was used to determine apparent density. A value of 0.42 was employed to determine apparent densities of the coal and char samples examined in this project.

Total surface area

Gas adsorption techniques were used to determine total specific surface areas. In such techniques, the number of molecules necessary to cover the surface of the adsorbent with a complete monolayer is determined. This quantity when multiplied by the area occupied by a single adsorbed molecule gives the total specific surface area. The monolayer coverage is conventionally determined by the Brunauer-Emmett-Teller (BET) equation (Brunauer *et al.*, 1938). The BET surface areas of porous and nonporous adsorbents are usually determined from N_2 adsorption isotherms measured at 77 K. At 77 K, extremely long equilibrium times (on the order of months) are required to achieve total surface coverage, especially for materials having high microporosity, which can behave as molecular sieve materials. Adsorption of N_2 at 77 K is considered to measure the area of the macropores, transition pores, and the larger micropores (Walker and Geller, 1956; Anderson *et al.*, 1965).

To determine the surface areas of microporous coals, it is essential to measure the adsorption of gases at as high a temperature as possible in order to overcome activated diffusion effects. In a series of tests employing different gases, Walker and Kini (1965) found that the adsorption of CO_2 at 298 K adequately measures the total surface area of coals (the critical

Figure 4.7 The volumes occupied by various weights of Pittsburgh #8 coal and its partially reacted chars as a function of height above the reactor inlet. Char particles were collected in 6 mole-% oxygen. The sample at the 6.35 cm height was collected just subsequent to devolatilization and may contain tars that had not yet burned.

temperature of CO_2 is 304 K). Tests indicate that adsorption of CO_2 is relatively insensitive to the temperature at which the measurements are performed and that only about 30 minutes are required to reach equilibrium adsorption with CO_2 . The Polanyi-Dubinin (P-D) equation is used to calculate surface areas of coals from CO_2 adsorption. For a number of coals, Walker and Patel (1970) found excellent agreement between surface areas calculated by the BET and P-D equations from adsorption of CO_2 measured at 298 K.

The choice of the proper technique for surface area measurement also depends on the role of microporosity during the gasification or oxidation process. If the heterogeneous reaction occurs on the large surface area associated with carbon micropores, the CO_2 adsorption technique may be expected to provide useful information on char reactivity. If, however, the micropores are inaccessible during combustion, N_2 adsorption, measuring only the surface area lying in larger pores, may be more appropriate. There is evidence that the microporous surface area of carbons fully participates for some systems but not for others (Hurt et al. 1991).

To obtain information on both the total, microporous surface area and the area in meso- plus macropores, both N_2 and CO_2 adsorption techniques were applied to selected coals and char samples. The coal and char samples were sent to the Coors Analytical Laboratory in Golden, Colorado for gas adsorption measurements. Before the measurements, each sample was outgassed under vacuum at 160 C for 4 to 20 hours to remove moisture. It is possible that water covers the hydrophilic sites in the coal (oxygen functional groups and mineral matter) thereby blocking entrances to some of the finer micropores. Outgassing eliminates this possibility. The adsorption measurements were performed using a LECO 2400 Surface Area Analyzer. Results of duplicate analyses of raw, unreacted coals suggest that the N_2 -BET measurements are accurate within 20% and CO_2 measurements within 10%.

Figure 4.8 shows results obtained for Hiawatha coal and its partially reacted chars. The chars were extracted from the 6 mole-% oxygen environment at various residence times, thus representing various stages of combustion. For each sample, the surface areas determined from the CO_2 adsorption data are higher than those determined from the N_2 data. Both the N_2 and CO_2 adsorption measurements show a large increase in surface area subsequent to heatup and volatiles release, indicating that the devolatilization process produces char particles with more microporosity than the parent coal particles. Both adsorption gases indicate that during burnoff, the total specific surface area of the char particle decreases, suggesting the loss of micro- and mesopores during combustion. The results shown in Fig. 4.8 are typical of those obtained with other coal and char samples burning in 6 and 12 mole-% oxygen environments.

Elemental analysis of organic material and elemental release rates

Samples of raw coals and their partially reacted chars were analyzed for their elemental carbon, hydrogen, nitrogen, oxygen, and sulfur contents. The relative weight fractions of these elements are determined via conventional ultimate analysis techniques. Proximate analysis techniques are used to determine the moisture and total ash contents of the samples. For descriptions of proximate and ultimate analyses see, for example, Elliot (1981). The elemental analyses were performed by the Coors Analytical Laboratory in Golden Colorado. A colorimetric combustion technique was used for carbon and hydrogen determinations, a pyrolysis technique for oxygen, a Fisher Sulfur Analyzer for sulfur, and a Carlo/Erba Nitrogen Analyzer for nitrogen. Each analysis was performed using a LECO instrument. The samples were dried before the analyses. Table 4.5 shows results obtained for Blue #1 coal (PSOC-1445D) and each of its partially reacted chars. These samples were extracted from 6 and 12 mole-% oxygen environments at selected heights above the reactor inlet (corresponding to various residence times and extents of burnoff). The values presented are the results of independent determinations and have not been normalized to sum to 100%.

Comparison of the results for the 106 to 125 μm size fraction of the raw coal (0.0 cm height) gives an indication of the variability of different samples. Comparison of the results for the 75 to 106 μm and 106 to 125 μm size fractions of the raw coal often reveal real differences between the size fractions. No significant differences in the elemental compositions or in the ash levels are noted for the different size fractions used in the combustion tests.

Two samples of char from Blue #1 coal (initial coal particle diameter 106 to 125 μm) were extracted from the flow reactor at the 19.1 cm height during combustion in 12 mole-% oxygen. From these data and from knowledge of sample-to-sample variations in the raw coal analyses, the true values at the 19.1 cm height are predicted with 95% confidence to lie in the following intervals (%): C, 65 ± 15 ; H, 0.88 ± 0.2 ; O, 6.6 ± 1.5 ; N, 0.89 ± 0.2 ; S, 1.2 ± 0.3 ; and ash, 25.2 ± 5.7 . Calculations for the other coal and char samples examined usually yield results of similar accuracy.

The data presented in the table can be used to determine the rates at which various important elements enter the gas phase during the combustion process. The fraction of the initial amount of element i remaining in the solid phase (char), f_i , is given by:

$$f_i = \left(\frac{x_i}{x_{i,0}} \right) \left(\frac{m}{m_o} \right) \quad (4.3)$$

where x_i and $x_{i,0}$ are the fractions of element i in the partially reacted char and in the raw coal, respectively, and m/m_o is the fractional mass remaining in the solid phase at the residence time of interest. The value of m/m_o is the mean value of several independent determinations using Si, Al, and total ash as tracers an overall mass balance on the coal injected. The fraction of the element i released up to the residence time of interest is $(1 - f_i)$ and the fraction of the initial mass released is $(1 - m/m_o)$.

To allow comparison of elemental release rates for different coals, the m/m_o values are expressed on an ash-free basis as follows:

$$\left(\frac{m}{m_o} \right)_{af} = \left(\frac{m}{m_o} \right) \frac{(1 - X_a)}{(1 - X_{a,o})} \quad (4.4)$$

The quantity $(m/m_o)_{af}$ represents the fraction of the initial amount of combustible material remaining in the char at the measurement height.

Figure 4.9 shows the extent of release of carbon, hydrogen, oxygen, nitrogen, and sulfur relative to the total mass release for Blue #1 coal char particles reacting in both the 6 and 12 mole-% oxygen environments. The line in each subplot represents the total release of mass to the gas phase during combustion. Points below the line indicate release rates slower than the total mass release rate and points above the line indicate release rates faster than the total mass release rate.

For Blue #1 coal particles injected into the gaseous environments employed here, about 51% of the mass leaves the solid phase during devolatilization, the remaining 49% during char oxidation. During the course of burnoff, carbon is released in approximate proportion to the total mass release rate on an ash-free basis. This is expected since carbon is the principal component of the char.

Hydrogen and oxygen are each released faster than is the total mass. Such behavior is consistent with hydrogen and oxygen in the char occurring primarily in labile peripheral groups such as -COOH, -OH, C=O, and -OCH₃ that are labile and more readily released than aromatic carbon. Some of the oxygen that is released relatively late in burnoff may be incorporated in aromatic and

Figure 4.8 Specific surface areas of Hiawatha coal and its partially reacted chars collected in the 6 mole-% oxygen environment. Initial coal particle size is 106 to 125 μm .

aliphatic ether-structures of the form $\text{C}_{(\text{ar})}\text{-O-C}_{(\text{ar})}$, $\text{C}_{(\text{ar})}\text{-O-C}_{(\text{al})}$, and/or $\text{C}_{(\text{al})}\text{-O-C}_{(\text{al})}$ that have been observed in coals (Berkowitz, 1985).

The release of nitrogen is approximately proportional to the release of carbon. This is consistent with the theory that nitrogen in coal chars is primarily bound in N-heterocyclics and C-N=C configurations distributed throughout the carbonaceous matrix rather than in loosely bound amino, amido, or cyano groups. Such nitrogen-containing functional groups are most likely released during devolatilization and during the early stages of burnoff.

Data analogous to that presented in Table 4.3 for Blue #1 coal and its partially reacted chars have been obtained for all the PETC coals examined in this project. These data, as well as figures similar to Fig. 4.9, are presented for each coal in Section 10.

Table 4.5
Organic Elemental Analysis and Percent Ash of Blue #1 Coal and its
Partially Reacted Chars

Initial particle size range, 75 - 106 μm

6 mole-% Oxygen Environment

Hgt (cm)	%-C	%-H	%-O	%-N	%S	%-Ash
0.0	74.24	5.19	14.92	1.85	0.66	3.16
6.4	85.04	0.62	4.32	1.39	0.89	8.30
12.7	82.20	0.74	3.48	1.21	1.04	11.63
19.1	72.30	0.95	4.30	1.09	1.17	21.24
25.4	58.60	0.64	4.53	0.83	1.43	34.44

12 mole-% Oxygen Environment

Hgt (cm)	%-C	%-H	%-O	%-N	%S	%-Ash
0.0	74.24	5.19	14.92	1.85	0.66	3.16
6.4	84.46	0.64	1.87	1.25	1.06	9.46
12.7	76.68	0.32	2.99	0.86	0.62	19.88
19.1	60.85	0.41	4.76	0.74	1.56	32.62
25.4	45.48	0.69	5.35	0.76	1.49	48.08

Initial particle size range, 106 - 125 μm

6 mole-% Oxygen Environment

Hgt (cm)	%-C	%-H	%-O	%-N	%S	%-Ash
0.0	74.49	5.25	13.80	1.36	0.68	3.53
6.4	77.18	2.26	6.02	1.48	0.56	10.12
12.7	85.60	0.58	0.35	1.38	0.19	10.49
19.1	82.06	0.55	0.48	1.07	0.31	9.06
25.4	79.89	0.80	2.07	1.08	0.49	12.45

12 mole-% Oxygen Environment

Hgt (cm)	%-C	%-H	%-O	%-N	%S	%-Ash
0.0	74.42	5.33	14.76	1.29	0.69	3.38
6.4	80.53	2.16	7.70	1.41	0.80	7.38
12.7	82.55	0.45	1.88	0.97	1.06	13.49
19.1	71.98	0.95	7.61	1.07	1.19	19.33
19.1	58.93	0.81	5.57	0.70	1.29	31.12
25.4	36.36	0.39	4.65	0.36	1.30	55.17

Elemental analysis of inorganic material and fractional combustion conversion

Samples of coals and their partially reacted chars were analyzed for aluminum, calcium, iron, magnesium, potassium, silicon, sodium, and titanium contents using inductively-coupled plasma atomic emission spectroscopy. The analyses were performed by the Coors Analytical Laboratory in Golden Colorado. Typical data are shown in Table 4.6 for raw Lower Wilcox coal and its char samples extracted from 6 and 12 mole-% oxygen environments at selected heights above the reactor inlet (the zero height corresponds to the raw coal). The table gives the percentages of the total char sample presented on a metal oxide basis.

The weight fractions of Si, Al, and Ti in each sample are used to determine values of m/m_o , the fraction of the initial mass remaining in the solid phase at each measurement height. These species are expected to be both non-reactive and non-volatile under the conditions present in the experiments. It is assumed that these species remain in the solid phase during burnoff, and hence, f_i in Eq. (4.3) equals unity for each. Thus, from Eq. (4.3)

$$\left(\frac{m}{m_o}\right) = \left(\frac{x_{i,o}}{x_i}\right)_{tracer} \quad (4.5)$$

The total amount of ash in the sample is also used to determine a value for m/m_o (via Eq. (4.5)). These values are not as reliable as the values determined using Al, Si, and Ti as tracers because some of the mineral matter in the coal may leave the char by reaction or vaporization processes. An overall mass balance yields yet another independent measure of m/m_o , where m is the total mass of sample collected and m_o the mass of coal injected. An accurate and reliable determination of m/m_o is achieved from the independent techniques by first discarding suspect data and then using the remainder to calculate an average m/m_o value. The statistical variation among the independent measurements also allow quantitative confidence limits to be placed on the estimates of the mean m/m_o .

Table 4.5 shows example results obtained for Lower Wilcox coal and char particles in the 106 to 125 μm size-range burning in 6 and 12 mole-% oxygen environments. Two values are shown when total ash was used as the tracer, one using a small sample ("Ash-s", approx. 100 mg) and the other, using a larger sample ("Ash-l", greater than 500 mg). The values determined from the mass balance are obviously low, indicating that material was lost during the collection process. The agreement observed in the values determined via the ash-tracer techniques indicates that each of the tracers can be used to get a good estimate of the extent of burnoff. The sample collected at the 12.7 cm height in the 6 mole-% oxygen environment yielded some rather unusual results for each analysis. The sample was assumed to be contaminated and the analyses were disregarded.

Also shown in Table 4.7 are the mean values and the standard deviations of m/m_o determined via the different techniques. A 90% confidence interval for m/m_o at each height can be obtained by multiplying each of the standard deviations at the height by a factor of 1.066 (Walpole and Myers, 1978).

Figure 4.9 Elemental release rates of C, H, O, N, and S relative to the total mass release rates for the char of Blue #1 coal

Table 4.6
Inorganic Analysis of Lower Wilcox Coal and its
Partially Reacted Chars

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	7.65	4.28	0.359	0.765	2.21	0.409	0.096	0.050
6.4	13.4	7.54	0.608	1.74	3.87	0.728	0.123	0.076
12.7	5.13	2.71	0.170	1.67	0.78	0.155	0.051	0.024
19.1	18.3	11	0.862	2.28	5.55	1.04	0.025	0.094
25.4	21.1	14.8	1.11	3.49	9.23	1.85	0.222	0.139

12 mole-% Oxygen Environment

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	9.10	4.70	0.415	0.944	3.13	0.554	0.051	0.029
6.4	14.6	8.01	0.652	2.13	4.43	0.822	0.123	0.065
12.7	20.8	11.7	0.967	6.14	6.97	1.36	0.144	0.084
19.1	30.9	18.2	1.41	8.30	9.91	1.80	0.261	0.110
25.4	34.8	19.6	1.48	7.28	10.3	1.82	0.295	0.101

At each measurement height, the fractional combustion conversion, X , on a dry, ash-free basis is calculated from:

$$X = \frac{1 - (m/m_o)}{1 - X_{a,o}} 100\% \quad (4.6)$$

where $X_{a,o}$ is the weight fraction of ash in the raw, unreacted coal.

Results analogous to that presented in Tables 4.6 and 4.7 have been obtained for all the PETC coals examined in this project and are presented in Section 10.

Table 4.7

**Comparisons of Values for m/m_o Determined via
Weight Measurements and Ash-Tracer Techniques:
106 to 125 μm Lower Wilcox Coal and Char Particles**

6 mole-% Oxygen Environment

Hgt (cm)	Weight meas.	Si tracer	Al tracer	Ti tracer	Ash-s tracer	Ash-l tracer	Mean value	Std. dev.
0.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
6.4	0.48	0.61	0.59	0.62	0.59	0.60	0.57	0.064
12.7	0.34	1.58	1.63	2.22	1.71	1.64	1.44	0.792
19.1	0.20	0.44	0.40	0.44	0.41	0.44	0.37	0.117
25.4	0.18	0.39	0.30	0.34	0.32	0.32	0.30	0.088

12 mole-% Oxygen Environment

Hgt (cm)	Weight meas.	Si tracer	Al tracer	Ti tracer	Ash-s tracer	Ash-l tracer	Mean value	Std. dev.
0.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
6.4	0.46	0.56	0.55	0.58	0.57	0.57	0.54	0.053
12.7	0.25	0.39	0.38	0.39	0.40	0.42	0.35	0.068
19.1	0.17	0.26	0.24	0.27	0.26	0.27	0.24	0.046
25.4	0.11	0.23	0.23	0.25	0.23	0.24	0.21	0.065

5. THEORETICAL APPROACH

Two models are required to determine combustion rates and kinetic parameters from the combined set of optical *in situ* and bulk sample measurements: a model of gas-particle transport processes in the CCL laminar flow reactor, and a model of the heterogeneous carbon oxidation reactions. The transport model, whose centerpiece is an unsteady particle heat balance, is used to calculate single-particle burning rates from the optical measurements of single-particle sizes, temperatures, and velocities. The transport model consists of a set of mass, momentum, and energy balance equations describing single particle combustion in the CCL laminar flow reactor (Mitchell, 1987a, 1988a).

The set of burning rates are, in turn, converted into rate coefficients using the carbon oxidation model. The carbon oxidation model is based on the single-film description of a burning carbon sphere (Field *et al.*, 1967). It is assumed that oxygen is the sole oxidizer and that both CO and CO₂ are heterogeneous reaction products. The model makes allowances for Stefan flow in the boundary layer surrounding the particle and for changes in both particle diameter and density as combustion progresses.

The set of combustion rate coefficients is, in turn, used to derive a global kinetic expression, in Arrhenius form, that describes the temperature and pressure dependence of the combustion rate for the particular coal of interest. The kinetic parameters determined comprise the global preexponential factor, A , the global activation energy, E , the global reaction order with respect to oxygen, n , and empirical parameters describing the CO/CO₂ product ratio at the particle surface. Additional parameters are determined that describe the char formation process (swelling and devolatilization) and the evolution of particle diameter and density during char combustion. This set of information is sufficient to allow predictions of particle size evolution, temperature, mode of burning, and overall combustion rate in any specified gaseous and radiative environment.

Char Oxidation Model

The single-film model of a burning carbon sphere (Field, 1967) is used here to extract oxidation kinetics from the optical *in situ* and off-line measurements. The primary assumption of the model is that there is no reaction in the boundary layer surrounding the particle. Results of previous theoretical investigations (Field *et al.*, 1967; Caram and Amundson, 1977) support the applicability of the single-film model with CO formation at the particle surface for particle sizes less than 50 μm and perhaps as large as 100 μm . The rate of the C-O₂ reaction is several orders of magnitude faster than the rate of either the C-CO₂ or C-H₂O reaction at temperatures less than about 1000 K (Walker *et al.*, 1959), and in coal combustor environments it is often assumed to be the only heterogeneous reaction of importance. This assumption is supported for particles in the pulverized-coal size-range. Studies that considered the effects of water vapor in the free-stream (Sundaresan and Amundson, 1980; Libby and Blake, 1981) indicate that modest amounts of water (less than 5 mole-%) have insignificant effects on the burning rates of particles less than 100 μm .

Mitchell *et al.* (1990b) used a detailed chemical kinetic model to examine the extent of conversion of CO to CO₂ in the boundary layers of char particles as large as 150 μm burning in gaseous environments containing 6 and 12 mole-% oxygen in the temperature range 1500 to 1700 K.

Particle temperatures and burning rates were adjusted to agree with those measured for the Pittsburgh #8 coal char. The detailed, finite-rate gas-phase chemistry calculations indicate that, for a 100 μm diameter particle, the effect of gas-phase reaction in the boundary layer on the overall particle burning rate is relatively small for gas temperatures in the range 1500 to 1700 K. In 6 mole-% oxygen, essentially no CO oxidation occurs in the boundary layer surrounding the particle. At 1700 K in 12 mole-% oxygen, CO oxidation in the boundary layer increases the particle temperature by less than 25 K and decreases its burning rates by about 5%. The results of Mitchell *et al.* (1990b) support the use of the single-film model for particles as large as 150 μm burning in gaseous environments containing up to 12 mole-% oxygen at temperatures less than 1700 K. The results indicate little oxidation via H_2O in 6 and 12 mole-% oxygen environments for H_2O concentrations less than about 17 mole-%.

In our analysis, the porous coal char particles are assumed to be spherical in shape and internally isothermal. Our previous studies on the combustion of bituminous coal chars indicate that the assumption of particle isothermality is valid when burning is under typical pulverized-coal combustor conditions (Mitchell and Hardesty, 1987). Oxygen is assumed to be the sole reactant and the global rate of reaction (which includes the combined effects of pore diffusion, internal surface area, and intrinsic surface reactivity) is represented by

$$q = k_s P_s^n \quad (5.1)$$

where k_s is a temperature-dependent rate coefficient, n is the global, or apparent, reaction order, and P_s is the partial pressure of oxygen at the particle surface. The temperature dependence of the global rate coefficient k_s is described by a correlation in Arrhenius form:

$$k_s = A \exp(-E/RT_p) \quad (5.2)$$

where A is the global preexponential factor and E is the global activation energy.

Both CO and CO_2 can be primary products of the heterogeneous oxidation reactions depending upon reaction conditions. At the high particle temperatures obtained in this study (1500 - 2000 K) CO is the dominant primary product. There is evidence, however, of some limited CO_2 formation at the lower particle temperatures in this range (Mitchell, 1988, 1990b). Following the lead of others (Arthur, 1951; Rossberg, 1956; Field, 1967), the CO to CO_2 product ratio is assumed to depend upon temperature and is expressed as:

$$\frac{\text{moles CO}}{\text{moles CO}_2} = A_c \exp(-E_c / R T_p) \quad (5.3)$$

The fraction ψ of the carbon content of the particle converted to CO_2 is determined from the relation $\psi = 1/(1 + MR)$, where MR denotes the molar CO to CO_2 ratio given above.

Using the values of A_c and E_c determined by Arthur (1951) for graphite and bituminous coal char particles ($A_c = 10^{3.4}$, $E_c = 14.3$ kcal/mole) and by Rossberg (1956) for electrode carbons ($A_c = 10^{3.3}$, $E_c = 12.4$ kcal/mole), the above expression yields relatively little heterogeneously formed CO_2 for particle temperatures greater than 1500 K. Recent results however, indicate a more

significant influence of CO₂ formation at such temperatures (Waters *et al.*, 1988b; Mitchell, 1988, 1990b; Tognotti *et al.*, 1990). The data obtained in this project indicate that as much as 15% of the carbonaceous particle material can be converted to CO₂ at temperatures in the range 1600 to 1700 K. At temperatures above 1800 K, very little CO₂ is formed; CO is essentially the sole heterogeneous reaction product.

The above evidence suggests that CO₂ formation may be important over part of the temperature range of interest in this study. It was therefore decided to determine values of A_c and E_c for each coal char that best describe both the optical data and the overall combustion rate determined by tracer analysis. Inclusion of A_c and E_c in the combustion parameter set, was, in fact, necessary to reconcile the optical data with the tracer-determined combustion rates in many cases. This is further discussed in Section 6. Sets of values for A_c and E_c , one set for each coal, are reported in Section 10. The data for any one individual coal char were insufficient to accurately determine unique, accurate values of both parameters A_c and E_c . Both A_c and E_c should therefore be regarded as empirical parameters useful for the prediction of particle temperatures and combustion rates over the range of gas environments targeted in this project. The reported values of A_c and E_c themselves, however, do not necessarily have fundamental significance, nor are they necessarily unique for the particular data set.

In the framework of the model applied here, the set of parameters A , E , n , A_c , and E_c fully describe the heterogeneous kinetics for a given system. They allow the prediction of the burning rate, q , and rate coefficient, k_s , given knowledge of the particle size, temperature, and surface oxygen partial pressure. Because at least several of these parameters are dependent upon char properties, complete parameter sets such as this one must be determined by experiment for each individual coal of interest.

Model of Gas-Particle Transport Processes

Reaction and diffusion in the particle boundary layer

The transport model is used to calculate single-particle burning rates from the optical measurements of single-particle sizes, temperatures, and velocities. Oxygen is transported to the outer surface of the particle by diffusion and consumed there by heterogeneous reaction.

The overall char-particle burning rate per unit external surface area is expressed as:

$$q = \left(\frac{k_d}{\gamma} \right) \ln \left[\frac{1 - \gamma P_s/P}{1 - \gamma P_g/P} \right] \quad (5.4)$$

where the mass transfer coefficient is given by:

$$k_d = \frac{M_C D_{ox} Sh}{d_p R' T_m v_o} \quad (5.5)$$

The value of γ in the above equations depends upon the moles of CO and CO₂ formed per mole of carbon consumed at the particle surface. A fraction ψ of the carbon content of the particle is converted to CO₂ at the particle surface and a fraction $(1-\psi)$ to CO. Within the framework of the single-film model, the heterogeneously formed CO escapes the boundary layer surrounding the particle before being oxidized to CO₂. In the particle's boundary layer, account is made for Stefan flow, the convective flow emanating from the particle surface when there is a change in the number of moles upon reaction.

When $\gamma = 0$ (i.e., when CO₂ is the sole heterogeneous reaction product or when account is not made for Stefan flow), the limiting form of Eq. (5.5) must be used. It can be shown readily that as $\gamma \rightarrow 0$, $q \rightarrow k_d (P_g - P_s)$.

Equation (5.4) can be rearranged to yield the following expression for the partial pressure of oxygen at the particle surface:

$$P_s = \frac{P}{\gamma} \left[1 - (1 - \gamma P_g / P) \exp\left(\frac{\gamma q}{k_d}\right) \right] \quad (5.6)$$

Knowledge of P_s is required in the oxidation reactions model for computation of the reaction rate coefficient, k_s in Eq. 5.1.

One-dimensional model of the CCL laminar flow reactor

A model for single-particle burning in the CCL laminar flow reactor was developed. A one-dimensional system is assumed that accounts for measured variations in gas and particle properties in the axial (z) direction along the centerline of the flow reactor. The following mass, momentum, and energy balance equations are used to describe a single char particle as it burns:

$$v_p \frac{dm}{dz} = - q A \quad (5.7)$$

$$m v_p \frac{dv_p}{dz} = - m g - 3 \Pi \mu d_p (v_p - v_g) \quad (5.8)$$

$$- \frac{m v_p c_{p,p}}{A} \frac{dT_p}{dz} + q \Delta H = - \frac{Nu \lambda}{d_p} \frac{\kappa}{(1 - e^{-\kappa})} (T_p - T_g) + \epsilon \sigma (T_p^4 - T_w^4) \quad (5.9)$$

where

$$\kappa = \frac{\gamma c_{p,g} d_p v_o q}{M_C \lambda Nu} \quad (5.10)$$

Integration of Eqs. (5.7), (5.8), and (5.9) gives the mass (m), velocity (v_p), and temperature (T_p), respectively, of a particle as a function of axial position (z) in the reactor. Since mass and heat effects associated with volatiles release and combustion are not accounted for, the equations are applicable only after the completion of coal devolatilization. The momentum balance assumes that Stokes's law applies, a reasonable assumption for the small particle sizes considered here. The

energy equation (Eq. 5.9) incorporates the following five terms (from left to right): (1) energy convected by the particle as it travels along the axial temperature gradient on the centerline of the CCL laminar flow reactor; (2) heat generated at the particle surface by chemical reaction; (3) conductive and convective heat transfer between the particle and gas, and; (4) radiative exchange between the particle and its environment. The formulation of Ranz and Marshall (1952) is used to evaluate the Nusselt number and mole fraction-weighted mixture laws are used to evaluate gas properties. Temperature-dependent properties in the particle's boundary layer are evaluated at the film temperature $(T_g + T_p)/2$.

The values of v_o , γ , and ΔH depend upon the products of the heterogeneous carbon oxidation reaction according to

$$v_o = 0.5(1 + \psi) \quad (5.11)$$

$$\gamma = \frac{\psi - 1}{\psi + 1} \quad (5.12)$$

$$\Delta H = \frac{1}{M_C} [(1 - \psi) \Delta H_1 + \psi \Delta H_2] \quad (5.13)$$

where ΔH_1 and ΔH_2 are the heats of reaction per mole carbon for the reactions $C + 1/2 O_2 = CO$ and $C + O_2 = CO_2$, respectively. The heats of reaction are evaluated at the particle temperature.

The presence of ash affects the particle heat capacity, affecting in turn the first term in Eq. 5.9. The following expression is employed for the heat capacity of the particle as a function of conversion:

$$c_{p,p} = \left(1 - \frac{X_a}{(m/m_o)}\right) c_{p,c} + \frac{X_a}{(m/m_o)} c_{p,a} \quad (5.14)$$

where $c_{p,p}$ denotes the heat capacity of the particle; $c_{p,c}$ and $c_{p,a}$ denote the heat capacities of carbon and ash, respectively; and, X_a denotes the weight fraction of ash in the parent coal. When all the combustible particle material is consumed, m/m_o equals X_a and the heat capacity of the particle is described by the heat capacity of the ash.

A temperature-dependent expression for the heat capacity of carbon was obtained by fitting the data in the JANAF Thermochemical Tables (1970). Coefficients for the polynomial expression employed are shown in Table 5.1. The heat capacity of the ash is determined from the heat capacities of the oxides of the major components of the ash. Elements considered are silicon, aluminum, calcium, magnesium, and iron. The heat capacities of the oxides of these metals and of sillimanite (Al_2SiO_5) are determined as functions of temperature using the data given in the JANAF Thermochemical Tables (1970). The heat capacity of sillimanite is taken to be representative of the heat capacities of the aluminosilicate clays (kaolinites, muscovites, and illites) found in most coals. Coefficients for the polynomial expressions for the heat capacities are also shown in Table 5.1. The heat capacities are weighed in accordance with the composition of the ash. The silicon and aluminum are assumed to be primarily associated with the aluminosilicate clays. If silicon is in

excess, the heat capacities of Al_2SiO_5 and SiO_2 are considered and if aluminum is in excess, the heat capacities of Al_2SiO_5 and Al_2O_3 are considered.

The emissivity of the particle is taken to be 0.8, based on measurements of the spectral emissivities of coal particles (Baxter et al. 1988). At high combustion conversions, particles consist mainly of ash, and the emissivity more closely approximates that of porous ash particles than of carbon particles. The ash emissivity is taken to be 0.5, the average value reported by Hottel and Sarofim (1967) for silica particles in the 70 to 600 μm size-range. Calculations performed in this project indicate that the transition from carbon-like emissivities (~ 0.8) to ash-like emissivities (~ 0.5) occurs quite late in combustion, primarily at $X > 90\%$.

Table 5.1
Coefficients for the Heat Capacities of
Major Constituents of Coal Char Particles

$$c_p = a_1 + a_2 T_p + a_3 T_p^2 + a_4 T_p^3$$

Component	a_1	a_2	a_3	a_4
C (graphite)	1.4162	0.6193	-0.2961	0.4870
Al_2O_3	9.1394	4.0513	2.3910	4.6887
Al_2SiO_5 *	2.0346	12.3260	-12.0580	41.3100
Al_2SiO_5 **	36.5410	1.1491	-0.1928	0.2771
CaO	8.3216	0.8330	-0.4635	0.9265
Fe_2O_3	14.7300	4.7323	-3.3109	7.1127
MgO	6.5610	1.0803	-0.6234	1.2393
SiO_2	-3.1428	4.2312	-2.7222	5.5452

* Particle temperature range: 300 - 1300 K
 ** Particle temperature range: 1300 - 2500 K

Empirical Model for the Mode of Particle Burning

A set of equations was derived that describe the evolution of particle size and density during combustion. Examination of the data reveals that both the density and diameter of a char particle change during the char combustion stage. Data obtained with low-ash coals indicate that, in general, the density of the char gradually decreases as mass is loss until very late in burnoff (greater than 90% burnoff, daf). Data obtained with high-ash coals indicate that the density of the char decreases with burnoff during the early to middle stages of burnoff, but starts to increase as early as 60% - 70% burnoff, daf. Since the apparent density of ash is higher than the apparent density of the carbonaceous material, increases in apparent densities of char particles with mass loss are expected at high extents of burnoff.

The correlations used to compute the heats of reaction and the thermodynamic and transport properties of the gas phase are listed in Table 5.2.

Table 5.2
Correlations for the Heat of Reaction
and for Thermodynamic and Transport Properties
of the Gas Phase

Heat of Reaction, cal/gm; $C + 1/2 O_2 = CO$

$$\Delta H = (25449. + 0.754T_p + (4.53E-4)T_p^2 - (8.85E-8)T_p^3 + (2.1E5)/T_p)/12.$$

Heat of Reaction, cal/gm; $C + O_2 = CO_2$

$$\Delta H = (92401. + 4.034T_p - 3.137E-3T_p^2 + 8.74E-7T_p^3 + 2.1E5/T_p)/12.$$

Gas Thermal Conductivity, cal/cm/sec/K

$$\lambda = (1. - P_{O_2})(7.689310^{-7} T_m^{0.7722}) + P_{O_2}(7.135210^{-7} T_m^{0.7968})$$

where T_m is the film temperature, $(T_g + T_p)/2$

Molar heat capacity of the gas, cal/mole/K

$$C_{pN_2} = 7.7099 - 5.5039 \cdot 10^{-3} T_m + 13.1214 \cdot 10^{-6} T_m^2 - 11.6810 \cdot 10^{-9} T_m^3 + 5.2340 \cdot 10^{-12} T_m^4 - 1.1732 \cdot 10^{-15} T_m^5 + 0.1039 \cdot 10^{-18} T_m^6$$

$$C_{pO_2} = 7.3611 - 5.3696 \cdot 10^{-3} T_m + 20.542 \cdot 10^{-6} T_m^2 - 25.865 \cdot 10^{-9} T_m^3 + 15.946 \cdot 10^{-12} T_m^4 - 4.8589 \cdot 10^{-15} T_m^5 + 0.5862 \cdot 10^{-18} T_m^6$$

$$C_p = (1. - P_{O_2})C_{pN_2} + P_{O_2}C_{pO_2}$$

Diffusion coefficient O_2 into N_2 at T_m and P , cm^2/sec

$$D_{O_2/N_2} = 1.523 \cdot 10^{-5} T_m^{1.67}/P$$

With respect to the apparent density of the particle, the char particle is assumed to consist of two components: a combustible component whose density changes with burnoff and a non-combustible inorganic component whose density is constant. The particle (or apparent) density is defined as:

$$\rho_p = \frac{\text{total weight of particle}}{\text{volume of particle}} = \frac{w_c + w_a}{V_p} \quad (5.15)$$

where the particle volume, V_p , is the volume occupied by a sphere having a diameter of d_p . Rewriting this equation in terms of the apparent densities of the combustible material and the ash and the volumes they occupy yields:

$$\rho_p = \frac{w_c}{V_p} + \frac{w_a}{V_p} = \frac{v_c}{V_p} \frac{w_c}{v_c} + \frac{v_a}{V_p} \frac{w_a}{v_a} = \frac{v_c}{V_p} \rho_c + \frac{v_a}{V_p} \rho_a \quad (5.16)$$

The weights of combustible material and ash in the particle can be expressed as:

$$w_a = x_a V_p \rho_p = v_a \rho_a \quad (5.17)$$

and

$$w_c = (1 - x_a) V_p \rho_p = v_c \rho_c \quad (5.18)$$

Utilizing Eqs. (5.17) and (5.18) to eliminate v_a and v_c from Eq. (5.16) yields the following relation for the apparent density of the coal char particle:

$$\frac{1}{\rho_p} = \frac{x_a}{\rho_a} + \frac{(1 - x_a)}{\rho_c} \quad (5.19)$$

This equation gives the apparent density of the particle in terms of the apparent densities of the ash and combustible material and the fraction of ash in the char particle. Since the weight of ash in the particle is assumed to be unchanged during burnoff, the fraction of ash is readily calculable from the fraction of the initial mass remaining (m/m_o) and the weight fraction of ash in the raw coal (X_a) using the relation $x_a = X_a/(m/m_o)$. This expression is only approximate since it is possible for some of the ash to leave the particle via reaction or vaporization processes during burnoff or to be convected from the particle during devolatilization (Baxter and Mitchell, 1989; Baxter *et al.*, 1990). Such losses are important with coals having relatively high pyritic iron contents and with coals having a large fraction of atomically-dispersed ash components. For the low rank coals that exhibit significant ash loss, the weight fraction ash is calculated directly from the chemical analysis of the partially reacted char samples and not estimated by the relation $x_a = X_a/(m/m_o)$. When the combustible material is completely consumed, x_a equals unity and from Eq. (5.19), the apparent density of the particle equals the apparent density of the ash. The apparent density of the ash is assumed to remain constant during burnoff. Apparent density measurements of solid samples extracted from the flow reactor at residence times longer than the time for complete burnout yield the apparent density of the ash.

The density of the combustible material is assumed to vary with conversion according to the following empirical relation:

$$\rho_c/\rho_{c,i} = (w_c/w_{c,i})^\alpha \quad (5.20)$$

where $w_{c,i}$ and $\rho_{c,i}$ are the weight and apparent density, respectively, of the combustible material in the initial char particle that is formed just subsequent to devolatilization, and α is the mode of burning parameter, which varies between zero and unity. Such a power-law expression relating apparent density and mass of combustible material has been used previously to correlate data

obtained with coal chars (Smith, 1971) and ash-free Spherocarb particles (Mitchell, 1987b; Waters *et al.*, 1988b). A theoretical justification for the power-law relation has been given by Essenhigh (1988).

The diameter of a particle is calculated from its mass and apparent density using the relation $d_p = [6m/(\pi\rho_p)]^{1/3}$. For α equal to zero, the density of the combustible material remains constant during combustion and the particle diameter progressively decreases. For α equal to unity, the density of the combustible material progressively decreases during combustion while the particle diameter remains constant. The particle density, on the other hand, may increase due to progressive enrichment of the more dense ash phase. In most cases α falls between these two extremes (zero and unity) indicating that both density and diameter are altered significantly by the combustion process.

6. DATA ANALYSIS

This section describes how the theoretical framework outlined in the previous section is applied to analyze the combined data set (optical *in situ* and off-line measurements) for each coal. The analysis procedure involves:

- (a) determination of the burning mode parameter α ;
- (b) statistical treatment of the raw optical data (single-particle sizes, temperatures, and velocities;
- (c) application of the numerical gas-particle transport model to determine burning rates;
- (d) application of the char oxidation reactions model to determine rate coefficients, k_s , for various particle temperatures;
- (e) determination of Arrhenius-form kinetic parameters (A , E , and n) describing the temperature and pressure dependence of the combustion rate and;
- (f) comparison of overall combustion rates determined by the optical technique with those determined by tracer analyses.

Steps c,d, and e are integrated in a series of FORTRAN programs and command files that convert the sorted optical data into values of A , E , and n , as well as individual rate coefficients, k_s , suitable for plotting in Arrhenius form.

Determination of the Mode of Particle Burning

The procedure begins with the determination of the mode of burning parameter (α) that best describes the particle density evolution. The values employed for m/m_o are mean values determined from the extracted samples using an overall mass balance as well as tracer analyses based on Si, Al, Ti, and total ash (see for example Table 4.5). The initial char density was taken to be the value at the first measurement height (6.35 cm above the burner surface), which marks the approximate end of devolatilization and the beginning of char combustion. A value of 2.25 g/cc was used for the density of the ash.

Fig. 6.1 shows measured and calculated values of particle density as a function of conversion for the set of partially reacted chars of Dietz coal from both the 6 and 12 mole-% oxygen environments.

Values for α have been determined for the partially reacted chars of each of the coals examined. The values are presented in Section 7. Values typically fall in the range 0 to 0.4, consistent with the near zero value determined by Hamor *et al.*, (1973) for the char of an Australian brown coal and with the value 0.25 determined by Smith (1971) for pulverized semi-anthracite.

The value of α determined is a qualitative indication of the extent of internal reaction, related to the extent of O_2 penetration into the particle; as α approaches unity O_2 penetration depth and the extent of internal reaction increase. The value of α is not, however, a quantitative estimate of the amount of internal reaction, as other phenomena, such as fragmentation and carbon densification (Hurt *et al.*, 1988) also influence the evolution of diameter and density.

Figure 6.1 Measured (points) and calculated (lines) particle density as a function of conversion for Dietz coal char.

Statistical Treatment of the Optical Data

An example of a complete set of raw optical data (measurements of single particle sizes, temperatures, and velocities) is given in Appendix 11 for PSOC-1451D, Pittsburgh #8 coal. Summary tables for each coal are found in section 10. Broad distributions of char particle temperatures are observed in any given combustion environment due to particle-to-particle variations in properties and reactivity. Because of this effect, kinetic analysis were performed not on the raw single-particle data, but on a statistically treated, reduced data set. A detailed discussion of the properties of single-particle kinetics and an evaluation of techniques for determining kinetic parameters is found elsewhere (Hurt and Mitchell, 1992). That discussion is summarized briefly in the following paragraphs.

Using the oxidation and transport models, single-particle temperatures and diameters can be converted to single-particle rate coefficients (k_s values). The single-particle k_s values can be directly plotted versus the measured particle temperatures in Arrhenius form, as seen in Fig. 6.2.

This distribution of particle temperatures is seen to produce distinct characteristic curves or bands of points on Arrhenius plots of single-particle rate constants (see Fig. 6.3). Each linear grouping of points corresponds to one of the six local gas environments used in the experiments (combinations of oxygen partial pressure and local gas temperature). These linear features have been shown to exhibit pseudo activation energies that are independent of the actual global kinetic activation energy (Hurt and Mitchell, 1992). The structure seen in Fig. 6.2 is the result of particle-to-particle distribution of reactivity and physical properties, related to differences in ash content, surface area, pore structure, particle morphology, etc.

Fig. 6.2 Rate constants for individual burning char particles from PSOC-1508D coal: reaction order 1/2. Initial particle diameter 106 - 125 μm . It is assumed that CO is the only combustion product and that the particles are in thermal equilibrium with their environment

In light of the known heterogeneity of the coal substance itself, this insight into single-particle behavior is not unexpected.

Fig. 6.3 Characteristic curves and experimentally determined single-particle rate constants for PSOC-1508 Pocahontas #3 coal. Curves for 150 μm particles; points for particles with diameters 140 - 160 μm . Reaction order, $n = 1/2$. The solid line illustrates an example Arrhenius rate law determined from the rate constants of the particles of median reactivity in the 6 mole-% oxygen environment and the 12 mole-% oxygen environment at 1532 K gas temperature.

It is therefore impossible to describe the combustion behavior of *each* individual particle by a single, common kinetic expression. A complete description of single-particle combustion behavior requires a detailed statistical treatment that explicitly accounts for the origin and implications of the observed temperature distributions. For the more limited goal of predicting overall burning rates for the entire particle population over narrow to moderate ranges of carbon conversion, kinetic parameters describing the combustion behavior of "typical" particles (those of median reactivity) is sufficient. A decision was made to determine engineering kinetic expressions, representing "average" combustion behavior for the complete suite of coals. Although this approach ignores some details of the single-particle reactivity distributions, this type of kinetic expression is more readily incorporated into comprehensive combustion codes for boiler design. At the same time, a parallel effort is underway at Sandia to gain additional insight from this data set by computing and analyzing single-particle reactivity distributions.

To determine simple, single kinetic expressions, one can, in principal, apply the oxidation and transport models directly to the raw optical data (measurements of single-particle sizes, temperatures and velocities). It has been shown, however, that direct application of the model to the raw data yields kinetic parameters that are in significant error (Hurt and Mitchell, 1992). When a single Arrhenius rate law is fit to all experimental points simultaneously, optimal (least-squares) coefficients are biased by the presence of particle-to-particle variations in properties and reactivity. The least-squares parameters obtained will be influenced both by the true average kinetic parameters (A, E, n), and by properties of characteristic curves on the Arrhenius diagram that represent the equations governing gas-particle transport processes (see Hurt and Mitchell, 1992).

A simple analytical procedure was developed that extracts the true kinetic information for particles of median reactivity within a heterogeneous particle population. To account for the joint distribution of size and temperature, a specific averaging technique was developed to avoid the bias introduced by the particle temperature distributions, while preserving much of the information contained in the joint temperature/size distributions.

The analysis technique utilizes a set of median particle temperatures computed for three different particle subpopulations: the 0th - 50th percentile in particle diameter (with a median at the 25th percentile), the 50th - 100th percentile in diameter (with a median at the 75th percentile) and the entire population. The new data set derived from this statistical treatment consists, therefore, of three data points (for the three particle sub-populations) at each measurement location. As the combustion studies involved measurements at three locations in each of two gas environments, a total of $2 \times 3 \times 3 = 18$ derived "data points" were typically used in the analysis. An example of the reduced data set, for PSOC-1451D, Pittsburgh #8 coal, is given in Tables 6.1 - 6.6.

In summary, this simple approach has the advantage of yielding a single engineering rate law (single set of values for A , E , and n) for convenient incorporation in comprehensive combustion models. This approach should be capable of adequately describing the overall combustion behavior of any given coal at low-to-intermediate carbon conversions ($< 90\%$). At very high carbon conversions on the other hand, it is expected that sample heterogeneity (e.g. the presence of low-reactivity coal components) may lead to first-order errors in the estimation of burning rates. The topic of reactivity in the late stages of burnout, and its relationship to particle-to-particle heterogeneity, will be the subject of future research. It will be seen in a later section, that this approach does successfully describe char combustion behavior in the CCL experiments, based on results from the suite of ten coals investigated.

Determination of Combustion Rates

The overall particle burning rate is determined directly from the energy balance equation, Eq. (5.9), suitably rearranged as:

$$q = \frac{-\frac{Nu \lambda}{d_p} \frac{\kappa}{(1 - e^{\kappa})} (T_p - T_g) + \epsilon \sigma (T_p^4 - T_w^4) + \frac{m v_p c_{p,p}}{A} \frac{dT_p}{dz}}{\Delta H} \quad (6.1)$$

Table 6.1
Statistical Summary of Optical Data
for PSOC-1451D, Pittsburgh #8 Coal

6.1A

OXYGEN CONTENT OF GAS: 6.0 mole-%

GAS TEMPERATURE: 1642.0 K

SAMPLING HEIGHT: 12.70 cm

	Diameter (mm)	Temperature (K)	Velocity (cm/sec)
Mean values	129	1705	255
Standard Deviation	34	44	15
Sample Size	125	125	125
<i>Median Values used</i>			
<i>in Kinetic Analysis:</i>	d_{med}	T_{med}	
For subpopulation $d_0 - d_{50\%}$:	101	1713	--
For entire population:	125	1708	--
For subpopulation $d_{50} - d_{100\%}$:	146	1707	--

6.1B

OXYGEN CONTENT OF GAS: 6.0 mole-%

GAS TEMPERATURE: 1593.0 K

SAMPLING HEIGHT: 19.10 cm

	Diameter (mm)	Temperature (K)	Velocity (cm/sec)
Mean values	126	1671	271
Standard Deviation	33	44	18
Sample Size	160	160	160
<i>Median Values used</i>			
<i>in Kinetic Analysis:</i>	d_{med}	T_{med}	
For subpopulation $d_0 - d_{50\%}$:	99	1679	--
For entire population:	125	1671	--
For subpopulation $d_{50} - d_{100\%}$:	141	1663	--

6.1C

OXYGEN CONTENT OF GAS: 6.0 mole-%

GAS TEMPERATURE: 1536.0 K

SAMPLING HEIGHT: 25.40 cm

	Diameter (mm)	Temperature (K)	Velocity (cm/sec)
Mean values	125	1608	288
Standard Deviation	34	44	15
Sample Size	157	157	157
<i>Median Values used in Kinetic Analysis:</i>			
	d_{med}	T_{med}	
For subpopulation $d_0 - d_{50\%}$:	100	1617	--
For entire population:	120	1604	--
For subpopulation $d_{50} - d_{100\%}$:	142	1601	--

6.1D

OXYGEN CONTENT OF GAS: 12.0 mole-%

GAS TEMPERATURE: 1645.0 K

SAMPLING HEIGHT: 12.70 cm

	Diameter (mm)	Temperature (K)	Velocity (cm/sec)
Mean values	130	1863	256
Standard Deviation	34	61	9
Sample Size	166	166	166
<i>Median Values used in Kinetic Analysis:</i>			
	d_{med}	T_{med}	
For subpopulation $d_0 - d_{50\%}$:	104	1871	--
For entire population:	128	1867	--
For subpopulation $d_{50} - d_{100\%}$:	151	1863	--

6.1E

OXYGEN CONTENT OF GAS: 12.0 mole-%

GAS TEMPERATURE: 1591.0 K

SAMPLING HEIGHT: 19.10 cm

	Diameter (mm)	Temperature (K)	Velocity (cm/sec)
Mean values	121	1821	273
Standard Deviation	28	61	11
Sample Size	167	167	167
<i>Median Values used in Kinetic Analysis:</i>			
	d_{med}	T_{med}	
For subpopulation $d_0 - d_{50\%}$:	99	1831	--
For entire population:	117	1831	--
For subpopulation $d_{50} - d_{100\%}$:	136	1834	--

6.1F

OXYGEN CONTENT OF GAS: 12.0 mole-%

GAS TEMPERATURE: 1592.0 K

SAMPLING HEIGHT: 25.40 cm

	Diameter (mm)	Temperature (K)	Velocity (cm/sec)
Mean values	115	1709	290
Standard Deviation	27	87	5
Sample Size	170	170	170
<i>Median Values used in Kinetic Analysis:</i>			
	d_{med}	T_{med}	
For subpopulation $d_0 - d_{50\%}$:	95	1730	--
For entire population:	112	1721	--
For subpopulation $d_{50} - d_{100\%}$:	132	1711	--

Except for the thermal inertia term (the last term in the numerator), all parameters on the right-hand side of this equation can be determined from the measurements after a CO/CO₂ product ratio has been specified. The iterative procedure for estimating the thermal inertia term is described in the following. Accurate values of the particle temperature gradient, dT_p/dz , are required at the three reactor locations from which the kinetic data are obtained (at 12.7, 19.1, and 25.4 cm above the burner surface). Particle temperatures are first calculated at a lower height (earlier residence time) using current estimates of the kinetic parameters (A , E , N , A_c , E_c) and assuming the particles to be in thermal equilibrium with their environment. The thermal inertia term is thus neglected at this point. With these starting particle temperatures, the one-dimensional model is integrated to simulate single-particle combustion along the entire reactor length. Results of this integration include axial profiles of particle temperature, particle temperature gradient (dT_p/dz), particle size, and particle properties. The gradients are calculated from the axial profiles and then used in the energy equation to compute new estimates of the kinetic parameters, and the procedure is repeated.

Values of dT/dz vary from about 0 to 15 K/cm, depending in a complex fashion upon combustion environment, particle properties, and particle reactivity. Accurate estimates of dT/dz may only be obtained by integrating the one-dimensional model of the laminar flow reactor. Thermal inertia makes a greater contribution to the heat balance for low reactivity coals (where the rate of heat generation by reaction is low) and for char particles that are larger and have higher densities. The contribution of thermal inertia (the first term on the right-hand side of equation 6.1) varies from near 0 to about 50% of the heat generated by reaction for the ten PETC suite coals. Ignoring the thermal inertia term therefore introduces errors in the estimation of the heat generation rate by 0 to 50%. Since the heat generation rate is directly proportional to the reaction rate, errors of the same magnitude (0 - 50%) are introduced in the estimation of the reaction rates.

Determination of Rate Coefficients and Kinetic Parameters

Assuming a value for the reaction order, n , the combustion rates, q , can now be used to compute global chemical reaction rate coefficients, k_s , as a function of T_p by

$$[k_s(T_p)] = \left[q \left\{ \frac{P}{\gamma} \left[1 - (1 - \gamma P_g / P) \exp\left(\frac{\gamma q}{k_d}\right) \right] \right\} \right]^{-n} \quad (6.2)$$

which is derived by combining Equations (5.3) and (5.4). There are several situations in which data points have been excluded from the kinetic analysis. One such situation arises when a data point yields a burning rate that is greater than 90% of the maximum, diffusion-limited burning rate under those conditions. The accuracy with which k_s values can be extracted from the data drops precipitously as q approaches q_{max} (i.e. as the particle temperature approaches the diffusion-limited temperature). A second situation arises, for some coals, at long residence times in the 12 mole-% oxygen environment. At this measurement point, the overall combustion conversion may be so high, that the particle population includes many high-ash content particles at, or near, extinction. These particles exhibit low temperatures, and if included in the analysis, would yield low reactivities associated with the local gas environment present at this reactor location. The low reactivity exhibited by these particles is not, however, related to the local gas environment, but

rather to the very high carbon conversion (high ash content) of these particular particles. In several cases, this effect is quite evident from examination of the single-particle temperature distributions at the longest residence time in the 12 mole-% oxygen environment. In such cases, those data points were excluded from the analysis to avoid biasing the kinetic parameters.

The above equations allow the calculation of values of k_s at measured T_p for the assumed value for n . An Arrhenius-form, least-squares fit of the k_s - T_p pairs yields values for A and E_a . The "goodness" of the fit, as determined by the root mean square residual, $[rms(k_s)]$, is calculated from

$$[rms(k_s)] = \sqrt{\frac{1}{I} \sum_{i=1}^I \left\{ \frac{[k_s(T_p)]_i - [A \exp(-E/RT_p)]_i}{[k_s(T_p)]_i} \right\}^2} \quad (6.3)$$

Values of A and E and the corresponding $[rms(k_s)]$ can be determined for various values of n and an optimum n chosen at the point of minimum $[rms(k_s)]$. In practice, the data sets were found to cover an insufficient range of temperature and oxygen pressure to uniquely determine statistically significant values of the reaction order. Although there always exists a minimum in a plot of $[rms(k_s)]$ vs. n , as is true of almost any unconstrained parameter estimation scheme, the minima were observed to be very shallow. For combustion in Zone II, there are compelling theoretical reasons to expect n values within the range 0.5 to 1. It was discovered that any value of n within this range would lead to a satisfactory fit of the data. A value of 0.5 for n gives slightly better fits to the majority of the individual coal char data sets, and is therefore adopted for all coals. Use of a common reaction order for the entire data set has the benefit of allowing more convenient comparisons between various coals.

Table 6.2 lists the results of these calculations for PSOC-1451D, Pittsburgh #8 coal, including values of the parameter χ , rate coefficient, k_s , burning rate, q , for each of the 15 points used in the analysis. The number of points was reduced from 18 to 15 by eliminating the data at the longest residence time in 12 mole-% oxygen, due to conversion-dependent effects, as discussed above. The CO/CO₂ ratio used in this calculation was obtained by the correlation shown in Table 6.2. The parameters A_c and E_c were determined by comparing combustion rates measured by the optical and sampling techniques respectively, as described in the next section.

Figure 6.4 gives an example of the set of global rate coefficients for Pittsburgh #8 coal char as well as the best-fit Arrhenius kinetic parameters. To illustrate the difference between the median kinetics and the kinetics of single-particles, the reaction/transport model was used to calculate rate coefficients for each individual particle from the raw (unsorted) optical data. Only those particles with χ values between 0.2 and 0.9 were included in the analysis, and a reaction order of 0.5 was used. Figure 6.5 displays the entire set of rate constants, in Arrhenius form. Also in Figure 6.5 is the curve from Fig. 6.4 generated from the "median" Arrhenius kinetic parameters reported in Table 6.2. Figure 5 shows the wide distribution of single-particle rate coefficients about the curve representing the kinetics of the median particles. The large sample size (particle number) in these data sets allows accurate median kinetics to be determined, despite the wide variation in single-particle behavior.

Table 6.2
Results of Kinetic Analysis for
PSOC-1451D, Pittsburgh #8 Coal

CALCULATION OF CHEMICAL RATE COEFFICIENT
(UNITS ARE GM/CM**2/SEC/ATM**N)
PSOC-1451 PITTSBURGH #8 COAL CHAR

N = OXYGEN REACTION ORDER = 0.50 in 6% O2
 = 0.50 in 12% O2
MOLAR CO TO CO2 PRODUCT RATIO = 0.400E+05 exp(- 30000./RTP)
37.02 PERCENT OF THE CARBON IS CONVERTED TO CO2
AT 1500 K EMPLOYING THIS EXPRESSION AND
6.60 PERCENT OF THE CARBON IS CONVERTED TO CO2 AT 1900 K

d _p (μm)	T _g (K)	P _{O2} (atm)	T _p (K)	CHI	K _d (g/cm ² -s-atm)	K _s (g/cm ² -s-atm ⁿ)	q (burning rate) (g/cm ² -s)
101.0	1642.0	0.060	1713.0	0.558	1.12E-01	2.51E-02	3.90E-03
125.0	1642.0	0.060	1708.0	0.643	9.04E-02	2.56E-02	3.56E-03
146.0	1642.0	0.060	1707.0	0.730	7.73E-02	2.83E-02	3.42E-03
99.0	1593.0	0.060	1679.0	0.524	1.10E-01	2.26E-02	3.64E-03
125.0	1593.0	0.060	1671.0	0.584	8.68E-02	2.10E-02	3.15E-03
141.0	1593.0	0.060	1663.0	0.604	7.64E-02	1.94E-02	2.85E-03
100.0	1536.0	0.060	1617.0	0.425	1.02E-01	1.59E-02	2.82E-03
120.0	1536.0	0.060	1604.0	0.433	8.38E-02	1.34E-02	2.36E-03
142.0	1536.0	0.060	1601.0	0.479	7.06E-02	1.29E-02	2.17E-03
104.0	1642.0	0.120	1871.0	0.596	1.20E-01	4.13E-02	8.59E-03
128.0	1642.0	0.120	1867.0	0.667	9.71E-02	4.10E-02	7.71E-03
151.0	1642.0	0.120	1863.0	0.733	8.22E-02	4.21E-02	7.09E-03
99.0	1591.0	0.120	1831.0	0.546	1.22E-01	3.68E-02	8.13E-03
117.0	1591.0	0.120	1831.0	0.599	1.03E-01	3.61E-02	7.47E-03
136.0	1591.0	0.120	1834.0	0.661	8.91E-02	3.69E-02	7.01E-03

RESULTS OF THE CURVE FIT TO CHEMICAL REACTION RATE
PARAMETERS FOR CHI BETWEEN 0.200 AND 0.900 ARE AS
FOLLOWS WHEN DATA AT ALL SAMPLING HEIGHTS ARE USED

A = 2.9 E+01
E = 2.4 E+04 kcal/mol

THE ROOT MEAN SQUARE PERCENTAGE ERROR IS 7.751
THE APPARENT OXYGEN REACTION ORDER IN 6% O2 IS 0.50
THE APPARENT OXYGEN REACTION ORDER IN 12% O2 IS 0.50

Figure 6.4 Arrhenius diagram and global kinetic parameters for PSOC-1451D, Pittsburgh #8 coal. CO/CO₂ ratio determined by correlation in Table 6.2

Comparison of Rates Determined by Optical and Extractive Measurements

The kinetic parameters obtained from the optical data can be used to predict the overall combustion rates in the CCL determined from extractive sampling and tracer analyses. This comparison serves as an independent validation of the data, model, and procedures used to derive the kinetic parameters. At the same time, this comparison provides additional valuable information regarding the product (CO or CO₂) of the heterogeneous char oxidation reaction.

The one-dimensional model of the CCL laminar flow reactor is used to predict the axial conversion profiles of each char burning in each of the two gas environments used (6 and 12 mole-%). Good agreement is generally found between the two independent techniques for combustion in the 12 mole-% environment if CO is assumed to be the sole product of the heterogeneous reactions. In the 6 mole-% environment, the extent of burning is often overpredicted by the optically-determined kinetic parameters when CO is assumed to be the sole reaction product. Some CO₂ production is

Single-particle rate coefficients for oxidation of PSOC-1451D, Pittsburgh #8 coal char

Figure 6.5 Arrhenius diagram of single-particle rate coefficients for PSOC-1451D, Pittsburgh #8 coal. Curve taken from Fig. 6.4 corresponding to median global kinetic parameters. CO/CO₂ ratio determined by correlation in Table 6.2

therefore incorporated in the analysis by varying the empirical parameters A_c and E_c to match the axial conversion profile in 6 mole-% oxygen.

The result of the complete analysis using the optimum values of A_c and E_c is shown in Fig. 6.3. For the Pittsburgh #8 coal, for A_c was determined to be 4×10^4 and E_c 30 kcal/mole, corresponding to 6 mole-% CO₂ at a particle temperature of 1900 K and 15 mole-% CO₂ at 1700 K. For a more detailed discussion of the effect of CO₂ formation on particle temperatures, burning rates, and on the kinetic analysis procedure, see Mitchell (1988).

Figure 6.6 Conversion profiles from combustion experiments in the CCL for PSOC-1451, Pittsburgh #8 coal. Points are determined by inorganic tracer analysis on extracted samples. Curves are predictions using the rate constants derived from optical measurements accounting for both CO and CO₂ production at the particle surface.

Calculation of the Coal Reactivity Index, τ_{50}

It is highly desirable at this point to cast the kinetic information determined here in a form that allows direct comparisons among the various coals. Although the values of A , E , n , A_c , and E_c fully describe the heterogeneous kinetics for each coal char, comparative char reactivities are not obtainable from this parameter set by simple inspection. A model is needed to compute rate coefficients or burning rates under a chosen set of conditions.

A characteristic burning time under standard conditions is chosen as the best single index of char reactivity, as it is most closely related to the true technological criterion of high char combustion efficiency. Combustion times are preferable to combustion rates, as the times reflect both surface reactivity (A , E , n , A_c , and E_c) and physical factors such as the swelling index, mode of burning parameter, and initial carbon density. These physical factors influence the combustion time by affecting particle size and density. The physical factors vary systematically with coal rank or type and play an almost equally important role as the chemical parameters in determining combustion behavior in practical systems.

The complete set of combustion parameters for Pittsburgh #8 coal, as an example, is presented in Table 6.3. These parameters are chosen to allow the computation of char combustion rates and char burnout times given any gas and radiative environment. The reactivity index chosen is the characteristic time for 50% conversion of the char by oxidation, τ_{50} , defined as:

$$\tau_{50} \equiv \frac{\frac{1}{2}m_c}{q_{25}A_{25}} \quad (6.4)$$

where m_c is the mass of carbonaceous (combustible) material in the unreacted char particle (after devolatilization), q_{25} is the oxidation rate per unit external surface area, and A_{25} is the external surface area, both evaluated at 25% carbon conversion. (Because the particle diameter changes between 0 and 50% carbon conversion, q and A are evaluated at the midpoint.) The properties of the unreacted char are approximated by the properties of the material collected after 47 msec residence time in oxygen containing environments in the laminar flow reactor. This is an approximation because the transition from devolatilization to combustion does not occur at precisely the same residence time for each individual particle nor is it necessarily sharp for any given particle. The errors introduced in τ_{50} by this approximation are slight and are discussed in detail elsewhere (Hurt and Hardesty, 1992).

An expression for τ_{50} must be derived in terms of the set of combustion parameters presented for each of the PSOC coals. The τ_{50} value defined above is a function of the coal ash content, because ash displaces the carbon and reduces the amount of reaction needed to completely burn the char. We choose to compare τ_{50} values for various coals on a common ash-free basis, for which the quantity m_c is given by $[\rho_{c,o} \pi d^3/6]$. The quantity A_{25} is equal to πd_{25}^2 where d_{25} is the particle diameter at 25% carbon conversion, given by $[d_o / ((0.75)^{(1-\alpha)/3})]$. Finally, relating d_o to the initial coal particle density by $d_o/d_c = \omega$, and substituting in Eq. 6.4, the following expression for τ_{50} is obtained:

$$\tau_{50} \equiv \frac{\omega d_c \rho_{c,o}}{12 q_{25} 0.75^{2(1-\alpha)/3}} \quad (6.5)$$

The characteristic burnout time, τ_{50} , is thus seen to be a function of the instantaneous combustion rate, q , (a function of A , E , n , A_c , and E_c), the swelling factor, ω , the mode of burning parameter, α , and the initial char density, $\rho_{c,o}$.

Equation 6.5 is used to compute the reactivity index, τ_{50} , for each coal, over a range of conditions typical of pulverized-coal fired boilers: gas temperature $1500 \text{ K} < T_g < 2000 \text{ K}$; oxygen partial pressures $0.03 \text{ atm} < P < 0.21 \text{ atm}$; and particle sizes $50 \mu\text{m} < d_p < 150 \mu\text{m}$. It is further assumed that the particles are in thermal equilibrium with their environment, and that radiative exchange occurs with surfaces at 500 K. Examples of these calculations are presented in Figs. 6.7 - 6.9 for the Pittsburgh #8 coal char.

The complete sets of combustion parameters are currently being used to develop a predictive correlation of char reactivity valid for the entire spectrum of commercially important coals burning under technologically-relevant conditions (see Hurt and Mitchell, 1992).

Table 6.3

Summary of Combustion Parameters for PSOC-1451D, Pittsburgh #8 Coal

Char oxidation rate parameters $q = A \exp(-E/RT_p) P^n$	A E n	29 24 0.5 *	gm-C / cm²-s-atmⁿ kcal / mole
Product ratio parameters $CO/CO_2 = A_c \exp(-E_c/RT_p)$	A_c E_c	4.0 x 10⁴ * 30 *	 kcal / mole
Burning mode parameter $\rho/\rho_o = (m/m_o)^\alpha$ $d/d_o = (m/m_o)^{(1-\alpha)/3}$	 α	 0.1	
Char structural parameters $\omega = d_o / d_c$ (linear swelling factor) $\rho_{c,o} \equiv m_c/V_c$ at $z = 6.5$ cm (initial char particle carbon density)	 ω $\rho_{c,o}$	 1.10 0.385	 gm / cm³
<p>As an example, this parameter set yields a combustion rate, q, of 0.0032 gm/sq.cm-sec for a 100 μm particle in a gas with $T_g = 1600$ K containing 6 mole-% oxygen</p> <p>These product ratio parameters yield 6 mole-% carbon dioxide at 1900 K and 15 mole-% carbon dioxide at 1700 K</p> <p>* These particular parameters should be regarded as empirical parameters useful for the prediction of burning rates. They do not necessarily have fundamental significance or uniqueness for this data set.</p>

Figure 6.7 Predicted times for 50% completion of char combustion for PSOC-1451D, Pittsburgh #8 coal at 1500 K gas temperature.

Figure 6.8 Predicted times for 50% completion of char combustion for PSOC-1451D, Pittsburgh #8 coal at 1750 K gas temperature.

Figure 6.9 Predicted times for 50% completion of char combustion for PSOC-1451D, Pittsburgh #8 coal at 2000 K gas temperature.

7. SUMMARY OF KINETIC RESULTS

Table 7.1 summarizes the sets of combustion parameters presented in individual coal data packages in section 11. In Fig. 7.1 combustion rates, q , and characteristic burning times, τ_{50} , for each of the ten coals burning in a selected standard environment containing 6 mole-% oxygen and having a gas temperature of 1600 K. A pronounced trend is evident in the data set; char reactivity decreases with increasing rank of the parent coal. Burning rates vary by a factor of about 7 between the Beulah lignite (PSOC-1507) and the Pocahontas #3 low-volatile bituminous coal (PSOC-1508). The characteristic burning time, τ_{50} , which also reflects variations in the physical properties of the chars, varies by a factor of about 10.

Figure 7.1 Instantaneous burning rates, q , and the char reactivity index, τ_{50} for 100 μm particles of the PETC suite of coals reacting in a selected standard combustion environment (6 mole-% oxygen, 1500 K gas temperature, cold walls). Combustion rates, q , in $\text{g-carbon}/\text{cm}^2\text{-sec} \times 100$; char reactivity index, τ_{50} , in seconds.

Table 7.1 Char Combustion Parameters and Selected Properties for the Suite of Coals Investigated

Seam Name, PETC Designation	Reported Rank (ASTM)	%Vol Matter (dmmf)	Calorific Val, mmf eq moist (kJ/gm)	Elemen Carbon Content (wt-%)	Preexp Factor, A (g carb/cm ² s atm ^{0.5})	Activation Energy E (kcal/mol)	Product [†] Ratio Correlation	Physical mode of burning α	Combustion swelling factor ω	Parameters initial carbon density (g/cc) ρ_c	Standard ^{††} burning rate q (g/cm ² s)	Characteristic ^{†††} burnout time τ_{50} (sec)
Pocahontas #3 PSOC-1508D	low vol bitum	16.21	35.74	89.0	114	30.0	1	0.3	1.21	0.63	1.2×10^{-3}	0.63
Low Kittanning PSOC-1516D	low vol bitum	18.55	34.84	82.8	10.5	20.5	2	0.0	1.27	48	2.1×10^{-3}	0.29
Pittsburgh #8 PSOC-1451D	hvA bitum	38.81	34.18	82.6	29	24	3	0.1	1.1	0.40	2.4×10^{-3}	0.19
Hiawatha PSOC-1502D	hvc bitum	44.24	29.39	79.6	—*	—*	1	0.1	1.16	0.44	6.5×10^{-3}	0.070
Illinois #6 PSOC-1493D	hvc bitum	42.91	29.18	78.2	22.4	22.5	4	0.45*	1.06*	0.39*	3.3×10^{-3}	0.11
Blue #1 PSOC-1445D	hvc bitum	47.86	27.81	77.9	3.8	15.3	1	0.25	1.16	0.26	4.5×10^{-3}	0.064
Dietz PSOC-1488D	Subbit	43.88	23.13	74.4	—*	—*	5	0.25	1.04	0.41	6.7×10^{-3}	0.061
Smith-Roland PSOC-1520D	Subbit	61.96	21.48	66.4	—*	—*	2	0.3	0.85	0.62	7.2×10^{-3}	0.069
Lower Wilcox PSOC-1443D	Lignite A	78.22	17.88	67.9	44	21.9	5	0.12	0.92	0.68	5.6×10^{-3}	0.11
Beulah PSOC-1507D	Lignite A	45.73	17.26	63.0	—*	—*	2	0.2	0.92	0.63	7.2×10^{-3}	0.078

* Combustion rates of chars from these coals are limited by the rate of diffusion of oxygen from the bulk gas to the particle surface (Zone 3 combustion) under the experimental conditions

** Values for 75 - 106 μ m size fraction (All others are for 106 - 125 μ m size fraction)

† CO/CO₂ product ratio under the experimental conditions correlated by the empirical relation $(\text{moles-CO})/(\text{moles-CO}_2) = A_c \exp(-E_c/RT_p)$ Correlation type 1 $A_c = 3 \cdot 10^8$, $E_c = 60$ kcal/mol, 2 CO only, 3 $A_c = 4 \cdot 10^4$, $E_c = 30$ kcal/mol, 4 $A_c = 2.5 \cdot 10^8$, $E_c = 60$ kcal/mol, 5 $A_c = 5 \cdot 10^8$, $E_c = 60$ kcal/mol These values are to be regarded as empirical parameters useful only for the prediction of char combustion rates in the range of gas environments investigated

†† Burning rates in 6 mole-% oxygen at 1500 K gas temperature with radiation to cold walls (g-carbon/s-cm²-external surface)

††† Characteristic time for 50 wt-% carbon conversion of char (volatile matter free basis) in 6 mole-% oxygen at 1500 K gas temperature with radiation to cold walls Values computed for each coal from A, E, n, A_c, E_c, α , ω , and ρ_{CO}

A unified treatment of the kinetic parameters (A , E , and n) can be found in Hurt and Mitchell (1992b), which culminates in a generalized reactivity correlation based on coal carbon content, allowing the prediction of char combustion rates under conditions relevant to pulverized coal-fired combustors. In Fig. 7.2, extracted from Hurt and Mitchell (1992b), the combustion rates for the ten PETC suite coals are compared to the predictions of this generalized correlation.

Figure 7.2 Comparison of char oxidation rates for chars from the PETC/Sandia coal suite in a selected environment having a gas temperature of 1500 K and containing 6 mole-% oxygen. Points: values predicted by the individual sets of kinetic parameters determined for each char. Curves: Values predicted by the Sandia coal char oxidation kinetic correlation.

A unified presentation and discussion of the physical combustion parameters (α , ω , and ρ_{co}) and the characteristic burning times (τ_{50}) can be found in Hurt and Hardesty (1992) and will be available later in the open literature. A unified presentation and discussion of the data base on elemental nitrogen release rates is currently in preparation.

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10. LIST OF PAPERS AND PRESENTATIONS

The publications and presentations listed are topical discussions on characteristics of coal-char combustion. The information discussed was obtained from results of experiments using the data presented in this report. The papers constitute journal articles and conference and meeting preprints. The presentations constitute invited seminars at companies, universities, contract review meeting, etc.

Journal Articles and Conference and Meeting Papers

1. R. E. Mitchell and W. J. McLean, "On the Temperature and Reaction Rate of Burning Pulverized Fuels," *Nineteenth Symposium (International) on Combustion/The Combustion Institute*, pp. 1113-1122 (1982).
2. R. E. Mitchell, D. A. Tichenor and K. R. Hencken, "Coal-Char Combustion", Proceedings of the Direct Utilization AR&TD Contractors Review Meeting, p. 241, Pittsburgh, PA, June 5-7, 1984.
3. S. Niksa, and R. E. Mitchell, "The Interpretation of Spatially-Resolved Mass Conversions and Two-Color Single-Particle Temperatures for Burning Polydisperse Pulverized Fuel Streams," Paper 83-13, 1983 Spring Meeting of the Western States Section/The Combustion Institute, Pasadena, CA, April 11-12, 1983; also Sandia National Laboratories Report SAND83-8707.
4. R. E. Mitchell and W. J. McLean, "Temperature Measurements of Single Pulverized Fuel Particles by Two-Color Pyrometry: II. Particle Burning Behavior," Paper No. 483, 163rd Meeting of the Electrochemical Society, San Francisco, CA, May 8-13, 1983.
5. S. Niksa and R. E. Mitchell, "Interpreting Spatially-Resolved Conversions and Two-Color Single Particle Temperatures for Burning Polydisperse Pulverized Fuel Streams," 1983 International Conference on Coal Science, Sponsored by IEA, Pittsburgh, PA, August 15-19, 1983.
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7. D. A. Tichenor, R. E. Mitchell, K. R. Hencken, and S. Niksa, "Simultaneous In Situ Measurements of the Size, Temperature and Velocity of Particles in a Combustion Environment," *Twentieth Symposium (International) on Combustion/The Combustion Institute*, p. 1213 (1984).
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10. R. E. Mitchell, D. A. Tichenor, and K. R. Hencken, "Rates and Mechanisms of Combustion of Pulverized Coals: Coal-Char Combustion", Proceedings of the AR&TD Direct Utilization Contractors Review Meeting, p. 84, Morgantown, West Virginia, August 13-15, 1985.
11. R. E. Mitchell, "Experimentally Determined Reactivities of Coal Chars," Paper No. 97, Second Annual Pittsburgh Coal Conference, Pittsburgh, PA, September 16-20, 1985.
12. R. M. Allen and R. E. Mitchell, "Mineral Matter Transformations During the Combustion of a Pulverized-Fuel in a Laminar Flow Reactor", 1985 International Conference on Coal Science, Sponsored by IEA, p. 401, Sydney, Australia, October 28 - November 1, 1985.
13. R. E. Mitchell, D. A. Tichenor, and K. R. Hencken, "Char Reactivities Determined from Measurements of Particle Size, Temperature and Velocity", 1985 International Conference on Coal Science, Sponsored by IEA, p. 375, Sydney, Australia, October 28 - November 1, 1985.
14. C. S. Daw, R. E. Mitchell and J. R. Byrd, "Char Combustion Kinetics of Kentucky No. 9 Coal as Applied to Atmospheric Fluidized Bed Combustion", Fall Meeting of the American Flame Research Committee, Sandia National Laboratories, Livermore, CA, October 17-18, 1985.
15. C. Stuart Daw and Reginald E. Mitchell, "Char Combustion Kinetics for Kentucky No. 9 Coal," AFB Technology for Utility Applications Seminar, Sponsored by the Electric Power Research Institute, Palo Alto, CA, April 8-10, 1986,
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21. Veli-Pekka Heiskanen and Reginald E. Mitchell, "Temperature, Size and Overall Burning Rates of Pulverized Peat from Finland", Paper 87-9, 1987 Spring Meeting of the Western States Section/The Combustion Institute, Provo, Utah, April 6-7, 1987.
22. R. E. Mitchell, "Rates and Mechanisms of Combustion of Pulverized-Coal Chars," Proceedings of the AR&TD Direct Utilization, Instrumentation and Diagnostics Contractors Review Meeting, Morgantown, West Virginia, October 14-16, 1987.
23. B. J. Waters, R. E. Mitchell, R. G. Squires, and N. M. Laurendeau, "Overall Kinetic Parameters for Combustion of a Highly Non-Spherical Carbon Char", Paper 88-2, Spring Meeting of the Western States Section/The Combustion Institute, Salt Lake City, Utah., March 21-22, 1988.
24. B. J. Waters, R. E. Mitchell, R. G. Squires, and N. M. Laurendeau, "Evidence for Formation of CO₂ in the Vicinity of Burning Pulverized Carbon Particles", *Combustion and Flame* **74**, 91-106 (1988).
25. R. E. Mitchell, "Determination of the Intrinsic Reactivities of Pulverized-Coal Chars at High Temperature", Paper 88-1, Spring Meeting of the Western States Section/The Combustion Institute, Salt Lake City, Utah, March 21-22, 1988; also, Sandia National Laboratories Report SAND88-8707.
26. B. J. Waters, R. E. Mitchell, R. G. Squires, and N. M. Laurendeau, "Overall Kinetic Parameters for Combustion of a Highly Non-Spherical Carbon Char", *Twenty-Second Symposium (International) on Combustion/The Combustion Institute*, pp. 17-29, 1988.
27. R. E. Mitchell, "On the Products of the Heterogeneous Oxidation Reaction at the Surfaces of Burning Coal-Char Particles", *Twenty-Second Symposium (International) on Combustion/The Combustion Institute*, pp. 69-78, 1988.
28. R. E. Mitchell, "Rates and Mechanisms of Combustion of Pulverized-Coal Chars," Proceedings of the AR&TD Direct Utilization and Instrumentation & Diagnostics Contractors' Review Meeting, Pittsburgh, PA, September 6-9, 1988.
29. Baxter, L. L. and Mitchell, R. E., "Experimental Observation and a Postulated Mechanism of Release of Iron During the Combustion of Illinois #6 Coal", 1988 Fall International Symposium of the American Flame Research Committee, Pittsburgh, PA, October 4-6, 1988.

30. R. E. Mitchell, "The Thermal Influence of Ash on the Temperatures Attained by Burning Coal Char Particles", Paper 88-78, Fall Meeting of the Western States Section/The Combustion Institute, Dana Point, CA, October 17-18, 1988.
31. T. F. Wall, R. E. Mitchell, A. Tate, and J. Bailey, "The Temperatures Attained by Burning Coal-Char Particles", Joint International Conference Australia/New Zealand and Japanese Sections/The Combustion Institute, Sydney, NSW, September 24-27, 1989.
32. L. L. Baxter and R. E. Mitchell, "The Release of Iron during the Combustion of Illinois #6 Coal, " Proceedings of the Sixth Annual International Pittsburgh Coal Conference, p. 64, Pittsburgh, PA, September 25-29, 1989; also, submitted to *Combustion and Flame*, 1989.
33. R. E. Mitchell, "The Influence of the Mineral Matter Content of Coal on the Temperatures and Burning Rates of Char Particles During Pulverized-Coal Combustion," Proceedings of the Sixth Annual International Pittsburgh Coal Conference, p. 32, Pittsburgh, PA, September 25-29, 1989.
34. R. E. Mitchell, "Rates and Mechanisms of Combustion of Pulverized-Coal Chars," Proceedings of the AR&TD Direct Utilization, Instrumentation and Diagnostics Contractors Review Meeting, Morgantown, West Virginia, October 3-5, 1989.
35. W. Richter and R. E. Mitchell, "Effect of True Particle Temperature on Boiler Furnace Performance", Paper 89-83, Fall Meeting of the Western States Section/The Combustion Institute, Sandia National Laboratories, Livermore, CA, October 23-24, 1989.
36. R. E. Mitchell, R. J. Kee, P. Glarborg, and M. E. Coltrin, "The Effect of CO Conversion in the Boundary Layers Surrounding Pulverized-Coal Char Particles", *Twenty-Third Symposium (International) on Combustion*, The Combustion Institute, pp 1169-1176 (1990).
37. R. E. Mitchell, "Variations in the Temperatures of Coal-Char Particles During Combustion: A Consequence of Particle-To-Particle Variations in Ash-Content", *Twenty-Third Symposium (International) on Combustion*, The Combustion Institute, pp 1297-1304 (1990).
38. R. H. Hurt and R. E. Mitchell. "On the Combustion Kinetics of Heterogeneous Char Particle Populations" *24th International Symposium on Combustion*, The Combustion Institute, Pittsburgh, PA, (1992)
39. R. H. Hurt and R. E. Mitchell. "Unified High-Temperature Char Combustion Kinetics for a Suite of Coals of Various Rank" *24th International Symposium on Combustion*, The Combustion Institute, Pittsburgh, PA, (1992)

40. T. F. Wall, A. G. Tate, J. G. Bailey, L. G. Jenness, R.E. Mitchell, and R. H. Hurt "The Temperature, Burning Rates and Char Character of Pulverised Coal Particles Prepared from Maceral Concentrates" *24th International Symposium on Combustion*, The Combustion Institute, Pittsburgh, PA, (1992)

Presentations at Symposia, Conferences, and Meetings, and Invited Seminars

presentations by R. E. Mitchell

1. "On the Temperature and Reaction Rate of Burning Pulverized Fuels," Nineteenth Symposium (International) on Combustion/The Combustion Institute, Technion-Israel Institute of Technology, Haifa, Israel, August 8-13, 1982.
2. "The Effect of the Particle Size Distribution on the Measured Temperature Distribution of Burning Pulverized Fuel Streams," Direct Utilization Advanced Research and Technology Development, Contractors Review Meeting, PETC, Pittsburgh, PA, April 5-8, 1983.
3. "Temperature Measurements of Single Pulverized Fuel Particles by Two-Color Pyrometry: II. Particle Burning Behavior," 163rd Meeting of the Electrochemical Society, San Francisco, CA, May 8-13, 1983.
4. "Simultaneous Measurements of Particle Size, Temperature, and Velocity in Burning Pulverized Fuel Streams," Direct Utilization Advanced Research and Technology Development, Peer Review Meeting, Washington D.C., February 2, 1984.
5. "Overall Particle Burning Rates from Simultaneous Measurements of Particle Size and Temperature in Burning Polydisperse Pulverized Fuel Streams", 1984 Spring Meeting of the Western States Section/The Combustion Institute, Boulder, CO, April 2-3, 1984.
6. "The Sandia Coal Char Combustion Program: Experimental Capabilities and Planned Research Activities", Working Group on Coal Combustion Chemistry, Organized by PETC, United Technologies Research Center, East Hartford, CT, November 1,2, 1984.
7. "Pulverized Coal Burning Rates from Measured Particle Size-Temperature Correlations", Chemical Engineering Department, Prairie View A & M University, Prairie View, Texas, February 19, 1985.
8. "Overall Burning Rates of Coal Chars from Simultaneous Measurements of Particle Size, Temperature, and Velocity in Burning Polydisperse Pulverized Fuel Streams", 23rd ASME/AIChE National Heat Transfer Conference, Denver, August 4-7, 1985.
9. "Experimentally Determined Reactivities of Coal Chars," Direct Utilization Advanced Research and Technology Development Contractors Meeting, Morgantown, West Virginia, August 13-15, 1985.

10. "Experimentally Determined Reactivities of Coal Chars," Pittsburgh Coal Conference, Pittsburgh, PA, September 16-20, 1985.
11. "Mineral Matter Transformations During the Combustion of a Pulverized Fuel in a Laminar Flow Reactor", 1985 International Conference on Coal Science, Sponsored by IEA, Sydney, NSW, Australia, October 28 - November 1, 1985.
12. "Char Reactivities Determined from Measurements of Particle Size, Temperature, and Velocity", 1985 International Conference on Coal Science, Sponsored by IEA, Sydney, NSW, Australia, October 28 - November 1, 1985.
13. "Experimentally Determined Reactivities of Coal Chars," Chemical Engineering Department, University of Sydney, Sydney, NSW, Australia, November 7, 1985.
14. "The Reactivities of Coal Chars and Mineral Matter Transformations During Combustion," CSIRO Division of Fossil Fuels, North Ryde, NSW, Australia, November 8, 1985.
15. "Experimentally Determined Reactivities of Coal Chars," 1986 Spring Meeting of the Western States Section/The Combustion Institute, Banff, Alberta Canada, April 28-30, 1986.
16. "Experimentally Determined Overall Burning Rates of Pulverized Coal Chars in Specified O₂ and CO₂ Environments," Twenty-First Symposium (International) on Combustion, Paper No. 1, Technical University of Munich, West Germany, August 4-8, 1986.
17. "The Reactivities of Coal Chars and Mineral Matter Transformations during Combustion," The Technical University of Denmark, Lyngby, Denmark, August 13, 1986.
18. "The Reactivities of Coal Chars and Mineral Matter Transformations during Combustion," Risoe National Laboratory, Roskilde, Denmark, August 14, 1986.
19. "Rates and Mechanisms of Combustion of Pulverized Coal Chars," PETC/METC Direct Utilization Advanced Research and Technology Development Contractor Review Meeting, Warrendale, PA, September 22-25, 1986.
20. "On the Reactivity of Coal Chars", Working Group on Coal Combustion Chemistry, Organized by PETC, Massachusetts Institute of Technology, Cambridge, MA, February 4-5, 1987.
21. "Coal Char Oxidation Studies", PETC/METC Direct Utilization Advanced Research and Technology Development Contractor's Meeting, Washington, D.C., February 10-12, 1987.
22. "High-Temperature Burning Rates of Pulverized Coal Chars", Mechanical Engineering Department, University of Colorado, Boulder, CO, February 18, 1987.
23. "Temperature, Size and Overall Burning Rates of Pulverized Peat from Finland", Paper 87-9, 1987 Spring Meeting Western States Section/The Combustion Institute, Provo, Utah, April 6-7, 1987.

24. "High-Temperature Burning Rates of Pulverized Coal Chars", 14th Annual Meeting of the National Organization of Black Chemists and Chemical Engineers, San Francisco, April 13-18, 1987.
25. "High-Temperature Burning Rates of Pulverized Coal Chars", Mechanical Engineering Department, University of California, Davis, CA, May 7, 1987.
26. "High-Temperature Burning Rates of Pulverized Coal Chars", Illinois Coal Development Boards' 5th Annual Contractors' Technical Conference, Urbana, Illinois, July 28-30, 1987.
27. "Coal Char Oxidation Studies", PETC/METC Direct Utilization Advanced Research and Technology Development Contractor's Meeting, Morgantown, WV, October 14-16, 1987.
28. "High-Temperature Burning Rates of Pulverized Coal Chars", Department of Mechanical and Aerospace Engineering, Princeton University, November 10, 1987.
29. "The Reactivity of Pulverized Coal Chars at High Temperatures", Division of Engineering, Brown University, November 12, 1987.
30. "High-Temperature Burning Rates of Pulverized Coal Chars", Advanced Fuels Research, East Hartford, CT., November 13, 1987.
31. "High-Temperature Burning Rates of Pulverized Coal Chars", 15th Annual WATtec Interdisciplinary Technical Conference and Exhibition, Knoxville, February 16 - 19, 1988.
32. "On the Products of the Heterogeneous Char Oxidation Reaction at High Temperature", Mechanical Engineering Department, Stanford University, February 24, 1988.
33. "Determination of the Intrinsic Reactivities of Pulverized-Coal Chars at High Temperatures", Paper 88-1, 1988 Spring Meeting, Western States Section/The Combustion Institute, Salt Lake City, UT, March 21-22, 1988.
34. "On the Products of the Coal Char Oxidation Reaction" ACS Regional Meeting, Morgantown, West Virginia, June 1-2, 1988.
35. "On the Products of the Heterogeneous Oxidation Reaction at the Surfaces of Burning Coal Char Particles", 22nd International Symposium on Combustion, Seattle, Washington, August 14-19, 1988.
36. "Recent Accomplishments in the Sandia Coal Char Combustion Program", 1988 Direct Utilization Advanced Research and Technology Development Contractor's Review Meeting, Pittsburgh, PA, September 6-9, 1988.
37. "On the Products of the Heterogeneous Char Oxidation Reaction" 5th Annual Western Region Meeting, National Organization of Black Chemists and Chemical Engineers, Oakland, CA, September 23-24, 1988.

38. "The Thermal Influence of Ash on the Temperatures Attained by Burning Coal Char Particles", Paper 88-78, Fall Meeting of the Western States Section/The Combustion Institute, Dana Point, CA, October 17-18, 1988.
39. "The Combustion Characteristics of Pulverized-Coal Chars", Student Chapter of the AIChE, Chemical Engineering Department, San Jose State University, San Jose, CA, November 17, 1988.
40. "The Influence of the Mineral Matter Content of Coal on the Temperatures and Burning Rates of Char Particles During Pulverized-Coal Combustion," Sixth Annual International Pittsburgh Coal Conference, Pittsburgh, PA, September 25-29, 1989.
41. "Rates and Mechanisms of Combustion of Pulverized-Coal Chars," AR&TD Direct Utilization, Instrumentation and Diagnostics Contractors Review Meeting, Morgantown, West Virginia, October 3-5, 1989.
42. "Particle-Sizing Pyrometry in Pulverized Coal-Seeded Flow Reactors", American Institute of Chemical Engineers 1989 Annual Meeting, San Francisco, CA, November 5-10, 1989.
43. "The Combustion Characteristics of Pulverized-Coal Chars", Advanced Combustion Engineering Research Center, Brigham Young University, Provo, UT, January 31, 1990.
44. "The Effect of CO Conversion in the Boundary Layers Surrounding Pulverized-Coal Char Particles", The Twenty-Third International Symposium on Combustion, University of Orleans, France, July 22-27, 1990.
45. "Variations in the Temperatures of Coal-Char Particles During Combustion: A Consequence of Particle-To-Particle Variations in Ash-Content", The Twenty-Third International Symposium on Combustion, University of Orleans, France, July 22-27, 1990.
46. "Modelling of Coal-Char Combustion", Danish Gas Technology Center, Horsholm, Denmark, July 30, 1990
47. "Pulverized-Coal Char Combustion", Technical University of Denmark, Lyngby, Denmark, July 31, 1990
48. "Rates and Mechanisms of Combustion of Pulverized-Coal Chars," AR&TD Direct Utilization, Instrumentation and Diagnostics Contractors Review Meeting, Pittsburgh, PA, September 16-18, 1990.

presentations by R. H. Hurt

49. "Sandia Coal Combustion Science Program: Task 2. The Rates and Mechanisms of Pulverized-Coal Char Combustion" presented at the Seventh Annual Coal Preparation, Utilization, and Environmental Control Contractors Conference, Pittsburgh (1991)

50. "On the Combustion Kinetics of Heterogeneous Char Particle Populations," Fall Meeting of the American Chemical Society, Division of Fuel Chemistry, New York, August 26, 1991.
51. "The Sandia Coal Combustion Science Program; Task 2: Rates and Mechanisms of Coal Char Oxidation" presented at the Pittsburgh Energy Technology Center, August (1991d)
52. "Kinetics and Mechanisms of Coal Char Oxidation" Chemical Engineering Department Seminar, Brigham Young University, Provo, Utah. March (1992)

SECTION 11

INDIVIDUAL COAL CHAR

DATA COMPILATIONS

Compilation of Data and Kinetic Analyses for

**Lower Wilcox Lignite
(Texas)**

PSOC-1443D

TABLE OF CONTENTS

- **Sample history, geologic information and chemical analysis of bulk, raw coal**
- **Chemical analysis of size-fractionated raw coal and partially reacted chars**
- **Time resolved measurements of the partitioning of elemental coal constituents between the gas and solid phases**
- **Mode of particle burning**
- **Statistical analyses of elemental composition measurements and derived quantities**
- **Optical measurements of single-particle temperature distributions**
- **Optical measurements of single-particle sizes, temperatures, and velocities**
- **Kinetic analysis and combustion parameters**
- **Calculations of the coal char reactivity index, τ_{50} , for various environments present in pulverized-coal combustion systems**

**SAMPLE HISTORY, GEOLOGIC INFORMATION AND
CHEMICAL ANALYSIS OF BULK, RAW COAL**

Data and Analysis Compilation
for PSOC-1443, Lower Wilcox Lignite

SAMPLE HISTORY

PENN STATE NUMBER	PSOC-1443
COLLECTED BY	PENNSYLVANIA STATE UNIVERSITY
COLLECTION DATE	3/29/85
COLLECTOR'S NUMBER	
REPORTED RANK	LIGNITE
SAMPLE TYPE	CHANNEL WHOLE SEAM
OTHER SAMPLE INFORMATION	
SAMPLE RESERVE	
SEAM NAME	
ALTERNATE SEAM NAME	LOWER WILCOX SEAM
TOTAL SEAM THICKNESS	10 FT. 8 IN.
THICKNESS OF SEAM SAMPLED	10 FT. 8 IN.
PORTION RECOVERED IN CORE	
DIAMETER OF CORE	

SAMPLE LOCATION

COUNTRY	U.S.A.
STATE	TEXAS
COUNTY	TITUS
TOWNSHIP	
NEAREST TOWN	WINFIELD
COAL PROVINCE	GULF
COAL REGION	
COAL FIELD	

SEAM NAME		COUNTRY	U.S.A.
APPARENT RANK	SUBBITUMINOUS C (SUBC)	STATE	TEXAS

GEOLOGIC INFORMATION

SYSTEM (AGE)	TERTIARY
SERIES	EOCENE
GROUP	WILCOX
FORMATION	
OVERBURDEN LITHOLOGY	SILTSTONE
FLOOR LITHOLOGY	BROWN SHALE

SEAM STRATA INFORMATION

<u>THICKNESS</u>	<u>LITHOTYPE</u>
------------------	------------------

SEAM NAME		COUNTRY	U.S.A.
APPARENT RANK	SUBBITUMINOUS C (SUBC)	STATE	TEXAS

CHEMICAL DATA 1

PROXIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF (PAFF)	DMMF (PARR-G)	DMMF (DIR MM)
% MOISTURE	28.54					
% ASH	15.31	21.43				
% VOLATILE MATTER	44.17	61.81	78.67	78.22	77.15	
% FIXED CARBON	11.98	16.76	21/33	21.78	22.85	

CALORIFIC VALUE (GROSS BTU/LB)	DRY	AS REC'D MOIST.	EQUIL MOIST.
MM-FREE, DIRECT			
MM-CONTAINING	9882	7062	6519
MM-FREE (PARR)	12878	8459	7689
MM-FREE (MOD.P)	13045	8510	7731
BEST MM FREE		8510	7731
NET CV, DMMF BTU/LB	12545		
ASH-FREE	12577		

MOTT-SPOONER DIFFERENCE =

ASSOCIATED ANALYSES	DRY	MMF
% EQUILIBRIUM MOISTURE	34.03	44.51
% TOTAL SULFUR	0.74	

RANK CALCULATIONS

APPARENT RANK (AS REC'D MOIST)	SUBBITUMINOUS C (SUBC)
ASTM RANK (EQUIL. MOIST.)	LIGNITE A (LIGA)
REFLECTANCE RANK CATEGORY	
INTERNATIONAL RANK	
AS REC'D MOIST.	
EQUIL. MOIST	
REPORTED RANK	LIGNITE

SEAM NAME		COUNTRY	U.S.A.
APPARENT RANK	SUBBITUMINOUS C (SUBC)	STATE	TEXAS

CHEMICAL DATA 2

<u>ULTIMATE ANALYSIS</u>	<u>AS REC'D</u>	<u>DRY</u>	<u>DAF</u>	<u>DMMF(PARR)</u> (23.55 % MM)
% ASH	15.31	21.43		
% CARBON	40.62	56.84	72.34	74.35
% HYDROGEN	*2.92	4.09	5.21	5.35
% NITROGEN	0.76	1.06	1.35	1.39
% SULFUR	0.53	0.74	0.94	
% CHLORINE	0.04	0.05	0.07	0.07
% OXYGEN (DIFF)	*11.26	15.78	20.11	18.86

<u>SULFUR FORMS</u>	<u>% PYRITIC</u>	<u>% SULFATIC</u>	<u>% ORGANIC</u>	<u>% TOTAL</u>
DRY	0.09	0.01	0.64	0.74
DAF	0.11	0.01	0.81	0.94
OPTICAL				

<u>ELEMENTAL ANALYSIS</u>	<u>DRY</u>	<u>DMMF (MOD.P)</u> (24.29 % MM)	<u>DMMF(DIR.)</u> (% MM)
% CARBON	56.64	74.81	
% HYDROGEN	3.82	5.05	
% NITROGEN	1.06	1.39	
% ORGANIC SULFUR	0.64	0.85	
% OXYGEN (DIFF)	13.55	17.84	
% CHLORINE	0.05	0.07	
% MINERAL MATTER (INCLUDES 0.17 % FES2)	24.29		

<u>ATOM RATIOS (DMMF)</u>	<u>PARR</u>	<u>MOD.PAR</u>	<u>DIRECT</u>
ATOMIC H/C	0.864	0.810	
ATOMIC O/C	0.190	0.237	

<u>MISC. CHEMICAL DATA</u>	<u>DRY</u>	<u>OF DMMF COAL</u>	<u>OF DMMF OXYGEN</u>
% O AS COOH			
% O AS OH			
% S AS SO4, IN ASH			
% CARBONATE AS CO2	0.72		
% CHLORINE	0.11		

INFRA-RED ANALYSIS

(*)- EXCLUDES MOISTURE

SEAM NAME		COUNTRY	U.S.A.
APPARENT RANK	SUBBITUMINOUS C (SUBC)	STATE	TEXAS

CHEMICAL DATA 3

% MOISTURE IN COAL = 14.70
 % HIGH TEMPERATURE ASH = 14.20 AT 750 DEGREES C

TRACE ELEMENT ANALYSIS	PPM HTA	PPM TOTAL COAL	MAJOR ELEMENT ANALYSIS	OXIDE % OF HTA	ELEMENT % OF TOTAL DRY COAL
AG			SI02	47.90	3.18
B			AL203	22.20	1.67
BA	1080	153	TI02	1.75	0.15
BE	4	1	FE203	3.51	0.35
BI			MG0	2.79	0.24
CE			CA0	14.00	1.42
CO			NA20	0.37	0.04
CR	120	17	K20	0.55	0.06
CU	160	23	P205	0.11	0.01
GA			S03	7.00	0.40
GE					
LA					
LI					
MN	1500	213			
MO			<u>VOLATILES</u>	<u>PPM TOTAL COAL</u>	
NI	35	5			
NB			AS		
PB			BR		
RB	25	4	CD		
SC			CL		
SN			F		
SR	1100	156	HG		
TH			SB		
U			SE		
V	240	34			
Y					
YB					
ZN	20	3			
ZR	310	44			

SEAM NAME		COUNTRY	U.S.A.
APPARENT RANK	SUBBITUMINOUS C (SUBC)	STATE	TEXAS

MINERALOGICAL DATA

TOTAL MINERAL MATTER

% MM-PARR	23.55
% MM-MODIFIED PARR	24.29
% MM-KMC	
% MM-DIRECT	
% MM-BEST AVAILABLE	24.29
VOL % MM-PARR	12.93

MINERAL COMPOSITION

NONE

SEAM NAME		COUNTRY	U.S.A.
APPARENT RANK	SUBBITUMINOUS C (SUBC)	STATE	TEXAS

PETROGRAPHIC DATA

MACERAL COMPOSITION WHITE ANALYSIS ONLY

	<u>DRY</u> <u>VOLUME %</u>	<u>DMMF</u> <u>VOLUME %</u>
HUMINITE	78.4	90.0
INERTINITE	6.0	6.9
LIPTINITE	2.7	3.1
MINERAL MATTER (CALC.)	12.9	
TEXTINITE	0.0	0.0
ULMINITE	70.1	80.05
ATTRINITE		
DENSINITE		
HUMODETRINITE(ANAL)	5.9	6.8
GELINITE	1.8	2.1
CORPOHUMINITE	0.5	0.6
SPORINITE		
CUTINITE		
EXINTITE(ANAL.)	2.1	2.4
RESINITE	0.6	0.7
SUBERINITE	0.0	0.0
EXUDATINITE	0.0	0.0
FLUORINITE	0.0	0.0
BITUMINITE	0.0	0.0
ALGINITE	0.0	0.0
LIPTODETRINITE	0.0	0.0
FUSINITE	1.1	1.3
SEMI-FUSINITE	2.7	3.1
MACRINITE	2.2	2.5
MICRINITE	0.0	0.0
SCLEROTINITE	0.0	0.0
INERTODETRINITE	0.0	0.0
MINERAL MATTER(ANAL.)		
HUMINITE(ANAL.)		
INERTINITE(ANAL.)		
LIPTINITE(ANAL.)		

<u>REFLECTANCE DATA</u> (% IN OIL)	<u>HIGH</u>	<u>LOW</u>	<u>RANGE</u>	<u>MEAN MAX</u>	<u>STAND.DEV.</u>
ULMINITE	0.52	0.35	0.17	0.44	0.03

SEAM NAME		COUNTRY	U.S.A.
APPARENT RANK	SUBBITUMINOUS C (SUBC)	STATE	TEXAS

PETROGRAPHIC DATA

CONTINUED

<u>% VITRINOID</u> <u>REFLECTANCE</u>	<u>HALF-TYPE</u>	<u>VOLUME</u> <u>PERCENT</u>	<u>% VITRINOID</u> <u>REFLECTANCE</u>	<u>V-TYPE</u>	<u>VOLUME</u> <u>PERCENT</u>
0.30-0.34	VHT 0.325	0.00			
0.35-0.39	VHT 0.375	7.00	0.30-0.39	V3	7.00
0.40-0.44	VHT 0.425	55.00			
0.45-0.49	VHT 0.475	34.00	0.50-0.59	V4	89.00
0.50-0.54	VHT 0.525	4.00			
0.55-0.59	VHT 0.575		0.50-0.59	V5	3.00

PHYSICAL PROPERTIES

HARDGROVE GRINDABILITY	52.7
VICKER'S MICROHARDNESS	
FREE SWELLING INDEX	0.0
GRAY KING COKE TYPE	

<u>ASH FUSION ANALYSIS (DEGREES F)</u>	<u>REDUCING</u>	<u>OXIDIZING</u>
INITIAL DEFORMATION TEMPERATURE	2310	2330
SOFTENING TEMPERATURE	2360	2585
HEMISPHERE TEMPERATURE	2500	2590
FLUID TEMPERATURE	2540	2630

ANALYSIS LOG

<u>ANALYSIS</u>	<u>DATE</u>	<u>PERFORMED BY</u>
A.R. MOIST	6/4/85	WARNER LABORATORIES
EQUIL. MOIST.	6/4/85	WARNER LABORATORIES
PROXIMATE	6/4/85	WARNER LABORATORIES
ULTIMATE	6/4/85	WARNER LABORATORIES
SULFUR FORMS	6/4/85	WARNER LABORATORIES
FSI	8/15/85	COAL PETROGRAPHY LABORATORIES-PSU
PLASTOMETER		
DIRECT MM		
GRAY-KING		

**CHEMICAL ANALYSES OF SIZE-FRACTIONATED RAW COAL
AND PARTIALLY REACTED CHARS**

Data and Analysis Compilation
for PSOC-1443, Lower Wilcox Lignite

**Organic Elemental Analysis and Percent Ash of Lower Wilcox Coal and its
Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	56.43	4.43	19.93	1.13	1.13	19.85
6.4	57.91	1.09	8.72	1.16	0.95	32.91
12.7	81.27	0.74	3.91	1.26	0.85	12.16
19.1	41.33	0.85	5.75	0.53	0.79	45.35
25.4	31.78	0.56	4.47	0.45	0.92	59.4

12 mole-% Oxygen Environment**

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	56.27	4.41	19.8	1.09	0.87	19.88
6.4	56.17	1.13	8.03	1.02	0.78	35
12.7	38.04	1.3	8.54	0.55	0.94	46.90
19.1	16.96	0.61	4.8	0.33	0.76	73.25
25.4	10.48	0.48	3.91	0.22	0.76	83.88

* Data taken in May 1988

** Data taken in July 1988

**Ash Content of Lower Wilcox Coal and its
Partially Reacted Chars**

Initial particle size range: 106 - 125 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	7.65	4.28	0.359	0.765	2.21	0.409	0.096	0.050
6.4	13.4	7.54	0.608	1.74	3.87	0.728	0.123	0.076
12.7	5.13	2.71	0.17	1.67	0.777	0.155	0.051	0.024
19.1	18.3	11	0.862	2.28	5.55	1.04	0.025	0.094
25.4	21.1	14.8	1.11	3.49	9.23	1.85	0.222	0.139

12 mole-% Oxygen Environment**

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	9.10	4.7	0.415	0.944	3.13	0.554	0.051	0.029
6.4	14.6	8.01	0.652	2.13	4.43	0.822	0.123	0.065
12.7	20.8	11.7	0.967	6.14	6.97	1.355	0.144	0.084
19.1	30.9	18.2	1.41	8.3	9.91	1.8	0.261	0.11
25.4	34.8	19.6	1.48	7.28	10.3	1.82	0.295	0.101

* Data taken in May 1988

** Data taken in July 1988

**TIME RESOLVED MEASUREMENTS OF THE
PARTITIONING OF ELEMENTAL COAL CONSITUTENTS
BETWEEN THE GAS AND SOLID PHASES**

Data and Analysis Compilation
for PSOC-1443, Lower Wilcox Lignite

MODE OF PARTICLE BURNING

Data and Analysis Compilation
for PSOC-1443, Lower Wilcox Lignite

**Fractional Mass Remaining and Apparent Density
of Lower Wilcox Coal and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.57	- -	0.37	0.30
Fractional burnoff, daf	0.0	0.52	- -	0.80	0.85
Apparent density, g/cc	1.19	0.83	- -	0.79	0.83

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.54	0.35	0.24	0.21
Fractional burnoff, daf	0.0	0.56	0.77	0.93	0.96
Apparent density, g/cc	1.19	0.86	0.90	1.08	1.16

**STATISTICAL ANALYSES
OF ELEMENTAL COMPOSITION MEASUREMENTS
AND DERIVED QUANTITIVES**

- **Raw Coal Composition**
- **Overall Combustion Conversion vs. Residence Time**
- **Elemental Partitioning between Gas and Solid Phases**

Data and Analysis Compilation
for PSOC-1443, Lower Wilcox Lignite

Average Initial Mass Percents and Statistics						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 6 % O ₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	8.130	0.865	3	0.106	2.148	4.955
Al ₂ O ₃	4.417	0.301	3	0.068	0.749	1.727
TiO ₂	0.377	0.041	3	0.110	0.103	0.237
Fe ₂ O ₃	0.825	0.112	3	0.136	0.278	0.641
CaO	2.513	0.546	3	0.217	1.357	3.130
Na ₂ O	0.043	0.016	3	0.371	0.039	0.091
K ₂ O	0.081	0.027	3	0.339	0.068	0.158
MgO	0.457	0.087	3	0.191	0.217	0.500
Σ Oxides	16.843					
C	55.240	1.655	5	0.030	2.054	3.407
H	4.426	0.281	5	0.063	0.349	0.578
O	18.390	1.712	4	0.093	2.724	5.001
N	1.074	0.062	5	0.058	0.077	0.128
S	0.938	0.130	4	0.139	0.207	0.380
Ash-s	19.193	1.829	6	0.095	1.920	3.011
Ash-l	19.910	0.498	3	0.025	1.237	2.852

Residual Total Mass (m/m ₀) as a Function of Residence Time						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 6 % O ₂		
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.48	0.61	0.59	0.62	0.59	0.60
72	0.34	1.58	1.63	2.22	1.72	1.64
95	0.20	0.44	0.40	0.44	0.41	0.44
117	0.18	0.39	0.30	0.34	0.32	0.34

Residual Total Mass (m/m0) with Statistics						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 6 % O₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	12	1.00	0.000	0.000
47	0.57	0.064	4	0.48	0.102	0.188
72	1.44	0.792	4	1.58	1.261	2.314
95	0.37	0.117	4	0.25	0.186	0.342
117	0.30	0.088	4	0.15	0.140	0.257

Residual Elemental Mass as a Function of Residence Time						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 6 % O₂		
	SiO₂	TiO₂	Al₂O₃	Fe₂O₃	CaO	Na₂O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.94	0.92	0.98	1.21	0.88	1.02
72	0.91	0.65	0.89	2.92	0.45	0.81
95	0.83	0.85	0.92	1.02	0.82	0.82
117	0.78	0.89	1.01	1.27	1.11	0.98
	K₂O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.87	0.60	0.14	0.27	0.62	0.58
72	0.91	2.12	0.24	0.31	1.69	1.31
95	0.11	0.28	0.07	0.12	0.18	0.31
117	0.82	0.17	0.04	0.07	0.13	0.30

Elemental Mass Release (Normalized) and Statistics						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 6 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.118	3	0.118	0.292	0.673
47	0.056	0.153	3	0.162	0.354	0.817
72	0.090	0.511	4	0.562	1.106	2.551
95	0.167	0.281	4	0.337	0.614	1.415
117	0.219	0.243	4	0.311	0.530	1.223
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.085	3	0.085	0.210	0.485
47	0.022	0.137	4	0.141	0.310	0.715
72	0.115	0.492	4	0.556	1.061	2.448
95	0.078	0.302	4	0.327	0.654	1.509
117	-0.008	0.304	4	0.301	0.658	1.518
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.121	3	0.121	0.300	0.691
47	0.077	0.152	3	0.165	0.352	0.811
72	0.350	0.365	4	0.562	0.791	1.824
95	0.154	0.286	4	0.338	0.625	1.442
117	0.115	0.273	4	0.309	0.596	1.375
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.145	3	0.145	0.359	0.829
47	-0.209	0.221	3	0.183	0.518	1.196
72	-1.921	1.659	4	0.568	3.599	8.302
95	-0.023	0.356	4	0.347	0.782	1.804
117	-0.273	0.395	4	0.310	0.861	1.985

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 6 % O2		
CaO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.223	3	0.223	0.554	1.278
47	0.118	0.220	3	0.250	0.530	1.222
72	0.554	0.264	4	0.593	0.579	1.336
95	0.183	0.316	4	0.387	0.710	1.638
117	-0.105	0.359	4	0.324	0.790	1.822
Na2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.374	3	0.374	0.930	2.144
47	-0.021	0.399	3	0.391	0.977	2.254
72	0.189	0.539	4	0.665	1.209	2.789
95	0.185	0.399	3	0.490	0.930	2.144
117	0.020	0.381	4	0.389	0.868	2.002
K2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.343	3	0.343	0.852	1.966
47	0.130	0.314	3	0.361	0.768	1.772
72	0.092	0.588	4	0.648	1.312	3.027
95	0.886	0.053	3	0.466	0.123	0.284
117	0.175	0.247	4	0.299	0.534	1.232
MgO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.197	3	0.197	0.490	1.131
47	0.087	0.207	3	0.227	0.495	1.142
72	0.511	0.286	4	0.584	0.623	1.438
95	0.158	0.314	4	0.372	0.700	1.615
117	-0.218	0.385	4	0.316	0.842	1.943

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 6 % O2		
C						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	5	0.071	0.088	0.146
47	0.399	0.080	4	0.133	0.122	0.225
72	-1.122	1.175	4	0.554	1.866	3.426
95	0.723	0.090	4	0.324	0.142	0.260
117	0.827	0.053	4	0.304	0.083	0.152
H						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.081	5	0.081	0.100	0.166
47	0.859	0.020	4	0.138	0.030	0.055
72	0.759	0.134	4	0.555	0.212	0.390
95	0.929	0.023	4	0.326	0.037	0.067
117	0.962	0.012	4	0.312	0.019	0.034
O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.106	4	0.106	0.168	0.309
47	0.728	0.042	4	0.154	0.067	0.122
72	0.693	0.172	4	0.559	0.273	0.501
95	0.884	0.039	4	0.333	0.061	0.113
117	0.927	0.023	4	0.320	0.037	0.068
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.077	5	0.077	0.095	0.158
47	0.381	0.084	4	0.136	0.129	0.236
72	-0.692	0.939	4	0.555	1.490	2.735
95	0.817	0.059	4	0.325	0.094	0.172
117	0.874	0.038	4	0.305	0.061	0.111

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 6 % O2		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.147	4	0.147	0.234	0.430
47	0.422	0.107	4	0.185	0.170	0.312
72	-0.308	0.744	4	0.569	1.183	2.172
95	0.688	0.109	4	0.349	0.173	0.318
117	0.705	0.094	4	0.320	0.150	0.276
Ash-l						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.053	0.126	4	0.133	0.280	0.647
72	0.119	0.488	4	0.554	1.052	2.426
95	0.157	0.273	4	0.324	0.591	1.363
117	0.102	0.269	4	0.299	0.581	1.341
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.108	6	0.108	0.113	0.177
47	0.031	0.151	5	0.155	0.215	0.395
72	0.161	0.469	4	0.560	0.740	1.359
95	0.095	0.302	4	0.334	0.469	0.860
117	0.050	0.291	4	0.306	0.453	0.831
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.077	5	0.077	0.095	0.158
47	0.381	0.084	4	0.136	0.129	0.236
72	-0.692	0.939	4	0.555	1.490	2.735
95	0.817	0.059	4	0.325	0.094	0.172
117	0.874	0.038	4	0.305	0.061	0.111

Average Initial Mass Percents and Statistics						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 12 % O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	8.130	0.865	3	0.106	2.148	4.955
Al ₂ O ₃	4.417	0.301	3	0.068	0.749	1.727
TiO ₂	0.377	0.041	3	0.110	0.103	0.237
Fe ₂ O ₃	0.825	0.112	3	0.136	0.278	0.641
CaO	2.513	0.546	3	0.217	1.357	3.130
Na ₂ O	0.043	0.016	3	0.371	0.039	0.091
K ₂ O	0.081	0.027	3	0.339	0.068	0.158
MgO	0.457	0.087	3	0.191	0.217	0.500
Σ Oxides	16.843					
C	55.240	1.655	5	0.030	2.054	3.407
H	4.426	0.281	5	0.063	0.349	0.578
O	18.390	1.712	4	0.093	2.724	5.001
N	1.074	0.062	5	0.058	0.077	0.128
S	0.938	0.130	4	0.139	0.207	0.380
Ash-s	19.193	1.829	6	0.095	1.920	3.011
Ash-l	19.910	0.498	3	0.025	1.237	2.852

Residual Total Mass (m/m₀) as a Function of Residence Time						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 12 % O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.46	0.56	0.55	0.58	0.57	0.57
72	0.25	0.39	0.38	0.39	0.40	0.42
95	0.17	0.26	0.24	0.27	0.26	0.27
117	0.11	0.23	0.23	0.25	0.23	0.24

Residual Total Mass (m/m0) with Statistics						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 12 % O₂		
	Mean (mf)	σ	n	Mean (daf)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	1.00	0.000	12	1.00	0.000	0.000
47	0.54	0.053	4	0.44	0.084	0.153
72	0.35	0.068	4	0.23	0.108	0.198
95	0.24	0.046	4	0.08	0.073	0.135
117	0.21	0.065	4	0.04	0.104	0.190

Residual Elemental Mass as a Function of Residence Time						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 12 % O₂		
	SiO₂	TiO₂	Al₂O₃	Fe₂O₃	CaO	Na₂O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.96	0.93	0.97	1.39	0.95	0.82
72	0.90	0.90	0.93	2.62	0.98	0.69
95	0.89	0.88	0.97	2.37	0.93	0.61
117	0.88	0.81	0.91	1.82	0.84	0.49
	K₂O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.82	0.55	0.14	0.23	0.51	0.44
72	0.63	0.24	0.10	0.16	0.18	0.35
95	0.76	0.07	0.03	0.06	0.07	0.19
117	0.75	0.04	0.02	0.04	0.04	0.17

Elemental Mass Release (Normalized) and Statistics						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 12 % O2		
SiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.118	3	0.118	0.292	0.673
47	0.036	0.147	3	0.153	0.343	0.792
72	0.098	0.203	4	0.226	0.453	1.046
95	0.106	0.205	4	0.229	0.456	1.051
117	0.118	0.295	4	0.334	0.642	1.481
Al2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.085	3	0.085	0.210	0.485
47	0.027	0.126	4	0.129	0.287	0.661
72	0.066	0.196	4	0.210	0.431	0.995
95	0.030	0.207	4	0.214	0.455	1.049
117	0.086	0.299	4	0.327	0.647	1.493
TiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.121	3	0.121	0.300	0.691
47	0.073	0.144	3	0.155	0.336	0.776
72	0.097	0.205	4	0.227	0.458	1.056
95	0.121	0.203	4	0.230	0.452	1.042
117	0.192	0.272	4	0.337	0.595	1.372
Fe2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.145	3	0.145	0.359	0.829
47	-0.386	0.242	3	0.175	0.572	1.320
72	-1.624	0.632	4	0.241	1.426	3.288
95	-1.369	0.578	4	0.244	1.301	3.001
117	-0.818	0.647	4	0.356	1.430	3.298

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 12 % O2		
CaO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.223	3	0.223	0.554	1.278
47	0.054	0.230	3	0.244	0.558	1.286
72	0.023	0.288	3	0.295	0.669	1.544
95	0.072	0.276	3	0.297	0.640	1.476
117	0.156	0.323	4	0.383	0.724	1.670
Na2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.374	3	0.374	0.930	2.144
47	0.182	0.316	3	0.387	0.777	1.793
72	0.306	0.292	3	0.421	0.701	1.618
95	0.393	0.256	3	0.423	0.615	1.419
117	0.512	0.251	3	0.516	0.589	1.358
K2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.343	3	0.343	0.852	1.966
47	0.185	0.291	3	0.357	0.714	1.646
72	0.374	0.247	3	0.393	0.589	1.359
95	0.242	0.300	3	0.395	0.716	1.651
117	0.250	0.329	4	0.439	0.756	1.743
MgO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.197	3	0.197	0.490	1.131
47	0.035	0.213	3	0.220	0.512	1.180
72	-0.045	0.288	3	0.276	0.664	1.531
95	0.073	0.258	3	0.278	0.594	1.369
117	0.180	0.305	4	0.372	0.680	1.569

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 12 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	5	0.071	0.088	0.146
47	0.454	0.066	4	0.121	0.101	0.185
72	0.757	0.050	4	0.205	0.078	0.143
95	0.928	0.015	4	0.209	0.024	0.043
117	0.961	0.013	4	0.330	0.020	0.037
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.081	5	0.081	0.100	0.166
47	0.863	0.017	4	0.127	0.026	0.048
72	0.896	0.022	4	0.209	0.034	0.062
95	0.968	0.007	4	0.212	0.011	0.020
117	0.978	0.007	4	0.330	0.012	0.021
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.106	4	0.106	0.168	0.309
47	0.766	0.034	4	0.144	0.054	0.099
72	0.836	0.036	4	0.220	0.057	0.105
95	0.939	0.014	4	0.223	0.022	0.040
117	0.956	0.015	4	0.340	0.024	0.044
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.077	5	0.077	0.095	0.158
47	0.490	0.063	4	0.124	0.096	0.177
72	0.820	0.037	4	0.207	0.059	0.107
95	0.928	0.015	4	0.211	0.024	0.044
117	0.958	0.014	4	0.332	0.022	0.040

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Wilcox Lignite 106-125 μm				PSOC-1443D 12 % O2		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.147	4	0.147	0.234	0.430
47	0.556	0.078	4	0.177	0.125	0.229
72	0.647	0.086	4	0.243	0.136	0.250
95	0.809	0.047	4	0.245	0.075	0.137
117	0.833	0.058	4	0.349	0.093	0.170
Ash-l						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.056	0.114	4	0.121	0.256	0.591
72	0.170	0.170	4	0.205	0.372	0.858
95	0.134	0.181	4	0.209	0.394	0.910
117	0.132	0.281	4	0.323	0.607	1.400
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.108	6	0.108	0.113	0.177
47	0.060	0.137	5	0.145	0.168	0.279
72	0.129	0.192	4	0.221	0.289	0.530
95	0.081	0.206	4	0.224	0.310	0.569
117	0.101	0.298	4	0.332	0.464	0.851
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.077	5	0.077	0.095	0.158
47	0.490	0.063	4	0.124	0.096	0.177
72	0.820	0.037	4	0.207	0.059	0.107
95	0.928	0.015	4	0.211	0.024	0.044
117	0.958	0.014	4	0.332	0.022	0.040

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE TEMPERATURE DISTRIBUTIONS**

Data and Analysis Compilation
for PSOC-1443, Lower Wilcox Lignite

8 mole-% Oxygen
 Environment

12 mole-% Oxygen
 Environment

LOWER WILCOX COAL CHAR

COAL TYPE: LOWER WILCOX COAL, 106 - 125 microns:
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	1	1407.3	0.0	2.38	0.00	0.809	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	1	1593.7	0.0	2.60	0.00	0.664	0.000
1650.0	10	1652.7	13.0	2.63	0.04	0.525	0.220
1700.0	146	1710.3	10.6	2.65	0.03	0.626	0.166
1750.0	74	1737.5	11.6	2.65	0.15	0.518	0.152
1800.0	2	1778.2	3.8	2.68	0.00	0.337	0.035
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 234
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 1.80

COAL TYPE: LOWER WILCOX COAL, 106 - 125 microns:
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	1	1491.8	0.0	2.50	0.00	0.868	0.000
1550.0	5	1558.5	12.8	2.76	0.03	0.556	0.339
1600.0	7	1604.0	11.9	2.77	0.04	0.559	0.129
1650.0	40	1657.0	12.8	2.80	0.03	0.514	0.142
1700.0	143	1701.0	13.0	2.82	0.03	0.507	0.138
1750.0	38	1739.5	11.7	2.84	0.02	0.399	0.237
1800.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 234
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 1.80

COAL TYPE: LOWER WILCOX COAL, 106 - 125 microns:
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1458.7	0.0	3.03	0.00	0.103	0.000
1500.0	11	1510.0	10.2	2.92	0.07	0.517	0.246
1550.0	19	1553.2	15.1	2.92	0.06	0.450	0.170
1600.0	39	1602.9	16.2	2.94	0.05	0.469	0.197
1650.0	79	1652.5	14.2	2.94	0.14	0.468	0.190
1700.0	80	1696.6	14.6	2.98	0.04	0.368	0.120
1750.0	8	1737.0	14.7	2.98	0.06	0.316	0.167
1800.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 237

PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 1.80

COAL TYPE: LOWER WILCOX COAL, 106 - 125 microns:
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	1	1621.5	0.0	2.55	0.00	0.355	0.000
1650.0	4	1645.2	17.6	2.58	0.04	0.515	0.031
1700.0	3	1692.9	9.6	2.57	0.04	0.554	0.108
1750.0	8	1748.9	15.3	2.62	0.04	0.404	0.169
1800.0	14	1797.3	11.2	2.63	0.04	0.534	0.225
1850.0	28	1856.7	12.0	2.61	0.04	0.492	0.183
1900.0	76	1903.8	14.9	2.64	0.04	0.484	0.194
1950.0	76	1946.7	13.5	2.62	0.14	0.419	0.172
2000.0	18	1988.8	9.9	2.66	0.04	0.278	0.113
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 228

PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 1.80

COAL TYPE: LOWER WILCOX COAL, 106 - 125 microns:
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	1	1510.8	0.0	2.71	0.00	0.734	0.000
1550.0	2	1547.8	5.2	2.76	0.02	0.480	0.298
1600.0	10	1606.8	10.1	2.75	0.05	0.278	0.173
1650.0	24	1650.4	15.6	2.78	0.03	0.181	0.145
1700.0	12	1696.2	14.6	2.78	0.02	0.291	0.135
1750.0	30	1751.5	14.2	2.74	0.22	0.317	0.166
1800.0	31	1799.0	17.1	2.79	0.03	0.266	0.165
1850.0	34	1850.1	15.3	2.76	0.19	0.325	0.233
1900.0	34	1903.1	15.0	2.72	0.31	0.362	0.200
1950.0	20	1945.0	10.4	2.81	0.04	0.227	0.128
2000.0	4	1999.6	13.4	2.76	0.05	0.127	0.124
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 202

PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 1.80

COAL TYPE: LOWER WILCOX COAL, 106 - 125 microns:
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1458.6	0.0	2.93	0.00	0.373	0.000
1500.0	22	1505.4	12.7	2.90	0.06	0.283	0.180
1550.0	75	1552.0	13.4	2.91	0.14	0.205	0.138
1600.0	60	1600.2	13.6	2.92	0.03	0.208	0.173
1650.0	37	1646.7	15.0	2.89	0.20	0.177	0.160
1700.0	19	1700.0	12.2	2.94	0.03	0.213	0.156
1750.0	17	1744.1	13.7	2.95	0.03	0.215	0.113
1800.0	19	1797.7	13.2	2.92	0.07	0.251	0.138
1850.0	11	1845.0	17.1	2.92	0.06	0.252	0.139
1900.0	5	1892.7	9.5	2.95	0.01	0.242	0.117
1950.0	2	1934.8	11.5	2.98	0.03	0.183	0.026
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 268

PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 1.80

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE SIZES, TEMPERATURES, AND VELOCITIES**

Data and Analysis Compilation
for PSOC-1443, Lower Wilcox Lignite

COAL TYPE: LOWER WILCOX, PSOC-1443: 106-125 microns
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
50.0	0	0.0	0.0	0.00	0.00	0.000	0.000
60.0	0	0.0	0.0	0.00	0.00	0.000	0.000
70.0	0	0.0	0.0	0.00	0.00	0.000	0.000
80.0	4	1731.3	24.9	2.67	0.01	0.780	0.253
90.0	16	1729.8	19.4	2.67	0.02	0.707	0.205
100.0	44	1721.9	21.7	2.67	0.02	0.625	0.192
110.0	54	1715.4	23.6	2.66	0.03	0.632	0.155
120.0	63	1715.9	25.7	2.66	0.03	0.563	0.139
130.0	29	1707.5	22.0	2.65	0.03	0.485	0.104
140.0	11	1684.9	88.8	2.63	0.08	0.526	0.121
150.0	3	1689.7	6.7	2.62	0.03	0.560	0.062
160.0	7	1708.7	16.1	2.53	0.26	0.424	0.091
170.0	2	1715.0	11.5	2.62	0.02	0.447	0.178
180.0	0	0.0	0.0	0.00	0.00	0.000	0.000
190.0	0	0.0	0.0	0.00	0.00	0.000	0.000
200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
210.0	1	1746.4	0.0	1.68	0.00	0.126	0.000
220.0	0	0.0	0.0	0.00	0.00	0.000	0.000
230.0	0	0.0	0.0	0.00	0.00	0.000	0.000
240.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 234
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: LOWER WILCOX, PSOC-1443: 106-125 microns
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

SIZE (micron)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
50.0	1	1727.5	0.0	2.80	0.00	1.688	0.000
60.0	0	0.0	0.0	0.00	0.00	0.000	0.000
70.0	0	0.0	0.0	0.00	0.00	0.000	0.000
80.0	6	1722.3	16.0	2.83	0.03	0.432	0.172
90.0	33	1706.7	41.3	2.84	0.03	0.469	0.192
100.0	50	1709.2	27.3	2.83	0.02	0.522	0.163
110.0	58	1693.2	36.1	2.82	0.04	0.500	0.142
120.0	42	1684.2	34.0	2.81	0.03	0.487	0.142
130.0	22	1677.7	30.3	2.80	0.03	0.501	0.109
140.0	8	1693.3	21.0	2.81	0.02	0.448	0.062
150.0	6	1659.4	21.7	2.82	0.03	0.427	0.060
160.0	4	1647.1	50.8	2.79	0.03	0.368	0.102
170.0	2	1649.6	7.2	2.77	0.04	0.334	0.074
180.0	0	0.0	0.0	0.00	0.00	0.000	0.000
190.0	2	1526.7	49.3	2.63	0.19	0.608	0.368
200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
210.0	0	0.0	0.0	0.00	0.00	0.000	0.000
220.0	0	0.0	0.0	0.00	0.00	0.000	0.000
230.0	0	0.0	0.0	0.00	0.00	0.000	0.000
240.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 234
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: LOWER WILCOX, PSOC-1443: 106-125 microns
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
50.0	2	1642.1	70.2	2.93	0.00	1.148	1.073
60.0	0	0.0	0.0	0.00	0.00	0.000	0.000
70.0	1	1693.2	0.0	2.96	0.00	0.589	0.000
80.0	10	1639.0	73.5	2.99	0.05	0.303	0.187
90.0	62	1658.3	59.2	2.97	0.04	0.438	0.210
100.0	67	1646.9	60.7	2.96	0.05	0.441	0.181
110.0	46	1649.7	50.1	2.94	0.05	0.422	0.144
120.0	25	1635.5	54.7	2.93	0.04	0.464	0.164
130.0	13	1632.4	43.8	2.94	0.05	0.424	0.128
140.0	3	1639.6	0.0	2.94	0.05	0.549	0.042
150.0	4	1600.9	51.4	2.93	0.06	0.348	0.128
160.0	4	1598.3	54.6	2.61	0.49	0.306	0.106
170.0	1	1713.5	0.0	3.00	0.00	0.033	0.000
180.0	0	0.0	0.0	0.00	0.00	0.000	0.000
190.0	0	0.0	0.0	0.00	0.00	0.000	0.000
200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
210.0	0	0.0	0.0	0.00	0.00	0.000	0.000
220.0	0	0.0	0.0	0.00	0.00	0.000	0.000
230.0	0	0.0	0.0	0.00	0.00	0.000	0.000
240.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 238
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: LOWER WILCOX, PSOC-1443: 106-125 microns
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
50.0	0	0.0	0.0	0.00	0.00	0.000	0.000
60.0	1	1974.4	0.0	2.68	0.00	0.537	0.000
70.0	10	1954.3	28.9	2.66	0.03	0.564	0.175
80.0	15	1893.7	62.6	2.64	0.03	0.473	0.141
90.0	45	1915.5	65.9	2.64	0.04	0.447	0.181
100.0	76	1898.0	70.8	2.63	0.04	0.468	0.199
110.0	37	1899.7	62.9	2.63	0.03	0.409	0.171
120.0	22	1864.3	86.3	2.62	0.05	0.479	0.179
130.0	10	1863.1	84.0	2.62	0.05	0.430	0.173
140.0	5	1840.9	113.0	2.61	0.05	0.366	0.102
150.0	3	1918.5	14.1	2.67	0.07	0.085	0.054
160.0	1	1897.8	0.0	2.74	0.00	0.016	0.000
170.0	1	1895.6	0.0	2.55	0.00	0.486	0.000
180.0	0	0.0	0.0	0.00	0.00	0.000	0.000
190.0	0	0.0	0.0	0.00	0.00	0.000	0.000
200.0	1	1946.4	0.0	1.47	0.00	0.176	0.000
210.0	0	0.0	0.0	0.00	0.00	0.000	0.000
220.0	0	0.0	0.0	0.00	0.00	0.000	0.000
230.0	1	1857.0	0.0	2.55	0.00	0.428	0.000
240.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 228
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: LOWER WILCOX, PSOC-1443: 106-125 microns
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.05 cm

SIZE (micron)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
50.0	0	0.0	0.0	0.00	0.00	0.000	0.000
60.0	1	1914.8	0.0	2.89	0.00	0.169	0.000
70.0	2	1757.8	211.2	2.82	0.02	0.463	0.262
80.0	8	1856.4	85.7	2.82	0.04	0.368	0.177
90.0	31	1821.7	97.0	2.80	0.03	0.355	0.186
100.0	56	1783.5	108.3	2.79	0.03	0.296	0.220
110.0	38	1793.1	114.7	2.78	0.03	0.311	0.157
120.0	27	1779.5	104.0	2.78	0.04	0.227	0.117
130.0	11	1757.0	105.8	2.76	0.04	0.355	0.187
140.0	6	1807.0	84.5	2.60	0.40	0.239	0.148
150.0	8	1808.2	82.8	2.81	0.03	0.148	0.177
160.0	3	1854.4	83.1	2.80	0.06	0.047	0.002
170.0	3	1860.4	109.8	2.38	0.56	0.163	0.095
180.0	4	1867.8	76.7	2.46	0.65	0.166	0.148
190.0	0	0.0	0.0	0.00	0.00	0.000	0.000
200.0	1	2019.1	0.0	2.68	0.00	0.000	0.000
210.0	0	0.0	0.0	0.00	0.00	0.000	0.000
220.0	1	1877.2	0.0	2.80	0.00	0.021	0.000
230.0	1	1893.3	0.0	1.63	0.00	0.076	0.000
240.0	1	1605.2	0.0	2.68	0.00	0.016	0.000

NUMBER OF PARTICLES = 202

PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: LOWER WILCOX, PSOC-1443: 106-125 microns
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
50.0	0	0.0	0.0	0.00	0.00	0.000	0.000
60.0	0	0.0	0.0	0.00	0.00	0.000	0.000
70.0	4	1687.7	54.5	2.93	0.04	0.096	0.080
80.0	9	1708.7	102.6	2.96	0.03	0.273	0.103
90.0	38	1619.7	78.1	2.93	0.04	0.231	0.179
100.0	71	1650.1	112.7	2.94	0.03	0.212	0.159
110.0	61	1628.6	97.8	2.91	0.16	0.208	0.144
120.0	42	1628.1	108.9	2.92	0.04	0.223	0.154
130.0	28	1587.9	79.8	2.90	0.05	0.217	0.151
140.0	5	1658.4	77.7	2.90	0.03	0.216	0.132
150.0	6	1629.4	119.0	2.90	0.04	0.235	0.165
160.0	0	0.0	0.0	0.00	0.00	0.000	0.000
170.0	1	1549.8	0.0	1.76	0.00	0.081	0.000
180.0	1	1496.1	0.0	2.74	0.00	0.294	0.000
190.0	0	0.0	0.0	0.00	0.00	0.000	0.000
200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
210.0	0	0.0	0.0	0.00	0.00	0.000	0.000
220.0	1	1792.7	0.0	2.63	0.00	0.068	0.000
230.0	0	0.0	0.0	0.00	0.00	0.000	0.000
240.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 267

PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**KINETIC ANALYSIS
AND COMBUSTION PARAMETERS**

Data and Analysis Compilation
for PSOC-1443, Lower Wilcox Lignite

Summary of Combustion Parameters for PSOC-1443D			
Char oxidation rate parameters $q = A \exp(-E/RT_p) P^n$	A E n	44 21.9 0.5 *	gm-C / cm²-s-atmⁿ kcal / mole
Product ratio parameters $CO/CO_2 = A_c \exp(-E_c/RT_p)$	A_c E_c	5 x 10⁸ * 60 *	 kcal / mole
Burning mode parameter $\rho/\rho_o = (m/m_o)^\alpha$ $d/d_o = (m/m_o)^{(1-\alpha)/3}$	α	0.1	
Char structural parameters $\omega = d_o / d_c$ (linear swelling factor) $\rho_{c,o} \equiv m_c/V_c$ at $z = 6.5$ cm (initial char particle carbon density)	ω ρ_{c,o}	0.92 0.68	 gm / cm³
<p>As an example, this parameter set yields a combustion rate, q, of 0.0050 gm/sq.cm-sec for a 100 μm particle in a gas with $T_g = 1600$ K containing 6 mole-% oxygen</p> <p>These product ratio parameters yield 3 mole-% carbon dioxide at 1900 K and 17 mole-% carbon dioxide at 1700 K</p> <p>* These particular parameters should be regarded as empirical parameters, useful for the prediction of burning rates. They do not necessarily have fundamental significance and/or are not necessarily unique for this data set.</p>

Heat-up and
Devolatilization

Char Oxidation

Measured Carbon Conversions in the CCL for PSOC-1443
and Predictions for Combustion in 12-mole% Oxygen

**CALCULATIONS OF THE COAL CHAR REACTIVITY INDEX, τ_{50} ,
FOR VARIOUS ENVIRONMENTS
PRESENT IN PULVERIZED-COAL COMBUSTION SYSTEMS**

Data and Analysis Compilation
for PSOC-1443, Lower Wilcox Lignite

Compilation of Data and Kinetic Analyses for
Blue #1 Sub-bituminous Coal
(New Mexico)
PSOC-1445D

TABLE OF CONTENTS

- **Sample history, geologic information and chemical analysis of bulk, raw coal**
- **Chemical analysis of size-fractionated raw coal and partially reacted chars**
- **Time resolved measurements of the partitioning of elemental coal constituents between the gas and solid phases**
- **Mode of particle burning**
- **Statistical analyses of elemental composition measurements and derived quantities**
- **Optical measurements of single-particle temperature distributions**
- **Optical measurements of single-particle sizes, temperatures, and velocities**
- **Kinetic analysis and combustion parameters**
- **Calculations of the coal char reactivity index, τ_{50} , for various environments present in pulverized-coal combustion systems**

**SAMPLE HISTORY, GEOLOGIC INFORMATION AND
CHEMICAL ANALYSIS OF BULK, RAW COAL**

Data and Analysis Compilation
for PSOC-1445, Blue #1 Coal

SAMPLE HISTORY

PENN STATE NUMBER	PSOC-1445
COLLECTED BY	PENNSYLVANIA STATE UNIVERSITY
COLLECTION DATE	4/2/85
COLLECTOR'S NUMBER	
REPORTED RANK	SUBBITUMINOUS
SAMPLE TYPE	CHANNEL WHOLE SEAM
OTHER SAMPLE INFORMATION	REPRESENTS BOTH UPPER & LOWER BLUE
SAMPLE RESERVE	900
SEAM NAME	BLUE #1
ALTERNATE SEAM NAME	
TOTAL SEAM THICKNESS	0 FT. 51 IN.
THICKNESS OF SEAM SAMPLED	0 FT. 51 IN.
PORTION RECOVERED IN CORE	
DIAMETER OF CORE	

SAMPLE LOCATION

COUNTRY	U.S.A.
STATE	NEW MEXICO
COUNTY	MCKINLEY
TOWNSHIP	
NEAREST TOWN	WINDOW ROCK
COAL PROVINCE	ROCKY MOUNTAIN
COAL REGION	SAN JUAN RIVER
COAL FIELD	

GEOLOGIC INFORMATION

SYSTEM (AGE)	CRETACEOUS
SERIES	
GROUP	MESAVERDE
FORMATION	GALLUP SANDSTONE
OVERBURDEN LITHOLOGY	SHALE
FLOOR LITHOLOGY	SHALE

SEAM STRATA INFORMATION

<u>THICKNESS</u>	<u>LITHOTYPE</u>
------------------	------------------

SEAM NAME	BLUE #1	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	NEW MEXICO

CHEMICAL DATA 1

PROXIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF (PAFF)	DMMF (PARR-G)	DMMF (DIR MM)
% MOISTURE	12.22					
% ASH	4.04	4.60				
% VOLATILE MATTER	40.33	45.95	48.17	47.86	47.87	
% FIXED CARBON	43.41	49.45	51.83	52.14	52.13	

CALORIFIC VALUE (GROSS BTU/LB)	DRY	AS REC'D MOIST.	EQUIL MOIST.
MM-FREE, DIRECT			
MM-CONTAINING	13179	11569	11435
MM-FREE (PARR)	13888	12107	11961
MM-FREE (MOD.P)	13906	12096	11950
BEST MM FREE		12096	11950
NET CV, DMMF BTU/LB	11379		
ASH-FREE	13814		

MOTT-SPOONER DIFFERENCE = 565.

ASSOCIATED ANALYSES	DRY	MMF
% EQUILIBRIUM MOISTURE	13.23	13.98
% TOTAL SULFUR	0.72	

RANK CALCULATIONS

APPARENT RANK (AS REC'D MOIST)	HIGH VOLATILE C BITUMINOUS (HVCB)
ASTM RANK (EQUIL. MOIST.)	HIGH VOLATILE C BITUMINOUS (HVCB)
REFLECTANCE RANK CATEGORY	HIGH VOLATILE C BITUMINOUS (HVCB)
INTERNATIONAL RANK	
AS REC'D MOIST.	
EQUIL. MOIST	
REPORTED RANK	SUBBITUMINOUS

SEAM NAME	BLUE #1	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	NEW MEXICO

CHEMICAL DATA 2

<u>ULTIMATE ANALYSIS</u>	<u>AS REC'D</u>	<u>DRY</u>	<u>DAF</u>	<u>DMMF(PARR)</u> (5.36 % MM)
% ASH	4.04	4.60		
% CARBON	62.78	71.52	74.97	75.57
% HYDROGEN	*4.72	5.38	5.64	5.68
% NITROGEN	1.18	1.34	1.40	1.42
% SULFUR	0.63	0.72	0.75	
% CHLORINE	0.03	0.03	0.03	0.03
% OXYGEN (DIFF)	*14.40	16.41	17.20	17.30

<u>SULFUR FORMS</u>	<u>% PYRITIC</u>	<u>% SULFATIC</u>	<u>% ORGANIC</u>	<u>% TOTAL</u>
DRY	0.16	0.01	0.55	0.72
DAF	0.17	0.01	0.58	0.75
OPTICAL				

<u>ELEMENTAL ANALYSIS</u>	<u>DRY</u>	<u>DMMF (MOD.P)</u> (5.29 % MM)	<u>DMMF(DIR.)</u> (% MM)
% CARBON	71.42	75.41	
% HYDROGEN	5.35	5.65	
% NITROGEN	1.34	1.42	
% ORGANIC SULFUR	0.55	0.58	
% OXYGEN (DIFF)	16.05	16.91	
% CHLORINE	0.03	0.03	
% MINERAL MATTER (INCLUDES 0.30 % FES2)	5.29		

<u>ATOM RATIOS (DMMF)</u>	<u>PARR</u>	<u>MOD.PAR</u>	<u>DIRECT</u>
ATOMIC H/C	0.904	0.900	
ATOMIC O/C	0.172	0.178	

<u>MISC. CHEMICAL DATA</u>	<u>DRY</u>	<u>OF DMMF COAL</u>	<u>OF DMMF OXYGEN</u>
% O AS COOH			
% O AS OH			
% S AS SO4, IN ASH			
% CARBONATE AS CO2	0.35		
% CHLORINE	0.06		

INFRA-RED ANALYSIS

(*)- EXCLUDES MOISTURE

SEAM NAME	BLUE #1	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	NEW MEXICO

CHEMICAL DATA 3

% MOISTURE IN COAL = 9.25
 % HIGH TEMPERATURE ASH = 3.62 AT 750 DEGREES C

TRACE ELEMENT ANALYSIS	PPM HTA	PPM TOTAL COAL	MAJOR ELEMENT ANALYSIS	OXIDE % OF HTA	ELEMENT % OF TOTAL DRY COAL
AG			SI02	48.60	0.82
B			AL203	23.50	0.45
BA	2880	104	TI02	1.12	0.02
BE	53	2	FE203	9.90	0.25
BI			MG0	1.19	0.03
CE			CA0	6.03	0.16
CO			NA20	0.24	0.01
CR	85	3	K20	0.50	0.02
CU	140	5	P205	0.17	0.00
GA			S03	6.00	0.09
GE					
LA					
LI					
MN	1060	38			
MO			<u>VOLATILES</u>		<u>PPM TOTAL COAL</u>
NI	100	4			
NB			AS		
PB			BR		
RB	25	1	CD		
SC			CL		
SN			F		
SR	930	34	HG		
TH			SB		
U			SE		
V	140	5			
Y					
YB					
ZN	570	21			
ZR	290	10			

SEAM NAME	BLUE #1	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	NEW MEXICO

MINERALOGICAL DATA

TOTAL MINERAL MATTER

% MM-PARR	5.36
% MM-MODIFIED PARR	5.29
% MM-KMC	
% MM-DIRECT	
% MM-BEST AVAILABLE	5.29
VOL % MM-PARR	2.66

MINERAL COMPOSITION

NONE

SEAM NAME	BLUE #1	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	NEW MEXICO

PETROGRAPHIC DATA

MACERAL COMPOSITION WHITE ANALYSIS ONLY

	<u>DRY VOLUME %</u>	<u>DMMF VOLUME %</u>
HUMINITE	80.9	83.1
INERTINITE	12.8	13.2
LIPTINITE	3.6	3.7
MINERAL MATTER (CALC.)	2.7	
TEXTINITE	0.0	0.0
ULMINITE	77.9	80.0
ATTRINITE		
DENSINITE		
HUMODETRINITE(ANAL)	0.4	0.4
GELINITE	1.3	1.3
CORPOHUMINITE	1.4	1.4
SPORINITE		
CUTINITE		
EXINTITE(ANAL.)	2.4	2.5
RESINITE	1.2	1.2
SUBERINITE	0.0	0.0
EXUDATINITE	0.0	0.0
FLUORINITE	0.0	0.0
BITUMINITE	0.0	0.0
ALGINITE	0.0	0.0
LIPTODETRINITE	0.0	0.0
FUSINITE	2.4	2.5
SEMI-FUSINITE	6.5	6.7
MACRINITE	3.8	3.9
MICRINITE	0.0	0.0
SCLEROTINITE	0.1	0.1
INERTODETRINITE	0.0	0.0
MINERAL MATTER(ANAL.)		
HUMINITE(ANAL.)		
INERTINITE(ANAL.)		
LIPTINITE(ANAL.)		

<u>REFLECTANCE DATA</u>	<u>HIGH</u>	<u>LOW</u>	<u>RANGE</u>	<u>MEAN MAX</u>	<u>STAND.DEV.</u>
(% IN OIL)					
ULMINITE	0.69	0.45	0.24	0.57	0.05

SEAM NAME	BLUE #1	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	NEW MEXICO

PETROGRAPHIC DATA

CONTINUED

<u>% VITRINOID REFLECTANCE</u>	<u>HALF-TYPE</u>	<u>VOLUME PERCENT</u>	<u>% VITRINOID REFLECTANCE</u>	<u>V-TYPE</u>	<u>VOLUME PERCENT</u>
0.40-0.44	VHT 0.425	0.00			
0.45-0.49	VHT 0.475	8.00	0.50-0.59	V4	8.00
0.50-0.54	VHT 0.525	33.00			
0.55-0.59	VHT 0.575	34.00	0.50-0.59	V5	67.00
0.60-0.64	VHT 0.625	24.00			
0.65-0.69	VHT 0.675	1.00	0.60-0.69	V6	25.00

PHYSICAL PROPERTIES

HARDGROVE GRINDABILITY	38.8
VICKER'S MICROHARDNESS	
FREE SWELLING INDEX	0.0
GRAY KING COKE TYPE	

<u>ASH FUSION ANALYSIS (DEGREES F)</u>	<u>REDUCING</u>	<u>OXIDIZING</u>
INITIAL DEFORMATION TEMPERATURE	2305	2535
SOFTENING TEMPERATURE	2395	2580
HEMISPHERE TEMPERATURE	2525	2630
FLUID TEMPERATURE	2680	2655

ANALYSIS LOG

<u>ANALYSIS</u>	<u>DATE</u>	<u>PERFORMED BY</u>
A.R. MOIST	6/4/85	WARNER LABORATORIES
EQUIL. MOIST.	6/4/85	WARNER LABORATORIES
PROXIMATE	6/4/85	WARNER LABORATORIES
ULTIMATE	6/4/85	WARNER LABORATORIES
SULFUR FORMS	6/4/85	WARNER LABORATORIES
FSI	8/15/85	COAL PETROGRAPHY LABORATORIES-PSU
PLASTOMETER		
DIRECT MM		
GRAY-KING		

**CHEMICAL ANALYSES OF SIZE-FRACTIONATED RAW COAL
AND PARTIALLY REACTED CHARs**

Data and Analysis Compilation
for PSOC-1445, Blue #1 Coal

**Organic Elemental Analysis and Percent Ash of Blue #1 Coal and its
Partially Reacted Chars**

Initial particle size range, 75 - 106 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	74.24	5.19	14.92	1.85	0.66	3.16
6.4	85.04	0.62	4.32	1.39	0.89	8.30
12.7	82.20	0.74	3.48	1.21	1.04	11.63
19.1	72.30	0.95	4.30	1.09	1.17	21.24
25.4	58.60	0.64	4.53	0.83	1.43	34.44

12 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	74.24	5.19	14.92	1.85	0.66	3.16
6.4	84.46	0.64	1.87	1.25	1.06	9.46
12.7	76.68	0.32	2.99	0.86	0.62	19.88
19.1	60.85	0.41	4.76	0.74	1.56	32.62
25.4	45.48	0.69	5.35	0.76	1.49	48.08

* Data taken in September 1988

**Organic Elemental Analysis and Percent Ash of Blue #1 Coal and its
Partially Reacted Chars**

Initial particle size range, 106 - 125 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%S	%-Ash
0.0	74.49	5.25	13.80	1.36	0.68	3.53
6.4	77.28	2.28	6.02	1.48	0.56	10.12
12.7	85.60	0.58	0.35	1.38	0.19	10.49
19.1	82.37	0.54	0.48	1.08	0.24	10.38
25.4	79.89	0.80	2.07	1.08	0.51	11.77

12 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%S	%-Ash
0.0	74.42	5.33	14.76	1.29	0.69	3.38
6.4	80.53	2.16	7.70	1.41	0.80	7.38
12.7	82.55	0.45	1.88	0.97	1.06	13.49
19.1	71.98	0.95	7.61	1.07	1.19	19.33
19.1	58.93	0.81	5.57	0.70	1.29	31.12
25.4	36.36	0.39	4.65	0.36	1.30	55.17

* Data taken in January 1988

**Ash Content of Blue #1 Coal
and its Partially Reacted Chars**

Initial particle size range, 75 - 106 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	1.33	0.707	0.048	0.26	0.204	0.047	<0.05	<0.01
6.4	3.51	1.87	0.127	0.787	0.528	0.129	<0.05	0.024
12.7	4.78	2.61	0.183	1.14	0.661	0.174	<0.05	0.021
19.1	9.32	5.18	0.342	1.87	1.25	0.294	<0.05	0.026
25.4	14.5	7.94	0.501	4.12	1.98	0.471	<0.05	0.061

12 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	1.40	0.717	0.049	0.294	0.144	0.41	<0.05	0.035
6.4	4.01	2.15	0.144	0.871	0.517	0.130	<0.05	0.024
12.7	9.52	4.96	0.307	1.67	1.07	0.226	<0.05	<0.01
19.1	14.3	7.67	0.429	3.69	1.75	0.386	0.052	0.055
25.4	22.1	12.5	0.767	3.71	2.96	0.612	0.102	<0.01

* Data taken in September 1988

**Ash Content of Blue #1 Coal
and its Partially Reacted Chars**

Initial particle size range, 106 - 125 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	1.77	0.921	0.052	0.329	0.278	0.104	<0.05	0.014
6.4	3.15	1.64	0.096	0.797	0.259	0.003	<0.05	0.03
12.7	4.50	2.23	0.138	1.44	1.15	0.310	0.063	0.063
19.1	4.51	2.71	0.166	0.834	0.695	0.220	0.080	0.05
25.4	4.89	3.03	0.179	1.36	1.05	0.070	0.065	0.092

12 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	1.30	0.605	0.036	0.203	0.162	0.038	0.075	<0.01
6.4	3.28	1.49	0.097	0.645	0.499	0.136	0.092	0.021
12.7	6.16	2.85	0.160	0.87	0.828	0.184	0.098	<0.01
19.1	9.72	4.66	0.279	1.62	1.57	0.337	0.098	<0.01
19.1	15.0	7.01	0.392	3.56	2.61	1.20	0.166	<0.01
25.4	25.6	12.6	0.732	5.82	4.14	0.200	0.172	<0.01

* Data taken in January 1988

**TIME RESOLVED MEASUREMENTS OF THE
PARTITIONING OF ELEMENTAL COAL CONSTITUENTS
BETWEEN THE GAS AND SOLID PHASES**

Data and Analysis Compilation
for PSOC-1445, Blue #1 Coal

MODE OF PARTICLE BURNING

Data and Analysis Compilation
for PSOC-1445, Blue #1 Coal

**Fractional Mass Remaining and Apparent Density
of Blue #1 Coal and its Partially Reacted Chars**

Initial particle size range: 75 - 106 μm

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.38	0.28	0.14	0.08
Fractional burnoff, daf	0.0	0.65	0.75	0.90	0.96
Apparent density, g/cc	1.12	0.26	0.25	0.21	0.24

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.32	0.14	0.10	0.06
Fractional burnoff, daf	0.0	0.71	0.90	0.94	0.99
Apparent density, g/cc	1.12	0.30	0.27	0.29	0.36

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.49	0.35	0.30	0.27
Fractional burnoff, daf	0.0	0.53	0.68	0.73	0.77
Apparent density, g/cc	1.12	0.35	0.34	0.32	0.29

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.49	0.26	0.13	0.06
Fractional burnoff, daf	0.0	0.53	0.78	0.91	0.99
Apparent density, g/cc	1.12	0.35	0.32	0.30	0.55

**STATISTICAL ANALYSES
OF ELEMENTAL COMPOSITION MEASUREMENTS
AND DERIVED QUANTITIES**

- **Raw Coal Composition**
- **Overall Combustion Conversion vs. Residence Time**
- **Elemental Partitioning between Gas and Solid Phases**

Data and Analysis Compilation
for PSOC-1445, Blue #1 Coal

Average Initial Mass Percents and Statistics						
	Blue #1 subbituminous 106-125 μm			PSOC-1445d 6 % O ₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	1.624	0.175	8	0.108	0.146	0.217
Al ₂ O ₃	0.818	0.109	8	0.133	0.091	0.134
TiO ₂	0.046	0.006	8	0.137	0.005	0.008
Fe ₂ O ₃	0.281	0.043	8	0.153	0.036	0.053
CaO	0.185	0.068	8	0.364	0.056	0.084
Na ₂ O	0.012	0.007	8	0.634	0.006	0.009
K ₂ O	0.013	0.027	8	2.138	0.022	0.033
MgO	0.039	0.045	8	1.162	0.038	0.056
Σ Oxides	3.017					
C	73.860	1.847	6	0.025	1.938	3.039
H	5.255	0.140	6	0.027	0.147	0.230
O	15.490	1.484	8	0.096	1.241	1.835
N	1.301	0.034	7	0.026	0.031	0.047
S	0.603	0.105	6	0.174	0.110	0.173
Ash-s	3.463	0.496	7	0.143	0.459	0.695
Ash-l	3.429	0.239	7	0.070	0.221	0.335

Residual Total Mass (m/m ₀) as a Function of Residence Time						
	Blue #1 subbituminous 106-125 μm			PSOC-1445d 6 % O ₂		
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.46	0.52	0.50	0.48	0.34	0.42
72	0.35	0.36	0.37	0.34	0.33	0.35
95	0.28	0.36	0.30	0.28	0.37	0.33
117	0.24	0.33	0.27	0.26	0.28	0.29

Residual Total Mass (m/m0) with Statistics						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 6 % O₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	26	1.00	0.000	0.000
47	0.49	0.028	3	0.46	0.069	0.160
72	0.36	0.007	3	0.34	0.017	0.039
95	0.31	0.041	3	0.29	0.103	0.237
117	0.28	0.047	3	0.26	0.118	0.272

Residual Elemental Mass as a Function of Residence Time						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 6 % O₂		
	SiO₂	TiO₂	Al₂O₃	Fe₂O₃	CaO	Na₂O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.95	1.02	0.99	1.40	0.69	1.27
72	1.00	1.07	0.98	1.85	2.24	1.95
95	0.87	1.12	1.04	0.93	1.18	1.35
117	0.84	1.08	1.04	1.36	1.59	2.22
	K₂O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.00	0.51	0.21	0.19	0.56	0.46
72	1.82	0.42	0.04	0.01	0.38	0.11
95	2.01	0.35	0.03	0.01	0.26	0.12
117	1.46	0.30	0.04	0.04	0.23	0.23

Elemental Mass Release (Normalized) and Statistics						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 6 % O2		
SiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.119	8	0.119	0.099	0.147
47	0.046	0.126	7	0.132	0.116	0.175
72	0.002	0.120	8	0.120	0.105	0.159
95	0.128	0.155	5	0.178	0.188	0.311
117	0.156	0.171	5	0.202	0.256	0.470
Al2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.142	8	0.142	0.119	0.176
47	0.014	0.151	7	0.153	0.136	0.207
72	0.018	0.141	8	0.143	0.122	0.186
95	-0.040	0.202	6	0.194	0.235	0.389
117	-0.039	0.221	5	0.213	0.320	0.587
TiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.146	8	0.146	0.122	0.180
47	-0.018	0.159	7	0.156	0.144	0.218
72	-0.072	0.157	8	0.147	0.137	0.207
95	-0.124	0.221	6	0.196	0.256	0.424
117	-0.082	0.235	5	0.217	0.335	0.616
Fe2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.161	8	0.161	0.135	0.199
47	-0.395	0.238	7	0.171	0.213	0.323
72	-0.846	0.299	8	0.162	0.260	0.394
95	0.068	0.194	6	0.208	0.220	0.365
117	-0.357	0.271	4	0.200	0.410	0.753

Elemental Mass Release (Normalized) and Statistics (con't)						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 6 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.368	8	0.368	0.308	0.455
47	0.313	0.256	8	0.372	0.223	0.338
72	-1.236	0.824	8	0.368	0.713	1.080
95	-0.178	0.460	7	0.391	0.413	0.626
117	-0.589	0.475	6	0.299	0.483	0.757
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.636	8	0.636	0.532	0.786
47	-0.269	0.810	8	0.638	0.702	1.064
72	-0.952	1.241	8	0.636	1.074	1.627
95	-0.350	0.877	8	0.649	0.768	1.164
117	-1.218	0.858	7	0.387	0.791	1.199
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	2.139	8	2.139	1.788	2.646
47	1.000	0.000	#NUM!	#NUM!	#NUM!	#NUM!
72	-0.815	3.882	8	2.139	3.359	5.088
95	-1.009	4.305	8	2.143	3.729	5.649
117	-0.458	3.844	8	2.637	3.330	5.045
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	1.163	8	1.163	0.973	1.439
47	0.962	0.044	8	1.165	0.038	0.058
72	-1.872	3.341	8	1.163	2.891	4.380
95	-0.776	2.080	8	1.171	1.806	2.737
117	0.495	1.846	8	3.657	1.598	2.421

Elemental Mass Release (Normalized) and Statistics (con't)						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 6 % O2		
C						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	6	0.071	0.074	0.116
47	0.486	0.047	5	0.091	0.068	0.124
72	0.583	0.031	6	0.073	0.035	0.058
95	0.650	0.052	4	0.150	0.118	0.271
117	0.697	0.056	3	0.184	0.129	0.297
H						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	6	0.071	0.074	0.116
47	0.787	0.019	5	0.091	0.028	0.051
72	0.960	0.003	6	0.073	0.003	0.006
95	0.968	0.005	4	0.150	0.011	0.025
117	0.957	0.008	3	0.179	0.018	0.042
O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.108	8	0.108	0.090	0.134
47	0.809	0.023	7	0.122	0.023	0.036
72	0.992	0.001	8	0.110	0.001	0.001
95	0.990	0.002	5	0.170	0.002	0.003
117	0.963	0.007	3	0.178	0.015	0.035
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	7	0.071	0.065	0.099
47	0.441	0.051	5	0.091	0.060	0.100
72	0.618	0.028	7	0.073	0.028	0.043
95	0.741	0.039	4	0.150	0.085	0.195
117	0.767	0.043	4	0.183	0.097	0.223

Elemental Mass Release (Normalized) and Statistics (con't)						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 6 % O2		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.181	6	0.181	0.190	0.298
47	0.544	0.086	6	0.189	0.100	0.166
72	0.887	0.021	6	0.182	0.023	0.039
95	0.878	0.027	5	0.224	0.039	0.072
117	0.765	0.046	4	0.194	0.102	0.234
Ash-l						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.086	7	0.086	0.079	0.120
47	-0.172	0.120	6	0.103	0.139	0.231
72	-0.026	0.090	7	0.088	0.089	0.139
95	0.050	0.149	4	0.157	0.232	0.426
117	0.038	0.180	4	0.187	0.401	0.924
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.152	7	0.152	0.140	0.213
47	-0.437	0.233	7	0.162	0.235	0.368
72	-0.091	0.167	7	0.153	0.163	0.255
95	0.145	0.172	5	0.201	0.208	0.344
117	-0.016	0.210	4	0.207	0.321	0.590
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	7	0.071	0.065	0.099
47	0.441	0.051	5	0.091	0.060	0.100
72	0.618	0.028	7	0.073	0.028	0.043
95	0.741	0.039	4	0.150	0.085	0.195
117	0.767	0.043	4	0.183	0.097	0.223

Average Initial Mass Percents and Statistics						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 6 % O ₂		
	Mean (mf)	σ	n	σ/μ	δ +/- 95 %	δ +/- 99 %
SiO ₂	1.365	0.049	2	0.036	0.445	2.228
Al ₂ O ₃	0.712	0.018	2	0.025	0.160	0.801
TiO ₂	0.049	0.001	2	0.025	0.011	0.055
Fe ₂ O ₃	0.277	0.024	2	0.087	0.216	1.082
CaO	0.174	0.042	2	0.244	0.381	1.910
Na ₂ O	0.018	0.025	2	1.414	0.222	1.114
K ₂ O	0.000	0.000	2	#NUM!	0.000	0.000
MgO	0.229	0.257	2	1.123	2.306	11.554
Σ Oxides	2.823					
C	74.240	1.856	2	0.025	16.675	83.542
H	5.190	0.130	2	0.025	1.166	5.840
O	14.923	0.373	3	0.025	0.927	2.138
N	1.850	0.721	2	0.390	6.480	32.465
S	0.657	0.016	3	0.025	0.041	0.094
Ash-s	2.900	0.261	3	0.090	0.647	1.493
Ash-l	3.155	0.079	2	0.025	0.709	3.550

Residual Total Mass (m/m ₀) as a Function of Residence Time						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 6 % O ₂		
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.37	0.39	0.38	0.38	0.36	0.38
72	0.29	0.29	0.27	0.27	0.26	0.27
95	0.12	0.15	0.14	0.14	0.14	0.15
117	0.07	0.09	0.09	0.10	0.08	0.09

Residual Total Mass (m/m0) with Statistics						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 6 % O ₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	8	1.00	0.000	0.000
47	0.38	0.009	3	0.36	0.022	0.051
72	0.28	0.009	5	0.26	0.011	0.019
95	0.14	0.011	4	0.11	0.018	0.032
117	0.08	0.014	4	0.06	0.022	0.040

Residual Elemental Mass as a Function of Residence Time						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 6 % O ₂		
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.98	1.00	1.00	1.08	1.15	0.52
72	0.99	1.07	1.04	1.16	1.08	0.33
95	0.93	0.96	0.99	0.92	0.98	0.20
117	0.89	0.87	0.94	1.25	0.96	0.29
	K ₂ O	C	H	O	N	S
t (ms)						
0	#NUM!	1.00	1.00	1.00	1.00	1.00
47	#NUM!	0.44	0.05	0.11	0.29	0.52
72	#NUM!	0.31	0.04	0.07	0.19	0.45
95	#NUM!	0.13	0.02	0.04	0.08	0.24
117	#NUM!	0.07	0.01	0.03	0.04	0.18

Elemental Mass Release (Normalized) and Statistics						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 6 % O2		
SiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.022	0.073	2	0.075	0.639	3.201
72	0.008	0.077	3	0.078	0.618	3.094
95	0.070	0.100	3	0.108	0.243	0.560
117	0.107	0.155	4	0.173	0.343	0.792
Al2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.001	0.074	2	0.075	0.653	3.269
72	-0.036	0.080	3	0.078	0.645	3.232
95	0.010	0.107	3	0.108	0.259	0.597
117	0.062	0.163	4	0.173	0.361	0.832
TiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.004	0.074	2	0.075	0.651	3.260
72	-0.069	0.083	3	0.078	0.665	3.333
95	0.040	0.103	3	0.108	0.251	0.579
117	0.131	0.151	4	0.174	0.335	0.773
Fe2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.100	2	0.100	0.900	4.509
47	-0.080	0.111	2	0.103	0.986	4.939
72	-0.161	0.122	2	0.105	1.028	5.148
95	0.081	0.118	3	0.129	0.901	4.512
117	-0.251	0.219	4	0.175	0.487	1.123

Elemental Mass Release (Normalized) and Statistics (con't)						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 6 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.249	2	0.249	2.236	11.204
47	-0.154	0.288	2	0.250	2.586	12.955
72	-0.075	0.270	2	0.251	2.396	12.002
95	0.022	0.256	2	0.262	2.197	11.008
117	0.043	0.220	3	0.230	0.545	1.258
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	1.415	2	1.415	12.714	63.696
47	0.479	0.738	2	1.415	6.630	33.215
72	0.668	0.470	2	1.415	4.219	21.135
95	0.798	0.287	2	1.417	2.572	12.883
117	0.707	0.184	2	0.626	1.597	8.000
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
47	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
72	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
95	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
117	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	1.124	2	1.124	10.103	50.613
47	0.785	0.241	2	1.125	2.169	10.865
72	0.785	0.242	2	1.125	2.173	10.885
95	0.825	0.197	2	1.127	1.770	8.865
117	0.827	0.125	2	0.722	1.096	5.493

Elemental Mass Release (Normalized) and Statistics (con't)						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 6 % O2		
C						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.564	0.032	2	0.075	0.285	1.426
72	0.686	0.024	3	0.078	0.195	0.978
95	0.867	0.014	3	0.108	0.035	0.080
117	0.934	0.012	4	0.181	0.027	0.063
H						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.955	0.003	2	0.075	0.030	0.149
72	0.960	0.003	3	0.078	0.025	0.126
95	0.975	0.003	3	0.108	0.007	0.015
117	0.990	0.002	4	0.186	0.004	0.010
O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.890	0.008	3	0.075	0.020	0.047
72	0.934	0.005	3	0.078	0.012	0.028
95	0.961	0.004	4	0.108	0.010	0.022
117	0.974	0.005	4	0.177	0.010	0.023
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.393	2	0.393	3.531	17.692
47	0.714	0.112	2	0.394	1.010	5.059
72	0.815	0.073	2	0.394	0.653	3.273
95	0.920	0.032	2	0.401	0.283	1.420
117	0.962	0.020	2	0.540	0.175	0.877

Elemental Mass Release (Normalized) and Statistics (con't)						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 6 % O2		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.485	0.038	3	0.075	0.095	0.220
72	0.551	0.035	3	0.078	0.082	0.189
95	0.757	0.026	4	0.108	0.059	0.137
117	0.817	0.032	4	0.175	0.070	0.162
Ash-l						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.000	0.075	2	0.075	0.654	3.275
72	-0.047	0.081	3	0.078	0.651	3.264
95	0.089	0.098	3	0.108	0.238	0.549
117	0.076	0.160	4	0.173	0.354	0.817
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.103	3	0.103	0.255	0.589
47	-0.059	0.112	3	0.105	0.278	0.640
72	-0.100	0.118	3	0.108	0.286	0.660
95	0.015	0.129	3	0.131	0.302	0.696
117	-0.012	0.181	4	0.179	0.398	0.917
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.393	2	0.393	3.531	17.692
47	0.714	0.112	2	0.394	1.010	5.059
72	0.815	0.073	2	0.394	0.653	3.273
95	0.920	0.032	2	0.401	0.283	1.420
117	0.962	0.020	2	0.540	0.175	0.877

Average Initial Mass Percents and Statistics						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 12 % O ₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	1.365	0.049	2	0.036	0.445	2.228
Al ₂ O ₃	0.712	0.018	2	0.025	0.160	0.801
TiO ₂	0.049	0.001	2	0.025	0.011	0.055
Fe ₂ O ₃	0.277	0.024	2	0.087	0.216	1.082
CaO	0.174	0.042	2	0.244	0.381	1.910
Na ₂ O	0.018	0.025	2	1.414	0.222	1.114
K ₂ O	0.000	0.000	2	#NUM!	0.000	0.000
MgO	0.229	0.257	2	1.123	2.306	11.554
Σ Oxides	2.823					
C	74.240	1.856	2	0.025	16.675	83.542
H	5.190	0.130	2	0.025	1.166	5.840
O	14.923	0.373	3	0.025	0.927	2.138
N	1.850	0.721	2	0.390	6.480	32.465
S	0.657	0.016	3	0.025	0.041	0.094
Ash-s	2.900	0.261	3	0.090	0.647	1.493
Ash-l	3.155	0.079	2	0.025	0.709	3.550

Residual Total Mass (m/m ₀) as a Function of Residence Time						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 12 % O ₂		
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.29	0.34	0.33	0.34	0.30	0.33
72	0.14	0.14	0.14	0.16	0.15	0.16
95	0.10	0.10	0.09	0.11	0.09	0.10
117	0.05	0.06	0.06	0.06	0.06	0.07

Residual Total Mass (m/m0) with Statistics						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 12 % O ₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	8	1.00	0.000	0.000
47	0.32	0.025	5	0.30	0.031	0.052
72	0.14	0.003	4	0.12	0.005	0.010
95	0.10	0.003	3	0.07	0.008	0.019
117	0.06	0.007	4	0.03	0.012	0.021

Residual Elemental Mass as a Function of Residence Time						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 12 % O ₂		
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.94	0.95	0.97	1.01	0.96	0.43
72	0.99	0.90	0.99	0.85	0.87	0.00
95	1.00	0.85	1.03	1.28	0.96	0.30
117	0.90	0.88	0.97	0.74	0.94	0.00
	K ₂ O	C	H	O	N	S
t (ms)						
0	#NUM!	1.00	1.00	1.00	1.00	1.00
47	#NUM!	0.37	0.04	0.04	0.22	0.52
72	#NUM!	0.15	0.01	0.03	0.07	0.13
95	#DIV/0!	0.08	0.01	0.03	0.04	0.23
117	#DIV/0!	0.03	0.01	0.02	0.02	0.13

Elemental Mass Release (Normalized) and Statistics						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 12 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.056	0.100	4	0.106	0.225	0.518
72	0.013	0.074	2	0.075	0.630	3.158
95	-0.005	0.079	2	0.079	0.680	3.406
117	0.103	0.129	4	0.144	0.290	0.670
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.029	0.103	4	0.106	0.231	0.533
72	0.014	0.074	2	0.075	0.630	3.155
95	-0.033	0.082	2	0.079	0.699	3.502
117	0.027	0.140	4	0.144	0.314	0.724
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.048	0.101	4	0.106	0.226	0.522
72	0.104	0.067	2	0.075	0.572	2.866
95	0.151	0.067	2	0.079	0.574	2.876
117	0.124	0.125	4	0.143	0.281	0.648
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.100	2	0.100	0.900	4.509
47	-0.011	0.129	3	0.127	0.313	0.721
72	0.147	0.088	2	0.103	0.769	3.852
95	-0.278	0.136	2	0.106	1.186	5.944
117	0.258	0.122	3	0.165	0.291	0.671

Elemental Mass Release (Normalized) and Statistics (con't)						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 12 % O2		
CaO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.249	2	0.249	2.236	11.204
47	0.044	0.249	2	0.261	2.103	10.535
72	0.130	0.218	2	0.250	1.946	9.748
95	0.035	0.243	2	0.251	2.168	10.863
117	0.057	0.190	3	0.201	1.427	7.149
Na2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	1.415	2	1.415	12.714	63.696
47	0.568	0.612	2	1.417	5.488	27.492
72	1.000	0.000	#NUM!	#NUM!	#NUM!	#NUM!
95	0.699	0.427	2	1.416	3.834	19.206
117	1.000	0.246	2	#DIV/0!	2.213	11.085
K2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
47	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
72	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
MgO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	1.124	2	1.124	10.103	50.613
47	0.816	0.207	2	1.127	1.854	9.287
72	0.860	0.157	2	1.125	1.414	7.082
95	0.838	0.182	2	1.125	1.637	8.204
117	0.852	0.107	2	0.722	0.948	4.747

Elemental Mass Release (Normalized) and Statistics (con't)						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 12 % O2		
C						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.634	0.039	4	0.106	0.087	0.201
72	0.854	0.011	2	0.075	0.093	0.468
95	0.921	0.006	2	0.079	0.053	0.266
117	0.966	0.005	3	0.155	0.012	0.028
H						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.960	0.004	4	0.106	0.009	0.022
72	0.991	0.001	2	0.075	0.006	0.028
95	0.992	0.001	2	0.079	0.005	0.026
117	0.993	0.001	4	0.143	0.002	0.005
O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.960	0.004	4	0.106	0.007	0.012
72	0.972	0.002	3	0.075	0.005	0.012
95	0.969	0.002	3	0.079	0.006	0.014
117	0.980	0.003	4	0.147	0.006	0.015
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.393	2	0.393	3.531	17.692
47	0.783	0.087	2	0.401	0.761	3.813
72	0.934	0.026	2	0.394	0.232	1.164
95	0.962	0.015	2	0.395	0.136	0.680
117	0.977	0.009	2	0.405	0.079	0.394

Elemental Mass Release (Normalized) and Statistics (con't)						
Blue #1 subbituminous 75-106 μm				PSOC-1445d 12 % O2		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.481	0.055	4	0.106	0.086	0.158
72	0.866	0.010	3	0.075	0.024	0.056
95	0.772	0.018	3	0.079	0.045	0.103
117	0.874	0.019	4	0.150	0.042	0.096
Ash-I						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.036	0.102	4	0.106	0.229	0.529
72	0.109	0.067	2	0.075	0.570	2.853
95	0.008	0.078	2	0.079	0.671	3.361
117	0.156	0.122	4	0.144	0.274	0.633
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.103	3	0.103	0.255	0.589
47	-0.079	0.140	4	0.129	0.311	0.717
72	0.069	0.098	3	0.106	0.242	0.559
95	-0.101	0.120	3	0.109	0.297	0.685
117	0.090	0.140	4	0.154	0.312	0.719
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.393	2	0.393	3.531	17.692
47	0.783	0.087	2	0.401	0.761	3.813
72	0.934	0.026	2	0.394	0.232	1.164
95	0.962	0.015	2	0.395	0.136	0.680
117	0.977	0.009	2	0.405	0.079	0.394

Average Initial Mass Percents and Statistics						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 12 % O ₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	1.624	0.175	8	0.108	0.146	0.217
Al ₂ O ₃	0.818	0.109	8	0.133	0.091	0.134
TiO ₂	0.046	0.006	8	0.137	0.005	0.008
Fe ₂ O ₃	0.281	0.043	8	0.153	0.036	0.053
CaO	0.185	0.068	8	0.364	0.056	0.084
Na ₂ O	0.012	0.007	8	0.634	0.006	0.009
K ₂ O	0.013	0.027	8	2.138	0.022	0.033
MgO	0.039	0.045	8	1.162	0.038	0.056
Σ Oxides	3.017					
C	73.860	1.847	6	0.025	1.938	3.039
H	5.255	0.140	6	0.027	0.147	0.230
O	15.490	1.484	8	0.096	1.241	1.835
N	1.301	0.034	7	0.026	0.031	0.047
S	0.603	0.105	6	0.174	0.110	0.173
Ash-s	3.463	0.496	7	0.143	0.459	0.695
Ash-l	3.429	0.239	7	0.070	0.221	0.335

Residual Total Mass (m/m ₀) as a Function of Residence Time						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 12 % O ₂		
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.42	0.50	0.55	0.48	0.50	0.46
72	0.16	0.26	0.29	0.29	0.27	0.25
95	0.20	0.13	0.15	0.15	0.15	0.13
117	0.15	0.09	0.11	0.11	0.09	0.10

Residual Total Mass (m/m0) with Statistics						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 12 % O₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	26	1.00	0.000	0.000
47	0.49	0.065	5	0.47	0.081	0.134
72	0.24	0.068	6	0.21	0.071	0.111
95	0.16	0.035	9	0.13	0.027	0.039
117	0.12	0.031	9	0.08	0.024	0.035

Residual Elemental Mass as a Function of Residence Time						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 12 % O₂		
	SiO₂	TiO₂	Al₂O₃	Fe₂O₃	CaO	Na₂O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.99	1.02	0.89	1.12	1.32	0.86
72	0.90	0.82	0.82	0.73	1.06	0.00
95	1.22	1.05	1.06	2.19	1.49	0.28
117	1.28	1.07	1.07	2.28	1.12	0.51
	K₂O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	3.60	0.53	0.20	0.24	0.53	0.65
72	1.85	0.26	0.02	0.03	0.18	0.42
95	3.70	0.15	0.02	0.06	0.12	0.41
117	4.44	0.09	0.01	0.03	0.07	0.29

Elemental Mass Release (Normalized) and Statistics						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 12 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.119	8	0.119	0.099	0.147
47	0.012	0.176	6	0.178	0.180	0.282
72	0.101	0.278	6	0.310	0.285	0.447
95	-0.221	0.301	9	0.247	0.240	0.356
117	-0.284	0.356	9	0.277	0.282	0.418
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.142	8	0.142	0.119	0.176
47	0.112	0.173	7	0.195	0.173	0.271
72	0.175	0.263	6	0.319	0.268	0.420
95	-0.061	0.274	9	0.258	0.220	0.325
117	-0.073	0.304	9	0.284	0.242	0.358
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.146	8	0.146	0.122	0.180
47	-0.023	0.202	7	0.197	0.201	0.316
72	0.182	0.262	6	0.321	0.266	0.418
95	-0.046	0.272	9	0.261	0.219	0.323
117	-0.074	0.305	9	0.284	0.243	0.359
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.161	8	0.161	0.135	0.199
47	-0.122	0.234	7	0.209	0.231	0.363
72	0.270	0.239	6	0.328	0.242	0.379
95	-1.186	0.589	9	0.269	0.474	0.701
117	-1.275	0.655	9	0.288	0.521	0.771

Elemental Mass Release (Normalized) and Statistics (con't)						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 12 % O2		
CaO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.368	8	0.368	0.308	0.455
47	-0.316	0.515	8	0.391	0.455	0.690
72	-0.059	0.493	7	0.466	0.448	0.679
95	-0.486	0.634	8	0.427	0.522	0.772
117	-0.121	0.499	8	0.445	0.409	0.605
Na2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.636	8	0.636	0.532	0.786
47	0.138	0.560	8	0.649	0.488	0.740
72	1.000	0.000	#NUM!	#NUM!	#NUM!	#NUM!
95	0.723	0.186	8	0.671	0.155	0.229
117	0.488	0.188	9	0.368	0.153	0.226
K2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	2.139	8	2.139	1.788	2.646
47	-2.598	7.710	8	2.143	6.675	10.112
72	-0.849	3.989	8	2.158	3.458	5.239
95	-2.705	7.963	8	2.150	6.654	9.845
117	-3.441	5.965	8	1.343	4.975	7.361
MgO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	1.163	8	1.163	0.973	1.439
47	-0.704	1.995	8	1.171	1.730	2.621
72	-0.122	1.344	8	1.198	1.171	1.774
95	-1.516	2.977	8	1.183	2.484	3.676
117	0.252	2.168	8	2.900	1.812	2.680

Elemental Mass Release (Normalized) and Statistics (con't)						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 12 % O2		
C						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	6	0.071	0.074	0.116
47	0.467	0.080	5	0.151	0.098	0.162
72	0.735	0.078	6	0.294	0.082	0.128
95	0.855	0.033	9	0.227	0.026	0.039
117	0.914	0.024	9	0.274	0.019	0.028
H						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	6	0.071	0.074	0.116
47	0.799	0.030	5	0.151	0.037	0.061
72	0.980	0.006	6	0.294	0.006	0.010
95	0.977	0.005	9	0.227	0.004	0.006
117	0.990	0.003	9	0.282	0.002	0.003
O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.108	8	0.108	0.090	0.134
47	0.757	0.042	6	0.171	0.043	0.067
72	0.971	0.009	6	0.306	0.009	0.014
95	0.936	0.015	9	0.241	0.012	0.018
117	0.971	0.009	9	0.309	0.007	0.011
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	7	0.071	0.065	0.099
47	0.470	0.080	5	0.151	0.095	0.157
72	0.823	0.052	6	0.294	0.054	0.085
95	0.877	0.028	9	0.227	0.022	0.033
117	0.926	0.020	9	0.274	0.016	0.024

Elemental Mass Release (Normalized) and Statistics (con't)						
Blue #1 subbituminous 106-125 μm				PSOC-1445d 12 % O2		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.181	6	0.181	0.190	0.298
47	0.348	0.146	6	0.224	0.171	0.284
72	0.584	0.141	6	0.338	0.148	0.232
95	0.587	0.116	8	0.282	0.102	0.155
117	0.713	0.093	8	0.324	0.081	0.122
Ash-I						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.086	7	0.086	0.079	0.120
47	-0.052	0.166	6	0.158	0.195	0.324
72	0.068	0.278	6	0.298	0.290	0.455
95	-0.195	0.278	9	0.232	0.222	0.329
117	-0.237	0.336	9	0.271	0.267	0.394
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.152	7	0.152	0.140	0.213
47	0.013	0.199	6	0.202	0.207	0.324
72	0.135	0.280	6	0.324	0.289	0.453
95	-0.102	0.291	8	0.264	0.238	0.352
117	-0.396	0.390	9	0.279	0.312	0.461
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.071	7	0.071	0.065	0.099
47	0.470	0.080	5	0.151	0.095	0.157
72	0.823	0.052	6	0.294	0.054	0.085
95	0.877	0.028	9	0.227	0.022	0.033
117	0.926	0.020	9	0.274	0.016	0.024

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE TEMPERATURE DISTRIBUTIONS**

Data and Analysis Compilation
for PSOC-1445, Blue #1 Coal

BLUE #1 COAL CHAR

COAL TYPE: BLUE #1, 106 - 125 microns:
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1650.0	1	1652.4	0.0	2.55	0.00	0.655	0.000
1700.0	63	1719.5	5.8	2.62	0.02	0.732	0.253
1750.0	147	1740.3	10.9	2.61	0.09	0.581	0.265
1800.0	1	1781.5	0.0	2.63	0.00	0.439	0.000
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 212
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 1.80

COAL TYPE: BLUE #1, 106 - 125 microns
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	1	1558.9	0.0	2.57	0.00	0.048	0.000
1600.0	1	1595.7	0.0	2.57	0.00	0.042	0.000
1650.0	6	1659.4	10.5	2.73	0.12	0.892	0.089
1700.0	218	1700.5	10.4	2.77	0.14	0.725	0.219
1750.0	9	1734.6	13.5	2.77	0.04	0.590	0.174
1800.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 235
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 1.80

COAL TYPE: BLUE #1, 106 - 125 microns
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	1	1522.6	0.0	2.93	0.00	0.065	0.000
1550.0	1	1566.2	0.0	3.03	0.00	0.610	0.000
1600.0	2	1608.3	22.3	3.00	0.05	1.214	0.081
1650.0	140	1662.8	8.5	2.98	0.05	0.705	0.201
1700.0	82	1684.3	7.5	2.99	0.05	0.629	0.173
1750.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1800.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 226
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 1.80

COAL TYPE: BLUE #1, 106 - 125 microns
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	1	1496.9	0.0	2.18	0.00	0.289	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1650.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1700.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1750.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1800.0	3	1804.5	8.2	2.60	0.00	0.697	0.099
1850.0	130	1865.3	7.6	2.61	0.03	0.833	0.221
1900.0	104	1887.1	10.5	2.60	0.11	0.755	0.180
1950.0	2	1926.6	1.2	2.05	0.83	0.514	0.021
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 240
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 1.80

COAL TYPE: BLUE #1, 106 - 125 microns
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	1	1543.1	0.0	2.65	0.00	0.660	0.000
1600.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1650.0	4	1659.2	8.2	2.81	0.02	0.104	0.144
1700.0	6	1693.2	15.3	2.70	0.11	0.391	0.196
1750.0	7	1750.4	14.2	2.77	0.07	0.358	0.164
1800.0	8	1812.3	6.6	2.75	0.05	0.595	0.200
1850.0	135	1857.5	12.5	2.75	0.13	0.682	0.167
1900.0	64	1889.5	11.7	2.77	0.06	0.569	0.171
1950.0	2	1936.0	1.9	2.80	0.04	0.332	0.074
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 227
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 1.80

COAL TYPE: BLUE #1, 106 - 125 microns
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1462.4	0.0	3.00	0.00	0.360	0.000
1500.0	11	1513.6	8.6	2.93	0.03	0.293	0.198
1550.0	16	1554.0	13.4	2.85	0.25	0.238	0.161
1600.0	14	1599.0	13.0	2.87	0.19	0.197	0.180
1650.0	8	1659.7	12.9	2.96	0.06	0.217	0.147
1700.0	5	1705.0	15.5	2.94	0.01	0.348	0.121
1750.0	16	1756.8	14.0	2.93	0.06	0.351	0.197
1800.0	33	1802.5	13.8	2.95	0.04	0.540	0.220
1850.0	50	1847.0	12.4	2.94	0.05	0.559	0.189
1900.0	5	1895.9	10.7	2.94	0.05	0.448	0.158
1950.0	1	1925.5	0.0	2.93	0.00	0.422	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 160
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 1.80

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE SIZES, TEMPERATURES, AND VELOCITIES**

Data and Analysis Compilation
for PSOC-1445, Blue #1 Coal

COAL TYPE: BLUE #1 COAL, 106 - 125 micron:
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
50.0	0	0.0	0.0	0.00	0.00	0.000	0.000
60.0	0	0.0	0.0	0.00	0.00	0.000	0.000
70.0	0	0.0	0.0	0.00	0.00	0.000	0.000
80.0	0	0.0	0.0	0.00	0.00	0.000	0.000
90.0	1	1737.0	0.0	2.63	0.00	1.349	0.000
100.0	5	1731.0	18.5	2.60	0.03	1.213	0.290
110.0	8	1738.2	15.7	2.59	0.04	1.014	0.197
120.0	23	1730.2	13.0	2.61	0.03	0.902	0.212
130.0	29	1733.9	13.5	2.61	0.03	0.766	0.158
140.0	22	1733.8	11.9	2.62	0.02	0.695	0.145
150.0	30	1731.0	15.3	2.62	0.02	0.633	0.130
160.0	24	1736.1	13.6	2.62	0.02	0.556	0.120
170.0	10	1736.2	16.1	2.62	0.02	0.474	0.134
180.0	12	1724.9	23.0	2.62	0.03	0.495	0.121
190.0	9	1736.1	11.1	2.62	0.01	0.399	0.134
200.0	11	1732.8	13.6	2.62	0.02	0.393	0.081
210.0	6	1742.0	8.7	2.62	0.02	0.308	0.061
220.0	7	1742.4	15.1	2.46	0.39	0.319	0.090
230.0	4	1742.9	12.5	2.61	0.01	0.304	0.068
240.0	6	1741.1	10.9	2.61	0.02	0.234	0.051

NUMBER OF PARTICLES = 207
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: BLUE #1 COAL, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

SIZE (micron)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
50.0	0	0.0	0.0	0.00	0.00	0.000	0.000
60.0	1	1724.5	0.0	2.77	0.00	3.303	0.000
70.0	1	1558.9	0.0	2.57	0.00	0.048	0.000
80.0	0	0.0	0.0	0.00	0.00	0.000	0.000
90.0	0	0.0	0.0	0.00	0.00	0.000	0.000
100.0	7	1704.4	6.7	2.79	0.02	1.055	0.096
110.0	26	1705.7	8.3	2.80	0.02	0.936	0.168
120.0	32	1704.2	18.4	2.79	0.03	0.849	0.175
130.0	48	1700.6	19.3	2.77	0.05	0.764	0.191
140.0	39	1697.0	13.7	2.78	0.05	0.720	0.169
150.0	26	1696.6	15.6	2.78	0.03	0.687	0.140
160.0	16	1700.4	14.9	2.78	0.02	0.531	0.116
170.0	10	1704.2	14.7	2.79	0.02	0.531	0.113
180.0	12	1696.2	10.4	2.64	0.46	0.518	0.116
190.0	4	1699.0	11.7	2.47	0.56	0.482	0.065
200.0	5	1692.2	14.8	2.78	0.03	0.459	0.072
210.0	2	1699.5	13.2	2.79	0.02	0.395	0.033
220.0	3	1697.3	14.1	2.77	0.00	0.348	0.063
230.0	1	1694.8	0.0	2.80	0.00	0.365	0.000
240.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 233
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: BLUE #1 COAL, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
50.0	0	0.0	0.0	0.00	0.00	0.000	0.000
60.0	0	0.0	0.0	0.00	0.00	0.000	0.000
70.0	1	1522.6	0.0	2.93	0.00	0.065	0.000
80.0	0	0.0	0.0	0.00	0.00	0.000	0.000
90.0	2	1693.8	0.7	3.04	0.05	0.978	0.516
100.0	8	1666.7	29.2	2.98	0.06	1.078	0.203
110.0	14	1675.5	10.8	3.00	0.03	0.819	0.140
120.0	42	1673.8	13.9	2.99	0.05	0.765	0.136
130.0	40	1668.2	13.3	2.99	0.04	0.778	0.179
140.0	46	1669.6	20.3	2.99	0.05	0.631	0.119
150.0	21	1672.6	13.3	2.97	0.04	0.578	0.137
160.0	24	1666.7	11.6	2.97	0.06	0.578	0.102
170.0	11	1665.0	11.2	2.97	0.05	0.535	0.109
180.0	3	1663.0	9.6	2.94	0.05	0.476	0.110
190.0	5	1666.6	7.9	2.97	0.03	0.457	0.021
200.0	3	1662.9	13.8	2.95	0.01	0.486	0.050
210.0	2	1646.2	5.2	2.96	0.00	0.365	0.094
220.0	1	1673.2	0.0	3.07	0.00	0.253	0.000
230.0	0	0.0	0.0	0.00	0.00	0.000	0.000
240.0	1	1654.4	0.0	2.93	0.00	0.346	0.000

NUMBER OF PARTICLES = 224

PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: BLUE #1 COAL, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
50.0	0	0.0	0.0	0.00	0.00	0.000	0.000
60.0	0	0.0	0.0	0.00	0.00	0.000	0.000
70.0	0	0.0	0.0	0.00	0.00	0.000	0.000
80.0	0	0.0	0.0	0.00	0.00	0.000	0.000
90.0	0	0.0	0.0	0.00	0.00	0.000	0.000
100.0	10	1892.8	14.3	2.62	0.04	0.875	0.144
110.0	32	1882.0	17.1	2.62	0.02	0.959	0.246
120.0	45	1875.6	10.9	2.62	0.03	0.874	0.179
130.0	48	1877.1	14.6	2.61	0.03	0.830	0.205
140.0	32	1867.3	20.5	2.61	0.03	0.773	0.134
150.0	19	1850.9	85.3	2.52	0.27	0.692	0.157
160.0	19	1866.9	10.2	2.61	0.03	0.698	0.096
170.0	14	1864.7	17.6	2.60	0.03	0.655	0.096
180.0	6	1866.4	8.4	2.62	0.02	0.604	0.120
190.0	7	1882.4	13.8	2.45	0.38	0.555	0.076
200.0	3	1864.3	5.6	2.61	0.03	0.512	0.052
210.0	1	1871.6	0.0	2.60	0.00	0.486	0.000
220.0	2	1893.2	4.2	2.60	0.00	0.394	0.061
230.0	1	1854.4	0.0	2.55	0.00	0.501	0.000
240.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 239

PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: BLUE #1 COAL, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.05 cm

SIZE (micron)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
50.0	0	0.0	0.0	0.00	0.00	0.000	0.000
60.0	0	0.0	0.0	0.00	0.00	0.000	0.000
70.0	0	0.0	0.0	0.00	0.00	0.000	0.000
80.0	2	1864.2	40.2	2.65	0.08	0.806	0.027
90.0	2	1864.5	21.6	2.83	0.00	0.604	0.568
100.0	36	1870.4	40.8	2.75	0.06	0.619	0.159
110.0	47	1871.0	23.7	2.77	0.05	0.631	0.171
120.0	58	1856.6	39.5	2.75	0.18	0.659	0.196
130.0	36	1847.5	43.8	2.75	0.07	0.682	0.150
140.0	18	1843.8	50.6	2.75	0.07	0.607	0.150
150.0	11	1825.6	95.3	2.75	0.07	0.520	0.171
160.0	5	1845.8	10.5	2.78	0.04	0.602	0.039
170.0	1	1756.4	0.0	2.80	0.00	0.272	0.000
180.0	1	1707.0	0.0	2.65	0.00	0.442	0.000
190.0	1	1682.4	0.0	2.80	0.00	0.021	0.000
200.0	4	1823.1	89.8	2.79	0.04	0.225	0.172
210.0	2	1801.1	93.2	2.68	0.12	0.455	0.059
220.0	1	1661.4	0.0	2.80	0.00	0.016	0.000
230.0	1	1649.4	0.0	2.77	0.00	0.012	0.000
240.0	1	1883.4	0.0	2.77	0.00	0.061	0.000

NUMBER OF PARTICLES = 227
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: BLUE #1 COAL, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
50.0	0	0.0	0.0	0.00	0.00	0.000	0.000
60.0	0	0.0	0.0	0.00	0.00	0.000	0.000
70.0	0	0.0	0.0	0.00	0.00	0.000	0.000
80.0	0	0.0	0.0	0.00	0.00	0.000	0.000
90.0	6	1770.3	122.2	2.95	0.03	0.635	0.249
100.0	26	1786.8	115.5	2.94	0.04	0.542	0.202
110.0	36	1781.3	102.1	2.95	0.06	0.565	0.190
120.0	35	1750.7	108.3	2.93	0.04	0.431	0.193
130.0	22	1689.0	115.8	2.89	0.23	0.338	0.194
140.0	9	1724.9	106.5	2.95	0.05	0.262	0.123
150.0	7	1674.5	142.3	2.92	0.08	0.286	0.157
160.0	4	1729.1	157.2	2.95	0.06	0.082	0.046
170.0	2	1596.0	104.9	2.93	0.00	0.117	0.112
180.0	1	1829.2	0.0	2.86	0.00	0.467	0.000
190.0	4	1677.8	152.6	2.88	0.14	0.271	0.109
200.0	2	1690.4	113.4	3.00	0.00	0.087	0.068
210.0	0	0.0	0.0	0.00	0.00	0.000	0.000
220.0	0	0.0	0.0	0.00	0.00	0.000	0.000
230.0	3	1623.6	98.4	2.94	0.01	0.060	0.049
240.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 157
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**KINETIC ANALYSIS
AND COMBUSTION PARAMETERS**

Data and Analysis Compilation
for PSOC-1445, Blue #1 Coal

Summary of Combustion Parameters for PSOC-1445			
Char oxidation rate parameters $q = A \exp(-E/RT_p) P^n$	A E n	3.8 15.3 0.5 *	gm-C / cm²-s-atmⁿ kcal / mole
Product ratio parameters $CO/CO_2 = A_c \exp(-E_c/RT_p)$	A_c E_c	3 x 10⁸ * 60 *	 kcal / mole
Burning mode parameter $\rho/\rho_o = (m/m_o)^\alpha$ $d/d_o = (m/m_o)^{(1-\alpha)/3}$	α	0.25	
Char structural parameters $\omega = d_o / d_c$ (linear swelling factor) $\rho_{c,o} = m_c/V_c$ at $z = 6.5$ cm (Initial char particle carbon density)	ω ρ_{c,o}	1.16 0.26	 gm / cm³
<p>As an example, this parameter set yields a combustion rate, q, of 0.0051 gm/sq.cm-sec for a 100 μm particle in a gas with $T_g = 1600$ K containing 6 mole-% oxygen</p> <p>These product ratio parameters yield 3.4 mole-% carbon dioxide in the 12 mole-% oxygen environment and 15 mole-% carbon dioxide in the 6 mole-% oxygen environment</p> <p>* These particular parameters should be regarded as empirical parameters useful for the prediction of burning rates. They do not necessarily have fundamental significance or uniqueness for this data set.</p>

Measured Carbon Conversions in the CCL
for PSOC-1445, initial coal particle size 106 - 125 μm

Measured Carbon Conversions in the CCL
for PSOC-1445, 75 - 106 μm initial coal particle size

**CALCULATIONS OF THE COAL CHAR REACTIVITY INDEX, τ_{50} ,
FOR VARIOUS ENVIRONMENTS
PRESENT IN PULVERIZED-COAL COMBUSTION SYSTEMS**

Data and Analysis Compilation
for PSOC-1445, Blue #1 Coal

**Compilation of Data and Kinetic Analyses for
Pittsburgh #8 Bituminous Coal
(Pennsylvania, hvA)**

PSOC-1451D

TABLE OF CONTENTS

- **Sample history, geologic information and chemical analysis of bulk, raw coal**
- **Chemical analysis of size-fractionated raw coal and partially reacted chars**
- **Time resolved measurements of the partitioning of elemental coal constituents between the gas and solid phases**
- **Mode of particle burning**
- **Statistical analyses of elemental composition measurements and derived quantities**
- **Optical measurements of single-particle temperature distributions**
- **Optical measurements of single-particle sizes, temperatures, and velocities**
- **Kinetic analysis and combustion parameters**
- **Calculations of the coal char reactivity index, τ_{50} , for various environments present in pulverized-coal combustion systems**

**SAMPLE HISTORY, GEOLOGIC INFORMATION AND
CHEMICAL ANALYSIS OF BULK, RAW COAL**

Data and Analysis Compilation
for PSOC-1451, Pittsburgh #8 Coal

SAMPLE HISTORY

PENN STATE NUMBER	PSOC-1451
COLLECTED BY	PENNSYLVANIA STATE UNIVERSITY
COLLECTION DATE	5/1/85
COLLECTOR'S NUMBER	
REPORTED RANK	HIGH VOLATILE A BITUMINOUS (HVAB)
SAMPLE TYPE	CHANNEL WHOLE SEAM
OTHER SAMPLE INFORMATION	
SAMPLE RESERVE	
SEAM NAME	PITTSBURGH
ALTERNATE SEAM NAME	#8
TOTAL SEAM THICKNESS	6 FT. 5 IN.
THICKNESS OF SEAM SAMPLED	6 FT. 5 IN.
PORTION RECOVERED IN CORE	
DIAMETER OF CORE	

SAMPLE LOCATION

COUNTRY	U.S.A.
STATE	PENNSYLVANIA
COUNTY	WASHINGTON
TOWNSHIP	NORTH STRABANE
NEAREST TOWN	LINDEN
COAL PROVINCE	EASTERN
COAL REGION	APPALACHIAN
COAL FIELD	MAIN BITUMINOUS

GEOLOGIC INFORMATION

SYSTEM (AGE)	PENNSYLVANIAN
SERIES	
GROUP	MONOGAHELA
FORMATION	
OVERBURDEN LITHOLOGY	SHALE
FLOOR LITHOLOGY	SHALE

SEAM STRATA INFORMATION

<u>THICKNESS</u>	<u>LITHOTYPE</u>
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SEAM NAME	PITTSBURGH	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE A BITUMINOUS (HVAB)	STATE	PENNSYLVANIA

CHEMICAL DATA 1

PROXIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF (PAFF)	DMMF (PARR-G)	DMMF (DIR MM)
% MOISTURE	2.54					
% ASH	13.32	13.67				
% VOLATILE MATTER	33.56	34.43	39.88	38.81	38.21	
% FIXED CARBON	50.58	51.90	60.12	61.19	61.79	

CALORIFIC VALUE (GROSS BTU/LB)	DRY	AS REC'D MOIST.	EQUIL MOIST.
MM-FREE, DIRECT			
MM-CONTAINING	12855	12528	12541
MM-FREE (PARR)	15135	14682	14699
MM-FREE (MOD.P)	15227	14736	14754
BEST MM FREE		14736	14754
NET CV, DMMF BTU/LB	14713		
ASH-FREE	14891		

MOTT-SPOONER DIFFERENCE =

ASSOCIATED ANALYSES	DRY	MMF
% EQUILIBRIUM MOISTURE	2.44	2.89
% TOTAL SULFUR	1.36	

RANK CALCULATIONS

APPARENT RANK (AS REC'D MOIST)	HIGH VOLATILE A BITUMINOUS (HVAB)
ASTM RANK (EQUIL. MOIST.)	HIGH VOLATILE A BITUMINOUS (HVAB)
REFLECTANCE RANK CATEGORY	HIGH VOLATILE A BITUMINOUS (HVAB)
INTERNATIONAL RANK	
AS REC'D MOIST.	
EQUIL. MOIST	
REPORTED RANK	HIGH VOLATILE A BITUMINOUS (HVAB)

SEAM NAME	PITTSBURGH	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE A BITUMINOUS (HVAB)	STATE	PENNSYLVANIA

CHEMICAL DATA 2

<u>ULTIMATE ANALYSIS</u>	<u>AS REC'D</u>	<u>DRY</u>	<u>DAF</u>	<u>DMMF(PARR)</u> (15.51 % MM)
% ASH	13.32	13.67		
% CARBON	70.05	71.88	83.26	85.08
% HYDROGEN	*455	4.67	5.41	5.53
% NITROGEN	1.33	1.36	1.58	1.61
% SULFUR	1.33	1.36	1.58	
% CHLORINE	0.07	0.08	0.09	0.09
% OXYGEN (DIFF)	*6.81	6.99	8.10	7.71

<u>SULFUR FORMS</u>	<u>% PYRITIC</u>	<u>% SULFATIC</u>	<u>% ORGANIC</u>	<u>% TOTAL</u>
DRY	0.82	0.01	0.53	1.36
DAF	0.95	0.01	0.61	1.58
OPTICAL				

<u>ELEMENTAL ANALYSIS</u>	<u>DRY</u>	<u>DMMF (MOD.P)</u> (15.87 % MM)	<u>DMMF(DIR.)</u> (% MM)
% CARBON	71.64	85.16	
% HYDROGEN	4.64	5.52	
% NITROGEN	1.36	1.61	
% ORGANIC SULFUR	0.53	0.63	
% OXYGEN (DIFF)	5.95	7.00	
% CHLORINE	0.08	0.09	
% MINERAL MATTER (INCLUDES 1.53 % FES2)	15.87		

<u>ATOM RATIOS (DMMF)</u>	<u>PARR</u>	<u>MOD.PAR</u>	<u>DIRECT</u>
ATOMIC H/C	0.780	0.778	
ATOMIC O/C	0.068	0.073	

<u>MISC. CHEMICAL DATA</u>	<u>DRY</u>	<u>OF DMMF COAL</u>	<u>OF DMMF OXYGEN</u>
% O AS COOH			
% O AS OH			
% S AS SO4, IN ASH			
% CARBONATE AS CO2	0.87		
% CHLORINE	0.15		

INFRA-RED ANALYSIS

(*)- EXCLUDES MOISTURE

SEAM NAME PITTSBURGH COUNTRY U.S.A.
 APPARENT RANK HIGH VOLATILE A BITUMINOUS (HVAB) STATE PENNSYLVANIA

CHEMICAL DATA 3

% MOISTURE IN COAL = 1.52
 % HIGH TEMPERATURE ASH = 13.20 AT 750 DEGREES C

TRACE ELEMENT ANALYSIS	PPM HTA	PPM TOTAL COAL	MAJOR ELEMENT ANALYSIS	OXIDE % OF HTA	ELEMENT % OF TOTAL DRY COAL
AG			SI02	54.40	3.36
B			AL203	24.50	1.71
BA	540	71	TI02	1.14	0.09
BE	7	1	FE203	9.16	0.85
BI			MG0	0.85	0.07
CE			CA0	2.97	0.28
CO			NA20	0.61	0.06
CR	150	20	K20	2.02	0.22
CU	80	11	P205	0.34	0.02
GA			S03	2.30	0.12
GE					
LA					
LI					
MN	140	18			
MO			<u>VOLATILES</u>	<u>PPM TOTAL COAL</u>	
NI	65	9			
NB			AS		
PB			BR		
RB	100	13	CD		
SC			CL		
SN			F		
SR	590	78	HG		
TH			SB		
U			SE		
V	200	26			
Y					
YB					
ZN	85	11			
ZR	240	32			

SEAM NAME	PITTSBURGH	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE A BITUMINOUS (HVAB)	STATE	PENNSYLVANIA

MINERALOGICAL DATA

TOTAL MINERAL MATTER

% MM-PARR	15.51
% MM-MODIFIED PARR	15.87
% MM-KMC	
% MM-DIRECT	
% MM-BEST AVAILABLE	15.87
VOL % MM-PARR	8.13

MINERAL COMPOSITION

NONE

SEAM NAME	PITTSBURGH	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE A BITUMINOUS (HVAB)	STATE	PENNSYLVANIA

PETROGRAPHIC DATA

MACERAL COMPOSITION WHITE ANALYSIS ONLY

	<u>DRY</u> <u>VOLUME %</u>	<u>DMMF</u> <u>VOLUME %</u>	<u>DRY</u> <u>WEIGHT %</u>
VITRINITE (CALC.)	80.1	87.2	73.7
INERTINITE (CALC.)	8.7	9.5	8.0
LIPTINITE (CALC.)	3.0	3.3	2.8
MINERAL MATTER (CALC.)	8.1		15.5
VITRINOIDS			
VITRINITE	80.1	87.2	73.7
PSEUDOVITRINITE	0.0	0.0	0.0
FUSINITE	1.8	2.0	1.7
SEMI-FUSINITE	4.2	4.6	3.9
MACRINITE	0.7	0.8	0.7
MICRINITE	1.9	2.1	1.8
SCLEROTINITE	0.0	0.0	0.0
SPORINITE			
CUTINITE			
EXINITE(ANAL.)	3.0	3.3	2.8
RESINITE	0.0	0.0	0.0
SUBERINITE			
EXUDATINITE			
FLOURINITE			
BITUMINITE			
ALGINITE	0.0	0.0	0.0
LIPTODETRINITE			
MINERAL MATTER (ANAL.)			
INERTINITE(ANAL.)			
LIPTINITE(ANAL.)			

<u>REFLECTANCE DATA</u> (% IN OIL)	<u>HIGH</u>	<u>LOW</u>	<u>RANGE</u>	<u>MEAN MAX</u>	<u>STAND.DEV.</u>
VITRINITE	0.89	0.62	0.27	0.77	0.06
PSEUDOVITRINITE					
VITRINOIDS					

SEAM NAME	PITTSBURGH	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE A BITUMINOUS (HVAB)	STATE	PENNSYLVANIA

PETROGRAPHIC DATA

CONTINUED

<u>% VITRINOID</u>		<u>VOLUME</u>	<u>% VITRINOID</u>		<u>VOLUME</u>
<u>REFLECTANCE</u>	<u>HALF-TYPE</u>	<u>PERCENT</u>	<u>REFLECTANCE</u>	<u>V-TYPE</u>	<u>PERCENT</u>
0.60-0.64	VHT 0.625	3.00			
0.65-0.69	VHT 0.675	9.00	0.60-0.69	V6	12.00
0.70-0.74	VHT 0.725	18.00			
0.75-0.79	VHT 0.775	37.00	0.70-0.79	V7	55.00
0.80-0.84	VHT 0.825	25.00			
0.85-0.89	VHT 0.875	8.00	0.80-0.89	V8	33.00

PHYSICAL PROPERTIES

HARDGROVE GRINDABILITY	38.9
VICKER'S MICROHARDNESS	
FREE SWELLING INDEX	7.5
GRAY KING COKE TYPE	

<u>ASH FUSION ANALYSIS (DEGREES F)</u>	<u>REDUCING</u>	<u>OXIDIZING</u>
INITIAL DEFORMATION TEMPERATURE	2435	2570
SOFTENING TEMPERATURE	2585	2640
HEMISPHERE TEMPERATURE	2670	2690
FLUID TEMPERATURE	2685	2700

ANALYSIS LOG

<u>ANALYSIS</u>	<u>DATE</u>	<u>PERFORMED BY</u>
A.R. MOIST	2/14/86	WARNER LABORATORIES
EQUIL. MOIST.	6/4/85	WARNER LABORATORIES
PROXIMATE	2/14/86	WARNER LABORATORIES
ULTIMATE	2/14/86	WARNER LABORATORIES
SULFUR FORMS	6/4/85	WARNER LABORATORIES
FSI	8/15/85	COAL PETROGRAPHY LABORATORIES-PSU
PLASTOMETER	5/29/85	COAL PETROGRAPHY LABORATORIES-PSU
DIRECT MM		
GRAY-KING		

**CHEMICAL ANALYSES OF SIZE-FRACTIONATED RAW COAL
AND PARTIALLY REACTED CHARS**

Data and Analysis Compilation
for PSOC-1451, Pittsburgh #8 Coal

**Organic Elemental Analysis and Percent Ash of Pittsburgh #8 Coal
and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	76.84	4.96	7.57	1.65	1.98	10.28
6.4	73.07	1.78	3.92	1.53	1.02	19.68
12.7	77.70	0.38	1.04	1.46	0.77	17.71
19.1	73.79	0.34	1.55	1.31	0.72	25.88
25.4	74.90	0.32	1.13	1.37	0.68	22.60

12 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	74.80	4.91	7.86	1.54	1.10	11.62
6.4	74.55	0.91	2.30	1.53	1.04	20.23
12.7	72.23	0.30	0.92	1.09	0.76	26.32
19.1	72.06	0.19	1.17	1.04	0.69	29.57
25.4	62.96	0.17	1.07	0.91	0.59	35.67

* Data taken in October 1988

**Ash Content of Pittsburgh #8 Coal and its
Partially Reacted Chars**

Initial particle size range: 106 - 125 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	5.39	2.55	0.117	0.646	0.222	0.066	0.186	0.034
6.4	10.2	5.19	0.249	1.35	0.753	0.167	0.308	0.231
12.7	9.48	4.58	0.223	1.27	0.591	0.119	0.268	0.019
19.1	13.5	6.63	0.313	1.47	0.612	0.175	0.374	0.113
25.4	11.5	5.74	0.268	1.34	0.708	0.185	0.322	0.093

12 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	5.23	2.51	0.116	0.637	0.268	0.068	0.184	0.028
6.4	11.1	5.27	0.244	1.33	0.612	0.169	0.383	0.037
12.7	14.5	6.80	0.318	1.27	0.730	0.222	0.476	0.111
19.1	16.2	7.73	0.359	1.41	1.06	0.307	0.470	0.183
25.4	19.9	9.51	0.436	1.67	0.951	0.273	0.559	0.236

* Data taken in October 1988

**TIME RESOLVED MEASUREMENTS OF THE
PARTITIONING OF ELEMENTAL COAL CONSTITUENTS
BETWEEN THE GAS AND SOLID PHASES**

Data and Analysis Compilation
for PSOC-1451, Pittsburgh #8 Coal

MODE OF PARTICLE BURNING

Data and Analysis Compilation
for PSOC-1451, Pittsburgh #8 Coal

**Fractional Mass Remaining and Apparent Density
of Pittsburgh #8 Coal and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.51	0.55	0.41	0.45
Fractional burnoff, daf	0.0	0.54	0.50	0.63	0.61
Apparent density, g/cc	1.21	0.45	0.50	0.56	0.50

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.51	0.38	0.34	0.28
Fractional burnoff, daf	0.0	0.54	0.69	0.78	0.80
Apparent density, g/cc	1.21	0.47	0.54	0.46	0.43

**STATISTICAL ANALYSES
OF ELEMENTAL COMPOSITION MEASUREMENTS
AND DERIVED QUANTITIES**

- **Raw Coal Composition**
- **Overall Combustion Conversion vs. Residence Time**
- **Elemental Partitioning between Gas and Solid Phases**

Data and Analysis Compilation
for PSOC-1451, Pittsburgh #8 Coal

Average Initial Mass Percents and Statistics						
	Pittsburgh #8 (hvab) 75-106 μm			PSOC-1451d 6 % O ₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Al ₂ O ₃	1.225	0.064	2	0.052	0.572	2.865
TiO ₂	0.034	0.001	2	0.025	0.008	0.038
Fe ₂ O ₃	0.470	0.012	2	0.025	0.106	0.529
CaO	0.260	0.014	2	0.054	0.127	0.637
Na ₂ O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
K ₂ O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
MgO	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Σ Oxides	#DIV/0!					
C	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
H	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
N	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
S	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Ash-s	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Ash-l	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!

Residual Total Mass (m/m ₀) as a Function of Residence Time						
	Pittsburgh #8 (hvab) 75-106 μm			PSOC-1451d 6 % O ₂		
	mass bal.	TiO ₂	Al ₂ O ₃	SiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	#DIV/0!	#DIV/0!	#DIV/0!
47	0.50	0.39	0.50	#DIV/0!	#DIV/0!	#DIV/0!
72	0.40	0.39	0.50	#DIV/0!	#DIV/0!	#DIV/0!
95	0.41	0.45	0.62	#DIV/0!	#DIV/0!	#DIV/0!
117	0.34	0.44	0.54	#DIV/0!	#DIV/0!	#DIV/0!

Residual Total Mass (m/m0) with Statistics						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 6 % O ₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	4	#DIV/0!	0.000	0.000
47	0.46	0.064	2	#DIV/0!	0.578	2.898
72	0.43	0.060	2	#DIV/0!	0.541	2.709
95	0.49	0.110	2	#DIV/0!	0.991	4.962
117	0.44	0.099	2	#DIV/0!	0.886	4.440

Residual Elemental Mass as a Function of Residence Time						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 6 % O ₂		
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O
t (ms)						
0	#DIV/0!	1.00	1.00	1.00	1.00	#DIV/0!
47	#DIV/0!	1.19	0.92	2.06	1.05	#DIV/0!
72	#DIV/0!	1.11	0.86	0.78	0.77	#DIV/0!
95	#DIV/0!	1.09	0.80	0.91	0.80	#DIV/0!
117	#DIV/0!	1.00	0.82	0.93	0.81	#DIV/0!
	K ₂ O	C	H	O	N	S
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 6 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.072	2	0.072	0.648	3.245
47	0.076	0.145	2	0.156	1.298	6.504
72	0.139	0.136	2	0.158	1.225	6.135
95	0.202	0.187	2	0.235	1.682	8.429
117	0.182	0.192	2	0.234	1.722	8.628
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.191	0.185	2	0.156	1.666	8.349
72	-0.109	0.175	2	0.158	1.571	7.870
95	-0.091	0.255	2	0.234	2.295	11.498
117	0.003	0.234	2	0.235	2.106	10.549
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-1.063	0.321	2	0.156	2.887	14.462
72	0.219	0.123	2	0.158	1.107	5.545
95	0.086	0.214	2	0.234	1.923	9.635
117	0.075	0.217	2	0.234	1.947	9.755

Elemental Mass Release (Normalized) and Statistics (con't)						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 6 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.074	2	0.074	0.664	3.326
47	-0.053	0.165	2	0.157	1.487	7.449
72	0.228	0.123	2	0.159	1.104	5.528
95	0.202	0.188	2	0.235	1.685	8.444
117	0.189	0.191	2	0.235	1.712	8.576
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 6 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 6 % O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Ash-l						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Average Initial Mass Percents and Statistics						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 12 % O ₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Al ₂ O ₃	1.225	0.064	2	0.052	0.572	2.865
TiO ₂	0.034	0.001	2	0.025	0.008	0.038
Fe ₂ O ₃	0.470	0.012	2	0.025	0.106	0.529
CaO	0.260	0.014	2	0.054	0.127	0.637
Na ₂ O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
K ₂ O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
MgO	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Σ Oxides	#DIV/0!					
C	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
H	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
N	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
S	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Ash-s	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Ash-l	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!

Residual Total Mass (m/m ₀) as a Function of Residence Time						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 12 % O ₂		
	mass bal.	TiO ₂	Al ₂ O ₃	SiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	#DIV/0!	#DIV/0!	#DIV/0!
47	0.41	0.38	0.51	#DIV/0!	#DIV/0!	#DIV/0!
72	0.32	0.26	0.38	#DIV/0!	#DIV/0!	#DIV/0!
95	0.23	0.21	0.34	#DIV/0!	#DIV/0!	#DIV/0!
117	0.23	0.20	0.36	#DIV/0!	#DIV/0!	#DIV/0!

Residual Total Mass (m/m0) with Statistics						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 12 % O ₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	4	#DIV/0!	0.000	0.000
47	0.43	0.069	2	#DIV/0!	0.622	3.117
72	0.32	0.058	2	#DIV/0!	0.519	2.599
95	0.26	0.068	2	#DIV/0!	0.611	3.059
117	0.26	0.083	2	#DIV/0!	0.750	3.758

Residual Elemental Mass as a Function of Residence Time						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 12 % O ₂		
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O
t (ms)						
0	#DIV/0!	1.00	1.00	1.00	1.00	#DIV/0!
47	#DIV/0!	1.14	0.85	0.87	0.77	#DIV/0!
72	#DIV/0!	1.22	0.85	0.64	0.84	#DIV/0!
95	#DIV/0!	1.22	0.77	0.85	0.78	#DIV/0!
117	#DIV/0!	1.30	0.74	0.97	0.71	#DIV/0!
	K ₂ O	C	H	O	N	S
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 12 % O2		
SiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Al2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.072	2	0.072	0.648	3.245
47	0.152	0.148	2	0.175	1.332	6.674
72	0.154	0.164	2	0.194	1.474	7.383
95	0.230	0.208	2	0.270	1.867	9.355
117	0.265	0.239	2	0.325	2.145	10.747
TiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.141	0.199	2	0.174	1.788	8.957
72	-0.217	0.235	2	0.193	2.113	10.588
95	-0.217	0.328	2	0.269	2.947	14.762
117	-0.301	0.421	2	0.324	3.781	18.944
Fe2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.131	0.151	2	0.174	1.361	6.819
72	0.358	0.124	2	0.193	1.115	5.586
95	0.155	0.228	2	0.269	2.046	10.252
117	0.034	0.312	2	0.323	2.806	14.057

Elemental Mass Release (Normalized) and Statistics (con't)						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 12 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.074	2	0.074	0.664	3.326
47	0.231	0.135	2	0.176	1.213	6.078
72	0.160	0.163	2	0.194	1.467	7.349
95	0.216	0.212	2	0.270	1.904	9.540
117	0.289	0.232	2	0.326	2.081	10.426
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 12 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Pittsburgh #8 (hvab) 75-106 μm				PSOC-1451d 12 % O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Ash-l						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Average Initial Mass Percents and Statistics						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 6 % O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	5.438	0.778	4	0.143	1.238	2.272
Al ₂ O ₃	2.543	0.354	4	0.139	0.563	1.033
TiO ₂	0.116	0.016	4	0.137	0.025	0.047
Fe ₂ O ₃	0.645	0.081	4	0.125	0.128	0.236
CaO	0.262	0.046	4	0.174	0.072	0.133
Na ₂ O	0.037	0.021	4	0.565	0.034	0.062
K ₂ O	0.183	0.006	4	0.032	0.009	0.017
MgO	0.067	0.012	3	0.172	0.029	0.066
Σ Oxides	9.290					
C	75.667	1.892	3	0.025	4.700	10.840
H	5.267	0.575	3	0.109	1.429	3.295
O	7.817	0.228	3	0.029	0.567	1.307
N	1.570	0.070	3	0.045	0.174	0.401
S	1.555	0.491	4	0.316	0.782	1.435
Ash-s	10.095	2.351	4	0.233	3.740	6.866
Ash-l	11.033	0.685	3	0.062	1.703	3.927

Residual Total Mass (m/m₀) as a Function of Residence Time						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 6 % O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.51	0.53	0.49	0.47	0.54	0.56
72	0.47	0.57	0.56	0.52	0.58	0.62
95	0.49	0.40	0.38	0.37	0.40	0.43
117	0.41	0.47	0.44	0.43	0.46	0.49

Residual Total Mass (m/m0) with Statistics						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 6 % O2		
	Mean (mf)	σ	n	Mean (daf)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	1.00	0.000	17	1.00	0.000	0.000
47	0.50	0.029	4	0.45	0.046	0.084
72	0.53	0.044	4	0.49	0.070	0.129
95	0.41	0.054	4	0.34	0.086	0.157
117	0.44	0.025	4	0.38	0.040	0.073

Residual Elemental Mass as a Function of Residence Time						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 6 % O2		
	SiO2	TiO2	Al2O3	Fe2O3	CaO	Na2O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.94	1.07	1.02	1.05	1.44	3.10
72	0.92	1.02	0.96	1.04	1.20	0.27
95	1.02	1.11	1.07	0.94	0.96	1.25
117	0.93	1.02	0.99	0.91	1.19	1.10
	K2O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.84	0.48	0.17	0.25	0.49	0.33
72	0.78	0.54	0.04	0.07	0.49	0.26
95	0.84	0.40	0.03	0.08	0.34	0.19
117	0.77	0.44	0.03	0.06	0.38	0.19

Elemental Mass Release (Normalized) and Statistics (con't)						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 6 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.181	4	0.181	0.288	0.529
47	-0.438	0.273	4	0.190	0.435	0.798
72	-0.198	0.239	4	0.199	0.380	0.698
95	0.037	0.215	4	0.223	0.342	0.628
117	-0.191	0.201	4	0.168	0.319	0.586
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.568	4	0.568	0.903	1.658
47	-2.099	1.768	4	0.571	2.813	5.163
72	0.729	0.155	4	0.574	0.247	0.453
95	-0.249	0.727	4	0.582	1.157	2.125
117	-0.100	0.760	4	0.691	1.209	2.219
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	4	0.071	0.113	0.207
47	0.160	0.076	4	0.091	0.122	0.223
72	0.224	0.085	4	0.109	0.135	0.248
95	0.160	0.125	4	0.149	0.199	0.365
117	0.226	0.074	4	0.095	0.117	0.215
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.179	3	0.179	0.445	1.027
47	-0.246	0.234	3	0.188	0.574	1.323
72	0.058	0.186	3	0.198	0.450	1.037
95	-0.075	0.239	3	0.222	0.561	1.294
117	-0.216	0.218	3	0.179	0.533	1.230

Elemental Mass Release (Normalized) and Statistics						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 6 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.152	4	0.152	0.241	0.443
47	0.063	0.152	4	0.162	0.242	0.444
72	0.075	0.160	4	0.173	0.255	0.467
95	-0.022	0.205	4	0.200	0.326	0.598
117	0.069	0.172	4	0.184	0.273	0.501
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.148	4	0.148	0.235	0.432
47	-0.020	0.162	4	0.159	0.257	0.472
72	0.044	0.162	4	0.170	0.258	0.474
95	-0.074	0.212	4	0.197	0.337	0.619
117	0.006	0.177	4	0.178	0.281	0.516
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.146	4	0.146	0.233	0.427
47	-0.073	0.168	4	0.157	0.268	0.492
72	-0.020	0.172	4	0.168	0.273	0.501
95	-0.111	0.218	4	0.196	0.347	0.636
117	-0.017	0.180	4	0.177	0.287	0.527
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.135	4	0.135	0.214	0.394
47	-0.046	0.153	4	0.146	0.244	0.447
72	-0.044	0.166	4	0.159	0.263	0.484
95	0.062	0.176	4	0.188	0.280	0.515
117	0.085	0.143	4	0.157	0.228	0.419

Elemental Mass Release (Normalized) and Statistics (con't)						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 6 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.517	0.044	3	0.091	0.103	0.237
72	0.455	0.060	4	0.109	0.135	0.312
95	0.598	0.060	4	0.149	0.132	0.305
117	0.564	0.039	3	0.090	0.092	0.212
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.120	3	0.120	0.298	0.688
47	0.831	0.022	3	0.133	0.054	0.125
72	0.962	0.006	3	0.146	0.013	0.030
95	0.973	0.005	4	0.178	0.011	0.025
117	0.973	0.004	3	0.138	0.009	0.021
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.749	0.023	3	0.091	0.053	0.123
72	0.929	0.008	4	0.109	0.018	0.040
95	0.918	0.012	4	0.149	0.027	0.062
117	0.936	0.006	3	0.102	0.015	0.035
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.513	0.044	3	0.091	0.104	0.239
72	0.507	0.054	4	0.109	0.123	0.283
95	0.656	0.051	4	0.149	0.113	0.261
117	0.616	0.034	3	0.089	0.080	0.185

Elemental Mass Release (Normalized) and Statistics (con't)						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 6 % O2		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.320	4	0.320	0.509	0.934
47	0.672	0.107	4	0.325	0.169	0.311
72	0.737	0.087	4	0.331	0.138	0.254
95	0.809	0.066	4	0.346	0.105	0.192
117	0.807	0.066	4	0.343	0.105	0.193
Ash-l						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.080	3	0.080	0.198	0.457
47	0.109	0.088	3	0.098	0.206	0.475
72	0.149	0.098	4	0.115	0.225	0.520
95	0.034	0.148	4	0.153	0.330	0.760
117	0.098	0.094	3	0.104	0.222	0.512
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.238	4	0.238	0.379	0.696
47	0.077	0.226	4	0.245	0.360	0.660
72	0.086	0.231	4	0.252	0.367	0.674
95	-0.029	0.280	4	0.272	0.445	0.817
117	0.035	0.267	4	0.276	0.424	0.778
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.513	0.044	3	0.091	0.104	0.239
72	0.507	0.054	4	0.109	0.123	0.283
95	0.656	0.051	4	0.149	0.113	0.261
117	0.616	0.034	3	0.089	0.080	0.185

Average Initial Mass Percents and Statistics						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 12 % O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	5.438	0.778	4	0.143	1.238	2.272
Al ₂ O ₃	2.543	0.354	4	0.139	0.563	1.033
TiO ₂	0.116	0.016	4	0.137	0.025	0.047
Fe ₂ O ₃	0.645	0.081	4	0.125	0.128	0.236
CaO	0.262	0.046	4	0.174	0.072	0.133
Na ₂ O	0.037	0.021	4	0.565	0.034	0.062
K ₂ O	0.183	0.006	4	0.032	0.009	0.017
MgO	0.067	0.012	3	0.172	0.029	0.066
Σ Oxides	9.290					
C	75.667	1.892	3	0.025	4.700	10.840
H	5.267	0.575	3	0.109	1.429	3.295
O	7.817	0.228	3	0.029	0.567	1.307
N	1.570	0.070	3	0.045	0.174	0.401
S	1.555	0.491	4	0.316	0.782	1.435
Ash-s	10.095	2.351	4	0.233	3.740	6.866
Ash-l	11.033	0.685	3	0.062	1.703	3.927

Residual Total Mass (m/m₀) as a Function of Residence Time						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 12 % O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.56	0.49	0.48	0.48	0.51	0.55
72	0.43	0.38	0.37	0.36	0.36	0.42
95	0.32	0.34	0.33	0.32	0.36	0.37
117	0.29	0.27	0.27	0.27	0.28	0.31

Residual Total Mass (m/m0) with Statistics						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 12 % O₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	17	1.00	0.000	0.000
47	0.50	0.038	4	0.45	0.060	0.110
72	0.38	0.027	4	0.31	0.043	0.080
95	0.33	0.007	4	0.26	0.011	0.020
117	0.27	0.010	4	0.20	0.016	0.029

Residual Elemental Mass as a Function of Residence Time						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 12 % O₂		
	SiO₂	TiO₂	Al₂O₃	Fe₂O₃	CaO	Na₂O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.02	1.05	1.04	1.03	1.17	0.50
72	1.03	1.05	1.03	0.76	1.07	1.15
95	0.97	1.01	0.99	0.71	1.32	1.61
117	1.00	1.03	1.02	0.71	0.99	1.73
	K₂O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.05	0.49	0.09	0.15	0.49	0.33
72	1.00	0.37	0.02	0.05	0.27	0.19
95	0.84	0.31	0.01	0.05	0.22	0.15
117	0.83	0.23	0.01	0.04	0.16	0.10

Elemental Mass Release (Normalized) and Statistics						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 12 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.152	4	0.152	0.241	0.443
47	-0.023	0.173	4	0.169	0.275	0.506
72	-0.026	0.172	4	0.167	0.273	0.501
95	0.026	0.149	4	0.153	0.237	0.435
117	-0.002	0.132	4	0.132	0.210	0.386
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.148	4	0.148	0.235	0.432
47	-0.039	0.172	4	0.166	0.274	0.503
72	-0.029	0.169	4	0.164	0.268	0.493
95	0.006	0.148	4	0.149	0.236	0.433
117	-0.024	0.132	4	0.129	0.210	0.386
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.146	4	0.146	0.233	0.427
47	-0.054	0.173	4	0.164	0.276	0.506
72	-0.055	0.171	4	0.162	0.273	0.500
95	-0.012	0.149	4	0.148	0.238	0.436
117	-0.029	0.133	4	0.129	0.211	0.388
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.135	4	0.135	0.214	0.394
47	-0.033	0.160	4	0.154	0.254	0.466
72	0.243	0.115	4	0.152	0.184	0.337
95	0.285	0.098	4	0.136	0.155	0.285
117	0.291	0.087	4	0.123	0.138	0.254

Elemental Mass Release (Normalized) and Statistics (con't)						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 12 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.181	4	0.181	0.288	0.529
47	-0.172	0.230	4	0.196	0.366	0.671
72	-0.073	0.209	4	0.195	0.332	0.609
95	-0.324	0.241	4	0.182	0.384	0.705
117	0.006	0.203	4	0.204	0.322	0.592
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.568	4	0.568	0.903	1.658
47	0.502	0.285	4	0.573	0.453	0.832
72	-0.146	0.656	4	0.572	1.043	1.915
95	-0.606	0.912	4	0.568	1.451	2.664
117	-0.734	0.768	4	0.443	1.221	2.242
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	4	0.071	0.113	0.207
47	-0.047	0.108	4	0.103	0.172	0.316
72	0.001	0.100	4	0.100	0.159	0.292
95	0.162	0.062	4	0.074	0.098	0.181
117	0.165	0.063	4	0.075	0.100	0.183
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.179	3	0.179	0.445	1.027
47	-0.264	0.246	3	0.194	0.596	1.374
72	-0.275	0.246	3	0.193	0.597	1.377
95	-0.498	0.270	3	0.180	0.670	1.546
117	-0.115	0.227	3	0.203	0.560	1.292

Elemental Mass Release (Normalized) and Statistics (con't)						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 12 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.506	0.051	4	0.103	0.117	0.269
72	0.633	0.037	4	0.100	0.085	0.195
95	0.689	0.023	3	0.074	0.056	0.130
117	0.772	0.019	3	0.084	0.046	0.107
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.120	3	0.120	0.298	0.688
47	0.913	0.012	3	0.142	0.029	0.067
72	0.978	0.003	3	0.139	0.007	0.017
95	0.988	0.001	3	0.122	0.004	0.008
117	0.991	0.001	3	0.137	0.003	0.007
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.853	0.015	4	0.103	0.035	0.080
72	0.955	0.005	4	0.100	0.010	0.024
95	0.951	0.004	3	0.074	0.009	0.020
117	0.963	0.003	3	0.083	0.007	0.017
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.512	0.050	4	0.103	0.115	0.266
72	0.733	0.027	4	0.100	0.061	0.142
95	0.783	0.016	3	0.074	0.039	0.090
117	0.842	0.013	3	0.085	0.032	0.074

Elemental Mass Release (Normalized) and Statistics (con't)						
Pittsburgh #8 (hvab) 106-125 μm				PSOC-1451d 12 % O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.320	4	0.320	0.509	0.934
47	0.666	0.110	4	0.329	0.174	0.320
72	0.812	0.062	4	0.328	0.098	0.180
95	0.855	0.047	4	0.321	0.074	0.136
117	0.896	0.039	4	0.375	0.062	0.114
Ash-l						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.080	3	0.080	0.198	0.457
47	0.081	0.101	3	0.110	0.233	0.537
72	0.082	0.098	3	0.107	0.227	0.524
95	0.124	0.072	3	0.082	0.178	0.410
117	0.115	0.071	3	0.081	0.171	0.395
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.238	4	0.238	0.379	0.696
47	0.024	0.244	4	0.250	0.388	0.712
72	-0.065	0.265	4	0.249	0.421	0.773
95	0.091	0.217	4	0.239	0.346	0.635
117	0.021	0.187	4	0.191	0.298	0.547
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.512	0.050	4	0.103	0.115	0.266
72	0.733	0.027	4	0.100	0.061	0.142
95	0.783	0.016	3	0.074	0.039	0.090
117	0.842	0.013	3	0.085	0.032	0.074

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE TEMPERATURE DISTRIBUTIONS**

Data and Analysis Compilation
for PSOC-1451, Pittsburgh #8 Coal

PITTSBURGH #8 COAL CHAR

COAL TYPE: Pittsburgh #8, psoc1451, 10kgcl33. 7-13-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	4	1560.8	8.2	2.38	0.01	0.680	0.069
1600.0	3	1586.5	3.8	2.41	0.04	0.458	0.108
1650.0	9	1657.3	9.8	2.44	0.31	0.528	0.165
1700.0	79	1702.5	14.1	2.57	0.14	0.954	1.106
1750.0	31	1743.9	12.7	2.58	0.03	0.766	0.322
1800.0	1	1777.5	0.0	2.60	0.00	0.294	0.000
1850.0	1	1865.2	0.0	2.60	0.00	0.945	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 128
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Pittsburgh #8, psoc1451, 15kgcl42. 7-13-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	2	1557.6	3.4	2.50	0.00	0.456	0.024
1600.0	3	1593.1	6.3	2.66	0.10	0.349	0.116
1650.0	2	1670.1	0.7	2.73	0.02	0.825	0.307
1700.0	4	1700.1	10.6	2.75	0.02	1.008	0.253
1750.0	19	1759.4	12.7	2.73	0.03	0.865	0.288
1800.0	47	1805.0	12.8	2.73	0.03	0.757	0.261
1850.0	66	1849.7	15.3	2.73	0.16	0.908	0.371
1900.0	25	1884.8	8.0	2.75	0.03	0.791	0.252
1950.0	1	1937.5	0.0	2.74	0.00	1.375	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 169
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Pittsburgh #8, psoc1451, 20kgc133. 7-13-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1448.3	0.0	2.93	0.00	0.784	0.000
1500.0	9	1505.8	15.1	2.83	0.10	0.782	0.248
1550.0	16	1554.6	15.0	2.88	0.09	0.693	0.370
1600.0	79	1599.3	12.6	2.87	0.19	0.857	0.294
1650.0	47	1644.5	13.5	2.91	0.03	0.881	0.350
1700.0	5	1689.0	7.7	2.91	0.02	0.983	0.293
1750.0	2	1739.4	18.4	2.73	0.23	0.986	0.349
1800.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 159
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Pittsburgh #8, psoc1451, 10kgc142. 7-13-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1652.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	1	1503.8	0.0	2.32	0.00	1.168	0.000
1550.0	2	1556.0	10.7	2.33	0.01	0.779	0.226
1600.0	1	1610.9	0.0	2.36	0.00	1.048	0.000
1650.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1700.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1750.0	1	1766.1	0.0	2.47	0.00	0.582	0.000
1800.0	13	1813.0	12.6	2.57	0.03	0.840	0.369
1850.0	77	1849.3	14.9	2.57	0.03	0.817	0.354
1900.0	63	1899.2	13.0	2.56	0.13	0.975	1.249
1950.0	8	1940.5	10.5	2.56	0.05	0.768	0.534
2000.0	1	1988.4	0.0	2.60	0.00	0.772	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 167
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Pittsburgh #8, psoc1451, 15kgc133. 7-13-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1472.1	0.0	2.43	0.00	0.256	0.000
1500.0	1	1505.8	0.0	2.80	0.00	0.286	0.000
1550.0	4	1557.5	16.1	2.66	0.13	0.486	0.170
1600.0	14	1606.7	12.8	2.70	0.08	0.633	0.227
1650.0	70	1654.7	12.3	2.70	0.22	0.785	0.279
1700.0	62	1693.4	12.3	2.72	0.15	0.768	0.390
1750.0	10	1751.9	13.0	2.75	0.01	0.930	0.414
1800.0	2	1779.4	6.0	2.70	0.06	1.048	0.047
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 164
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Pittsburgh #8, psoc1451, 20kgc142. 7-13-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	4	1498.0	6.6	2.74	0.07	0.800	0.295
1550.0	12	1556.7	14.2	2.83	0.08	0.647	0.300
1600.0	16	1601.4	15.0	2.91	0.03	0.928	0.258
1650.0	22	1647.0	13.2	2.92	0.03	0.885	0.321
1700.0	31	1698.1	13.6	2.90	0.03	0.892	0.305
1750.0	41	1752.5	17.3	2.90	0.03	1.042	0.405
1800.0	35	1799.5	16.4	2.90	0.02	0.987	0.347
1850.0	8	1837.1	8.0	2.93	0.03	0.840	0.323
1900.0	1	1879.6	0.0	2.93	0.00	0.406	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 170
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE SIZES, TEMPERATURES, AND VELOCITIES**

Data and Analysis Compilation
for PSOC-1451, Pittsburgh #8 Coal

COAL TYPE: PSOC-1451
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	7	1727	58	2.58	0.02	1.56	0.50
90.	11	1719	21	2.60	0.02	1.23	0.23
100.	17	1713	29	2.59	0.03	1.04	0.31
110.	14	1689	52	2.56	0.07	0.84	0.18
120.	13	1711	43	2.47	0.33	0.75	0.16
130.	14	1693	54	2.55	0.07	0.78	0.22
140.	11	1708	28	2.58	0.02	0.54	0.16
150.	16	1699	46	2.56	0.06	0.56	0.14
160.	7	1696	39	2.57	0.01	0.55	0.15
170.	3	1715	19	2.58	0.01	0.33	0.07
180.	4	1663	42	2.52	0.09	0.44	0.09
190.	2	1754	26	2.51	0.06	0.37	0.00
200.	1	1685	0	2.60	0.00	0.30	0.00
210.	1	1685	0	2.57	0.00	0.31	0.00
220.	1	1715	0	2.57	0.00	0.17	0.00
230.	2	1691	44	2.10	0.75	0.49	0.20
240.	1	1707	0	2.60	0.00	0.23	0.00

NUMBER OF PARTICLES = 125
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1451
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.1 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	1	1719	0	2.77	0.00	1.57	0.00
80.	4	1707	65	2.71	0.04	1.58	0.68
90.	23	1681	39	2.74	0.03	1.07	0.19
100.	29	1681	36	2.75	0.02	1.02	0.22
110.	8	1671	28	2.74	0.02	0.87	0.14
120.	14	1679	23	2.66	0.29	0.76	0.24
130.	27	1663	40	2.73	0.04	0.61	0.15
140.	16	1662	65	2.71	0.10	0.52	0.14
150.	14	1658	21	2.74	0.02	0.59	0.15
160.	8	1672	26	2.70	0.05	0.52	0.13
170.	7	1665	24	2.73	0.01	0.45	0.08
180.	1	1721	0	1.58	0.00	0.35	0.00
190.	2	1658	18	1.97	1.05	0.40	0.07
200.	1	1673	0	2.74	0.00	0.28	0.00
210.	0	0	0	0.00	0.00	0.00	0.00
220.	1	1593	0	2.74	0.00	0.82	0.00
230.	2	1557	73	2.73	0.11	0.39	0.14
240.	2	1609	5	2.71	0.04	0.36	0.00

NUMBER OF PARTICLES = 160
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1451
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.4 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	1	1616	0	2.93	0.00	1.27	0.00
80.	7	1643	13	2.91	0.02	1.35	0.14
90.	22	1626	45	2.90	0.08	1.19	0.22
100.	20	1613	33	2.92	0.03	1.08	0.25
110.	26	1613	44	2.90	0.04	0.92	0.20
120.	10	1619	28	2.90	0.02	0.78	0.16
130.	20	1597	38	2.86	0.08	0.76	0.20
140.	14	1606	39	2.90	0.03	0.66	0.12
150.	11	1611	24	2.91	0.03	0.57	0.11
160.	8	1611	34	2.88	0.05	0.43	0.13
170.	1	1588	0	1.71	0.00	0.58	0.00
180.	6	1568	45	2.63	0.44	0.45	0.20
190.	4	1549	32	2.90	0.03	0.57	0.21
200.	1	1485	0	2.96	0.00	0.73	0.00
210.	4	1572	51	2.92	0.03	0.48	0.26
220.	2	1541	17	2.93	0.05	0.58	0.05
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 157
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1451
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.1 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	1	1719	0	2.77	0.00	1.57	0.00
80.	4	1707	65	2.71	0.04	1.58	0.68
90.	23	1681	39	2.74	0.03	1.07	0.19
100.	29	1681	36	2.75	0.02	1.02	0.22
110.	8	1671	28	2.74	0.02	0.87	0.14
120.	14	1679	23	2.66	0.29	0.76	0.24
130.	27	1663	40	2.73	0.04	0.61	0.15
140.	16	1662	65	2.71	0.10	0.52	0.14
150.	14	1658	21	2.74	0.02	0.59	0.15
160.	8	1672	26	2.70	0.05	0.52	0.13
170.	7	1665	24	2.73	0.01	0.45	0.08
180.	1	1721	0	1.58	0.00	0.35	0.00
190.	2	1658	18	1.97	1.05	0.40	0.07
200.	1	1673	0	2.74	0.00	0.28	0.00
210.	0	0	0	0.00	0.00	0.00	0.00
220.	1	1593	0	2.74	0.00	0.82	0.00
230.	2	1557	73	2.73	0.11	0.39	0.14
240.	2	1609	5	2.71	0.04	0.36	0.00

NUMBER OF PARTICLES = 160
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1451
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.4 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	1	1616	0	2.93	0.00	1.27	0.00
80.	7	1643	13	2.91	0.02	1.35	0.14
90.	22	1626	45	2.90	0.08	1.19	0.22
100.	20	1613	33	2.92	0.03	1.08	0.25
110.	26	1613	44	2.90	0.04	0.92	0.20
120.	10	1619	28	2.90	0.02	0.78	0.16
130.	20	1597	38	2.86	0.08	0.76	0.20
140.	14	1606	39	2.90	0.03	0.66	0.12
150.	11	1611	24	2.91	0.03	0.57	0.11
160.	8	1611	34	2.88	0.05	0.43	0.13
170.	1	1588	0	1.71	0.00	0.58	0.00
180.	6	1568	45	2.63	0.44	0.45	0.20
190.	4	1549	32	2.90	0.03	0.57	0.21
200.	1	1485	0	2.96	0.00	0.73	0.00
210.	4	1572	51	2.92	0.03	0.48	0.26
220.	2	1541	17	2.93	0.05	0.58	0.05
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 157
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1451
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	2	1890	1	2.60	0.00	1.97	0.42
70.	1	1912	0	2.52	0.00	3.15	0.00
80.	6	1858	51	2.56	0.02	1.63	0.29
90.	12	1886	41	2.57	0.02	1.21	0.41
100.	22	1875	28	2.58	0.03	1.07	0.28
110.	18	1861	26	2.58	0.02	0.86	0.26
120.	16	1863	100	2.56	0.07	0.80	0.18
130.	20	1852	70	2.57	0.06	0.77	0.15
140.	21	1835	92	2.54	0.08	0.64	0.17
150.	16	1863	39	2.57	0.03	0.60	0.17
160.	8	1873	34	2.59	0.03	0.53	0.18
170.	11	1850	33	2.57	0.03	0.51	0.13
180.	3	1914	15	2.52	0.05	0.45	0.10
190.	1	1798	0	2.60	0.00	1.07	0.00
200.	3	1869	27	2.24	0.47	0.45	0.11
210.	0	0	0	0.00	0.00	0.00	0.00
220.	5	1881	31	2.59	0.01	0.21	0.04
230.	1	1814	0	2.52	0.00	0.40	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 166
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1451
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.1 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	3	1814	33	2.76	0.03	2.01	0.00
80.	8	1824	40	2.76	0.03	1.43	0.25
90.	18	1828	48	2.75	0.03	1.07	0.20
100.	29	1832	53	2.75	0.02	1.05	0.24
110.	22	1802	68	2.72	0.04	0.82	0.20
120.	18	1841	40	2.74	0.04	0.77	0.14
130.	22	1807	75	2.73	0.06	0.67	0.20
140.	15	1799	72	2.74	0.04	0.59	0.14
150.	13	1836	28	2.74	0.03	0.64	0.12
160.	9	1797	96	2.71	0.08	0.56	0.07
170.	2	1857	17	2.09	0.93	0.54	0.02
180.	3	1824	50	2.73	0.04	0.55	0.19
190.	2	1829	11	2.71	0.08	0.61	0.20
200.	2	1814	0	2.74	0.04	0.43	0.06
210.	0	0	0	0.00	0.00	0.00	0.00
220.	0	0	0	0.00	0.00	0.00	0.00
230.	1	1862	0	2.71	0.00	0.50	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 167
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1451
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.4 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	2	1621	160	2.89	0.05	1.60	0.96
70.	2	1809	53	2.93	0.00	1.56	0.01
80.	10	1782	25	2.90	0.02	1.43	0.22
90.	29	1707	83	2.91	0.04	1.16	0.32
100.	26	1691	89	2.90	0.05	1.11	0.25
110.	21	1699	81	2.90	0.02	0.95	0.19
120.	20	1714	75	2.89	0.04	0.79	0.17
130.	26	1727	92	2.87	0.06	0.74	0.18
140.	14	1679	86	2.89	0.06	0.62	0.11
150.	7	1670	41	2.91	0.04	0.60	0.17
160.	3	1679	87	2.88	0.01	0.56	0.09
170.	4	1762	62	2.89	0.00	0.51	0.17
180.	3	1626	63	2.85	0.12	0.35	0.04
190.	0	0	0	0.00	0.00	0.00	0.00
200.	1	1879	0	2.93	0.00	0.41	0.00
210.	2	1723	75	2.91	0.03	0.44	0.10
220.	0	0	0	0.00	0.00	0.00	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 170
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**KINETIC ANALYSIS
AND COMBUSTION PARAMETERS**

Data and Analysis Compilation
for PSOC-1451, Pittsburgh #8 Coal

Summary of Combustion Parameters for PSOC-1451D			
Char oxidation rate parameters $q = A \exp(-E/RT_p) P^n$	A	29	gm-C / cm ² -s-atm ⁿ
	E	24	kcal / mole
	n	0.5 *	
Product ratio parameters $CO/CO_2 = A_c \exp(-E_c/RT_p)$	A _c	4.0 x 10 ⁴ *	
	E _c	30 *	kcal / mole
Burning mode parameter $\rho/\rho_o = (m/m_o)^\alpha$ $d/d_o = (m/m_o)^{(1-\alpha)/3}$			
	α	0.1	
Char structural parameters $\omega = d_o / d_c$ (linear swelling factor) $\rho_{c,o} = m_c/V_c$ at z = 6.5 cm (initial char particle carbon density)	ω	1.10	
	ρ _{c,o}	0.4	gm / cm ³
<p>As an example, this parameter set yields a combustion rate, q, of 0.0032 gm/sq.cm-sec for a 100 μm particle in a gas with T_g = 1600 K containing 6 mole-% oxygen</p> <p>These product ratio parameters yield 6 mole-% carbon dioxide at 1900 K and 15 mole-% carbon dioxide at 1700 K</p> <p>* These particular parameters should be regarded as empirical parameters useful for the prediction of burning rates. They do not necessarily have fundamental significance or uniqueness for this data set.</p>

**CALCULATIONS OF THE COAL CHAR REACTIVITY INDEX, τ_{50} ,
FOR VARIOUS ENVIRONMENTS
PRESENT IN PULVERIZED-COAL COMBUSTION SYSTEMS**

Data and Analysis Compilation
for PSOC-1451, Pittsburgh #8 Coal

Compilation of Data and Kinetic Analyses for

**Dietz Sub-bituminous Coal
(Montana, SubB)**

PSOC-1488D

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- **Sample history, geologic information and chemical analysis of bulk, raw coal**
- **Chemical analysis of size-fractionated raw coal and partially reacted chars**
- **Time resolved measurements of the partitioning of elemental coal constituents between the gas and solid phases**
- **Mode of particle burning**
- **Statistical analyses of elemental composition measurements and derived quantities**
- **Optical measurements of single-particle temperature distributions**
- **Optical measurements of single-particle sizes, temperatures, and velocities**
- **Kinetic analysis and combustion parameters**
- **Calculations of the coal char reactivity index, τ_{50} , for various environments present in pulverized-coal combustion systems**

**SAMPLE HISTORY, GEOLOGIC INFORMATION AND
CHEMICAL ANALYSIS OF BULK, RAW COAL**

Data and Analysis Compilation
for PSOC-1488, Dietz Coal

SAMPLE HISTORY

PENN STATE NUMBER	PSOC-1488
COLLECTED BY	PENNSYLVANIA STATE UNIVERSITY
COLLECTION DATE	7/17/85
COLLECTOR'S NUMBER	
REPORTED RANK	SUBBITUMINOUS
SAMPLE TYPE	CHANNEL BENCH
OTHER SAMPLE INFORMATION	
SAMPLE RESERVE	900
SEAM NAME	DIETZ
ALTERNATE SEAM NAME	
TOTAL SEAM THICKNESS	80 FT. 0 IN.
THICKNESS OF SEAM SAMPLED	40 FT. 0 IN.
PORTION RECOVERED IN CORE	
DIAMETER OF CORE	

SAMPLE LOCATION

COUNTRY	U.S.A.
STATE	MONTANA
COUNTY	BIGHORN
TOWNSHIP	
NEAREST TOWN	DECKER
COAL PROVINCE	NORTHERN GREAT PLAINS
COAL REGION	FORT UNION
COAL FIELD	

GEOLOGIC INFORMATION

SYSTEM (AGE)	TERTIARY
SERIES	PALEOCENE
GROUP	
FORMATION	FORT UNION
OVERBURDEN LITHOLOGY	
FLOOR LITHOLOGY	GREY SHALE

SEAM STRATA INFORMATION

<u>THICKNESS</u>	<u>LITHOTYPE</u>
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SEAM NAME	DIETZ	COUNTRY	U.S.A.
APPARENT RANK	SUBBITUMINOUS B (SUBB)	STATE	MONTANA

CHEMICAL DATA 1

PROXIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF (PAFF)	DMMF (PARR-G)	DMMF (DIR MM)
% MOISTURE	23.66					
% ASH	4.08	5.35				
% VOLATILE MATTER	31.95	41.85	44.22	43.88	43.80	
% FIXED CARBON	40.31	52.80	55.78	56.12	56.20	

CALORIFIC VALUE (GROSS BTU/LB)	DRY	AS REC'D MOIST.	EQUIL MOIST.
MM-FREE, DIRECT			
MM-CONTAINING	12519	9557	9508
MM-FREE (PARR)	13299	10000	9946
MM-FREE (MOD.P)	13327	10000	9946
BEST MM FREE		10000	9946
NET CV, DMMF BTU/LB	12839		
ASH-FREE	13227		

MOTT-SPOONER DIFFERENCE = 93.

ASSOCIATED ANALYSES	DRY	MMF
% EQUILIBRIUM MOISTURE	24.05	25.60
% TOTAL SULFUR	0.50	

RANK CALCULATIONS

APPARENT RANK (AS REC'D MOIST)	SUBBITUMINOUS B (SUBB)
ASTM RANK (EQUIL. MOIST.)	SUBBITUMINOUS B (SUBB)
REFLECTANCE RANK CATEGORY	
INTERNATIONAL RANK	
AS REC'D MOIST.	
EQUIL. MOIST	
REPORTED RANK	SUBBITUMINOUS

SEAM NAME	DIETZ	COUNTRY	U.S.A.
APPARENT RANK	SUBBITUMINOUS B (SUBB)	STATE	MONTANA

CHEMICAL DATA 2

ULTIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF(PARR) (6.05 % MM)
% ASH	4.08	5.35		
% CARBON	54.91	71.93	76.00	75.56
% HYDROGEN	*3.78	4.95	5.23	5.27
% NITROGEN	0.68	0.89	0.94	0.95
% SULFUR	0.38	0.50	0.53	
% CHLORINE	0.03	0.04	0.04	0.04
% OXYGEN (DIFF)	*12.47	16.35	17.27	17.18

SULFUR FORMS	% PYRITIC	% SULFATIC	% ORGANIC	% TOTAL
DRY	0.02	0.00	0.48	0.50
DAF	0.02	0.00	0.51	0.53
OPTICAL				

ELEMENTAL ANALYSIS	DRY	DMMF (MOD.P) (6.07 % MM)	DMMF(DIR.) (% MM)
% CARBON	71.91	76.55	
% HYDROGEN	4.88	5.20	
% NITROGEN	0.89	0.95	
% ORGANIC SULFUR	0.48	0.51	
% OXYGEN (DIFF)	15.77	16.76	
% CHLORINE	0.04	0.04	
% MINERAL MATTER (INCLUDES 0.04 % FES2)	6.07		

ATOM RATIOS (DMMF)	PARR	MOD.PAR	DIRECT
ATOMIC H/C	0.827	0.815	
ATOMIC O/C	0.169	0.175	

MISC. CHEMICAL DATA	DRY	OF DMMF COAL	OF DMMF OXYGEN
% O AS COOH			
% O AS OH			
% S AS SO4, IN ASH			
% CARBONATE AS CO2	0.09		
% CHLORINE	0.07		

INFRA-RED ANALYSIS

(*)- EXCLUDES MOISTURE

SEAM NAME	DIETZ	COUNTRY	U.S.A.
APPARENT RANK	SUBBITUMINOUS B (SUBB)	STATE	MONTANA

CHEMICAL DATA 3

% MOISTURE IN COAL = 16.40
 % HIGH TEMPERATURE ASH = 3.79 AT 750 DEGREES C

TRACE ELEMENT ANALYSIS	PPM HTA	PPM TOTAL COAL	MAJOR ELEMENT ANALYSIS	OXIDE % OF HTA	ELEMENT % OF TOTAL DRY COAL
AG			SI02	32.50	0.58
B			AL2O3	19.60	0.39
BA	8010	304	TI02	1.46	0.03
BE	7	0	FE2O3	5.33	0.14
BI			MG0	5.62	0.13
CE			CA0	16.20	0.44
CO			NA2O	3.17	0.09
CR	95	4	K2O	0.37	0.01
CU	190	7	P2O5	0.24	0.00
GA			S03	12.50	0.19
GE					
LA					
LI					
MN	255	10			
MO			<u>VOLATILES</u>	<u>PPM TOTAL COAL</u>	
NI	65	2			
NB			AS		
PB			BR		
RB	20	1	CD		
SC			CL		
SN			F		
SR	5500	208	HG		
TH			SB		
U			SE		
V	260	10			
Y					
YB					
ZN	50	2			
ZR	410	316			

SEAM NAME	DIETZ	COUNTRY	U.S.A.
APPARENT RANK	SUBBITUMINOUS B (SUBB)	STATE	MONTANA

MINERALOGICAL DATA

TOTAL MINERAL MATTER

% MM-PARR	6.05
% MM-MODIFIED PARR	6.07
% MM-KMC	
% MM-DIRECT	
% MM-BEST AVAILABLE	6.07
VOL % MM-PARR	3.01

MINERAL COMPOSITION

NONE

SEAM NAME	DIETZ	COUNTRY	U.S.A.
APPARENT RANK	SUBBITUMINOUS B (SUBB)	STATE	MONTANA

PETROGRAPHIC DATA

PETROGRAPHIC DATA NOT AVAILABLE

PHYSICAL PROPERTIES

HARDGROVE GRINDABILITY	35.2
VICKER'S MICROHARDNESS	
FREE SWELLING INDEX	0.0
GRAY KING COKE TYPE	

<u>ASH FUSION ANALYSIS (DEGREES F)</u>	<u>REDUCING</u>	<u>OXIDIZING</u>
INITIAL DEFORMATION TEMPERATURE	2085	2190
SOFTENING TEMPERATURE	2101	2320
HEMISPHERE TEMPERATURE	2175	2460
FLUID TEMPERATURE	2235	2470

ANALYSIS LOG

<u>ANALYSIS</u>	<u>DATE</u>	<u>PERFORMED BY</u>
A.R. MOIST	4/25/86	WARNER LABORATORIES
EQUIL. MOIST.	4/25/86	WARNER LABORATORIES
PROXIMATE	4/25/86	WARNER LABORATORIES
ULTIMATE	4/25/86	WARNER LABORATORIES
SULFUR FORMS	4/25/86	WARNER LABORATORIES
FSI	4/8/86	COAL PETROGRAPHY LABORATORIES-PSU
PLASTOMETER		
DIRECT MM		
GRAY-KING		

**CHEMICAL ANALYSES OF SIZE-FRACTIONATED RAW COAL
AND PARTIALLY REACTED CHARS**

Data and Analysis Compilation
for PSOC-1488, Dietz Coal

**Organic Elemental Analysis and Percent Ash of Dietz Coal
and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	71.1	4.76	18.5	0.95	0.33	4.22
6.4	77.9	1.7	6.53	1.02	0.44	9.61
12.7	83.25	0.45	3.83	0.93	0.46	12.25
19.1	73.91	0.64	5.05	0.85	0.6	17.69
25.4	66.06	0.32	5.48	0.76	0.98	28.03

12 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	70.4	4.78	19.2	0.96	0.32	4.39
6.4	81.33	1.59	7.08	1.1	0.45	9.57
12.7	72.36	0.54	4.08	0.7	0.91	22.58
19.1	42.86	0.52	5.83	0.53	0.8	51.1
25.4	--	--	--	--	--	--

* Data taken in August 1988

**Ash Content of Dietz Coal and its
Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	1.02	0.732	0.067	0.152	--	--	--	--
6.4	2.34	1.63	0.141	1.45	--	--	--	--
12.7	2.83	2.05	0.184	0.883	--	--	--	--
19.1	4.49	3.12	0.274	1.49	--	--	--	--
25.4	6.99	5.09	0.449	2.17	--	--	--	--

12 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	1.05	0.739	0.067	0.162	--	--	--	--
6.4	2.34	1.64	0.146	0.627	--	--	--	--
12.7	6.27	4.27	0.353	2.37	--	--	--	--
19.1	13.5	9.76	0.799	7.85	--	--	--	--
25.4	--	--	--	--	--	--	--	--

* Data taken in August 1988

**TIME RESOLVED MEASUREMENTS OF THE
PARTITIONING OF ELEMENTAL COAL CONSTITUENTS
BETWEEN THE GAS AND SOLID PHASES**

Data and Analysis Compilation
for PSOC-1488, Dietz Coal

MODE OF PARTICLE BURNING

Data and Analysis Compilation
for PSOC-1488, Dietz Coal

Fractional Mass Remaining and Apparent Density of Dietz Coal and its Partially Reacted Chars

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.46	0.34	0.22	0.13
Fractional burnoff, daf	0.0	0.57	0.69	0.81	0.90
Apparent density, g/cc	1.21	0.45	0.38	0.37	0.32

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.43	0.18	0.08	--
Fractional burnoff, daf	0.0	0.59	0.86	0.96	--
Apparent density, g/cc	1.21	0.42	0.44	0.63	--

**STATISTICAL ANALYSES
OF ELEMENTAL COMPOSITION MEASUREMENTS
AND DERIVED QUANTITIES**

- **Raw Coal Composition**
- **Overall Combustion Conversion vs. Residence Time**
- **Elemental Partitioning between Gas and Solid Phases**

Average Initial Mass Percents and Statistics						
	Dietz subbituminous 106-125 μm			PSOC-1488d 6 % O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	1.035	0.026	2	0.025	0.232	1.165
Al ₂ O ₃	0.736	0.018	2	0.025	0.165	0.828
TiO ₂	0.067	0.002	2	0.025	0.015	0.075
Fe ₂ O ₃	0.157	0.007	2	0.045	0.064	0.318
CaO	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Na ₂ O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
K ₂ O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
MgO	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Σ Oxides	#DIV/0!					
C	70.755	1.769	2	0.025	15.892	79.620
H	4.770	0.119	2	0.025	1.071	5.368
O	18.855	0.502	2	0.027	4.511	22.598
N	0.955	0.024	2	0.025	0.215	1.075
S	0.325	0.008	2	0.025	0.073	0.366
Ash-s	4.165	0.573	2	0.138	5.146	25.781
Ash-l	4.305	0.120	2	0.028	1.080	5.411

Residual Total Mass (m/m₀) as a Function of Residence Time						
	Dietz subbituminous 106-125 μm			PSOC-1488d 6 % O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.50	0.44	0.45	0.48	0.35	0.45
72	0.29	0.37	0.36	0.36	0.41	0.35
95	0.20	0.23	0.24	0.24	0.23	0.24
117	0.11	0.15	0.14	0.15	0.15	0.15

Residual Total Mass (m/m0) with Statistics						
Dietz subbituminous 106-125 μm				PSOC-1488d 6 % O₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	6	1.00	0.000	0.000
47	0.46	0.031	3	0.43	0.077	0.178
72	0.34	0.042	5	0.31	0.052	0.085
95	0.22	0.019	3	0.19	0.048	0.111
117	0.13	0.022	3	0.10	0.055	0.127

Residual Elemental Mass as a Function of Residence Time						
Dietz subbituminous 106-125 μm				PSOC-1488d 6 % O₂		
	SiO₂	TiO₂	Al₂O₃	Fe₂O₃	CaO	Na₂O
t (ms)						
0	1.00	1.00	1.00	1.00	#DIV/0!	#DIV/0!
47	1.05	0.98	1.03	4.29	#DIV/0!	#DIV/0!
72	0.93	0.93	0.94	1.91	#DIV/0!	#DIV/0!
95	0.96	0.91	0.94	2.11	#DIV/0!	#DIV/0!
117	0.90	0.89	0.92	1.85	#DIV/0!	#DIV/0!
	K₂O	C	H	O	N	S
t (ms)						
0	#DIV/0!	1.00	1.00	1.00	1.00	1.00
47	#DIV/0!	0.51	0.17	0.16	0.50	0.63
72	#DIV/0!	0.40	0.03	0.07	0.33	0.48
95	#DIV/0!	0.23	0.03	0.06	0.20	0.41
117	#DIV/0!	0.12	0.01	0.04	0.11	0.40

Elemental Mass Release (Normalized) and Statistics						
Dietz subbituminous 106-125 μm				PSOC-1488d 6 % O2		
SiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.050	0.102	2	0.097	0.826	4.138
72	0.074	0.131	4	0.141	0.202	0.371
95	0.037	0.108	3	0.112	0.850	4.260
117	0.098	0.159	3	0.176	1.190	5.960
Al2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.029	0.100	2	0.097	0.810	4.056
72	0.058	0.133	4	0.141	0.206	0.377
95	0.058	0.106	3	0.112	0.831	4.166
117	0.076	0.163	3	0.176	1.217	6.095
TiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.022	0.095	2	0.097	0.769	3.851
72	0.070	0.132	4	0.141	0.203	0.373
95	0.092	0.102	3	0.112	0.802	4.016
117	0.105	0.158	3	0.176	1.178	5.901
Fe2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-3.290	0.417	2	0.097	3.374	16.902
72	-0.905	0.270	4	0.141	0.416	0.764
95	-1.108	0.236	3	0.112	1.860	9.320
117	-0.846	0.326	3	0.177	2.442	12.234

Elemental Mass Release (Normalized) and Statistics (con't)						
Dietz subbituminous 106-125 μm				PSOC-1488d 6 % O2		
CaO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Na2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
K2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
MgO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Dietz subbituminous 106-125 μm				PSOC-1488d 6 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.489	0.050	2	0.097	0.402	2.015
72	0.601	0.056	4	0.141	0.087	0.160
95	0.768	0.026	3	0.112	0.205	1.026
117	0.875	0.023	3	0.182	0.172	0.860
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.834	0.016	2	0.097	0.130	0.652
72	0.968	0.005	4	0.141	0.007	0.013
95	0.970	0.003	3	0.112	0.026	0.131
117	0.991	0.002	3	0.200	0.014	0.069
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.839	0.016	2	0.097	0.127	0.634
72	0.931	0.010	4	0.141	0.015	0.028
95	0.941	0.007	3	0.112	0.052	0.263
117	0.961	0.007	3	0.179	0.052	0.262
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.504	0.048	2	0.097	0.390	1.955
72	0.670	0.047	4	0.141	0.072	0.132
95	0.802	0.022	3	0.112	0.174	0.874
117	0.894	0.019	3	0.182	0.146	0.733

Elemental Mass Release (Normalized) and Statistics (con't)						
Dietz subbituminous 106-125 μm				PSOC-1488d 6 % O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.371	0.061	2	0.097	0.495	2.478
72	0.520	0.068	4	0.141	0.105	0.192
95	0.590	0.046	3	0.112	0.362	1.813
117	0.597	0.071	3	0.176	0.530	2.656
Ash-l						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.037	0.101	2	0.097	0.815	4.085
72	0.036	0.136	4	0.141	0.210	0.386
95	0.087	0.102	3	0.112	0.805	4.035
117	0.131	0.153	3	0.176	1.146	5.741
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.146	2	0.146	1.315	6.586
47	-0.342	0.216	2	0.161	1.861	9.321
72	0.178	0.157	3	0.191	0.375	0.866
95	0.049	0.162	2	0.170	1.367	6.850
117	0.129	0.170	3	0.196	1.311	6.569
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.504	0.048	2	0.097	0.390	1.955
72	0.670	0.047	4	0.141	0.072	0.132
95	0.802	0.022	3	0.112	0.174	0.874
117	0.894	0.019	3	0.182	0.146	0.733

Average Initial Mass Percents and Statistics						
Dietz subbituminous 106-125 μm				PSOC-1488d 12 % O ₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	1.035	0.026	2	0.025	0.232	1.165
Al ₂ O ₃	0.736	0.018	2	0.025	0.165	0.828
TiO ₂	0.067	0.002	2	0.025	0.015	0.075
Fe ₂ O ₃	0.157	0.007	2	0.045	0.064	0.318
CaO	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Na ₂ O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
K ₂ O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
MgO	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Σ Oxides	#DIV/0!					
C	70.755	1.769	2	0.025	15.892	79.620
H	4.770	0.119	2	0.025	1.071	5.368
O	18.855	0.502	2	0.027	4.511	22.598
N	0.955	0.024	2	0.025	0.215	1.075
S	0.325	0.008	2	0.025	0.073	0.366
Ash-s	4.165	0.573	2	0.138	5.146	25.781
Ash-l	4.305	0.120	2	0.028	1.080	5.411

Residual Total Mass (m/m ₀) as a Function of Residence Time						
Dietz subbituminous 106-125 μm				PSOC-1488d 12 % O ₂		
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.41	0.44	0.45	0.46	0.52	0.45
72	0.19	0.17	0.17	0.19	0.20	0.19
95	0.08	0.08	0.08	0.08	0.09	0.08
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Residual Total Mass (m/m0) with Statistics						
Dietz subbituminous 106-125 μm				PSOC-1488d 12 % O ₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	6	1.00	0.000	0.000
47	0.43	0.021	5	0.41	0.027	0.044
72	0.18	0.013	3	0.14	0.033	0.075
95	0.08	0.005	3	0.04	0.012	0.027
117	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!

Residual Elemental Mass as a Function of Residence Time						
Dietz subbituminous 106-125 μm				PSOC-1488d 12 % O ₂		
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O
t (ms)						
0	1.00	1.00	1.00	1.00	#DIV/0!	#DIV/0!
47	0.98	0.95	0.97	1.73	#DIV/0!	#DIV/0!
72	1.07	0.93	1.02	2.66	#DIV/0!	#DIV/0!
95	1.03	0.94	1.04	3.94	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	K ₂ O	C	H	O	N	S
t (ms)						
0	#DIV/0!	1.00	1.00	1.00	1.00	1.00
47	#DIV/0!	0.50	0.14	0.16	0.50	0.60
72	#DIV/0!	0.18	0.02	0.04	0.13	0.49
95	#DIV/0!	0.05	0.01	0.02	0.04	0.19
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics						
Dietz subbituminous 106-125 μm				PSOC-1488d 12 % O2		
SiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.020	0.084	3	0.086	0.621	3.113
72	-0.066	0.110	3	0.103	0.877	4.393
95	-0.027	0.096	2	0.093	0.781	3.911
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Al2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.034	0.083	3	0.086	0.612	3.068
72	-0.022	0.105	3	0.103	0.840	4.210
95	-0.045	0.097	2	0.093	0.794	3.979
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
TiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.053	0.082	3	0.086	0.600	3.007
72	0.073	0.095	3	0.103	0.763	3.821
95	0.061	0.087	2	0.093	0.714	3.576
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Fe2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.733	0.149	3	0.086	1.099	5.507
72	-1.656	0.273	3	0.103	2.185	10.948
95	-2.937	0.367	2	0.093	2.993	14.992
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Dietz subbituminous 106-125 μm				PSOC-1488d 12 % O2		
CaO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Na2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
K2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
MgO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Dietz subbituminous 106-125 μm				PSOC-1488d 12 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.501	0.043	3	0.086	0.317	1.586
72	0.820	0.019	3	0.103	0.148	0.742
95	0.952	0.004	2	0.093	0.036	0.182
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.855	0.012	3	0.086	0.092	0.460
72	0.980	0.002	3	0.103	0.016	0.082
95	0.991	0.001	2	0.093	0.007	0.033
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.837	0.014	3	0.086	0.103	0.518
72	0.962	0.004	3	0.103	0.031	0.157
95	0.976	0.002	2	0.093	0.019	0.093
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.500	0.043	3	0.086	0.317	1.590
72	0.871	0.013	3	0.103	0.106	0.532
95	0.956	0.004	2	0.093	0.033	0.166
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Dietz subbituminous 106-125 μm				PSOC-1488d 12 % O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.399	0.052	3	0.086	0.381	1.911
72	0.507	0.051	3	0.103	0.405	2.031
95	0.806	0.018	2	0.093	0.147	0.738
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Ash-l						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.035	0.083	3	0.086	0.612	3.066
72	0.077	0.095	3	0.103	0.759	3.804
95	0.065	0.087	2	0.093	0.710	3.559
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.146	2	0.146	1.315	6.586
47	0.172	0.128	2	0.154	1.070	5.360
72	0.116	0.145	2	0.164	1.243	6.227
95	0.085	0.145	2	0.158	1.257	6.299
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.500	0.043	3	0.086	0.317	1.590
72	0.871	0.013	3	0.103	0.106	0.532
95	0.956	0.004	2	0.093	0.033	0.166
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE TEMPERATURE DISTRIBUTIONS**

Data and Analysis Compilation
for PSOC-1488, Dietz Coal

6 mole-% Oxygen
Environment

12 mole-% Oxygen
Environment

DIETZ COAL CHAR

COAL TYPE: Dietz, psoc-1488. 7-05-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1650.0	1	1666.3	0.0	2.52	0.00	0.598	0.000
1700.0	65	1714.5	8.0	2.59	0.02	0.750	0.239
1750.0	209	1744.7	12.4	2.58	0.16	0.617	0.187
1800.0	11	1785.7	8.6	2.58	0.05	0.505	0.150
1850.0	1	1844.0	0.0	2.65	0.00	0.206	0.000
1900.0	1	1884.9	0.0	2.65	0.00	0.104	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 288
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Dietz, psoc-1488, 15kgcl33. 7-05-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1650.0	4	1664.8	8.8	2.71	0.04	1.007	0.195
1700.0	100	1708.7	12.3	2.76	0.03	0.701	0.237
1750.0	145	1743.1	14.0	2.78	0.12	0.496	0.145
1800.0	19	1792.4	12.7	2.80	0.04	0.350	0.129
1850.0	1	1846.2	0.0	2.86	0.00	0.145	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 269
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Dietz, psoc-1488, 20kgcl33. 7-05-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	1	1522.1	0.0	2.74	0.00	0.860	0.000
1550.0	1	1532.6	0.0	3.00	0.00	0.010	0.000
1600.0	4	1600.7	8.3	2.90	0.04	0.318	0.391
1650.0	18	1660.9	13.0	2.93	0.04	0.573	0.215
1700.0	118	1703.4	12.5	2.95	0.11	0.509	0.158
1750.0	98	1744.3	14.1	2.97	0.03	0.351	0.124
1800.0	21	1788.7	9.0	2.97	0.04	0.209	0.121
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 261
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Dietz, psoc-1488, 10kgcl42. 7-05-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1652.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1650.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1700.0	1	1684.1	0.0	2.30	0.00	0.414	0.000
1750.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1800.0	3	1797.8	9.1	2.57	0.02	0.213	0.157
1850.0	8	1853.2	13.1	2.55	0.03	0.648	0.321
1900.0	86	1905.7	13.0	2.58	0.03	0.575	0.144
1950.0	113	1947.4	13.6	2.58	0.10	0.415	0.131
2000.0	63	1993.1	13.5	2.60	0.07	0.270	0.162
2050.0	3	2030.4	3.3	2.58	0.02	0.685	0.880
2100.0	2	2095.7	9.2	64.80	88.49	0.577	0.535
2150.0	1	2150.8	0.0	2.60	0.00	0.045	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 280
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Dietz, psoc-1488, 15kgc142. 7-05-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1650.0	12	1659.1	15.1	2.72	0.05	0.185	0.216
1700.0	10	1693.5	4.5	2.71	0.05	0.092	0.100
1750.0	12	1747.3	12.1	2.75	0.04	0.087	0.108
1800.0	17	1807.4	12.6	2.71	0.08	0.281	0.376
1850.0	13	1843.4	13.1	2.75	0.04	0.431	0.376
1900.0	32	1902.7	15.8	2.76	0.04	0.502	0.266
1950.0	68	1953.8	15.5	2.76	0.05	0.318	0.214
2000.0	29	1989.4	9.1	2.76	0.05	0.208	0.129
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	1	2082.0	0.0	127.37	0.00	0.959	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 194

PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE SIZES, TEMPERATURES, AND VELOCITIES**

Data and Analysis Compilation
for PSOC-1488, Dietz Coal

COAL TYPE: PSOC-1488
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	1	1741	0	2.63	0.00	1.02	0.00
100.	5	1750	19	2.60	0.03	0.96	0.18
110.	17	1737	10	2.61	0.02	0.88	0.17
120.	43	1747	34	2.60	0.03	0.70	0.24
130.	61	1745	16	2.60	0.02	0.63	0.20
140.	61	1741	21	2.59	0.03	0.62	0.17
150.	44	1737	15	2.53	0.26	0.58	0.15
160.	22	1729	18	2.59	0.03	0.61	0.21
170.	10	1725	9	2.57	0.04	0.56	0.12
180.	11	1737	19	2.46	0.38	0.56	0.23
190.	3	1707	4	2.57	0.02	0.46	0.06
200.	3	1736	27	2.61	0.01	0.51	0.18
210.	2	1709	19	2.59	0.02	0.47	0.02
220.	2	1708	11	2.60	0.04	0.53	0.06
230.	0	0	0	0.00	0.00	0.00	0.00
240.	1	1720	0	2.55	0.00	0.43	0.00

NUMBER OF PARTICLES = 286
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1488
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.1 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	1	1778	0	2.80	0.00	0.72	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	5	1746	42	2.79	0.01	0.88	0.47
100.	17	1709	232	2.79	0.04	1.13	2.23
110.	50	1741	26	2.79	0.02	0.62	0.23
120.	67	1735	23	2.78	0.03	0.57	0.16
130.	44	1732	20	2.77	0.03	0.55	0.22
140.	38	1728	23	2.73	0.20	0.51	0.18
150.	21	1721	22	2.77	0.04	0.55	0.26
160.	11	1703	16	2.75	0.03	0.53	0.16
170.	4	1700	21	2.75	0.02	0.69	0.09
180.	4	1710	17	2.76	0.02	0.41	0.03
190.	2	1686	51	2.71	0.04	0.65	0.54
200.	2	1700	26	2.76	0.02	0.49	0.11
210.	2	1681	4	2.76	0.02	0.58	0.01
220.	1	1758	0	3.31	0.00	0.07	0.00
230.	1	1694	0	2.77	0.00	0.50	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 270
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1488
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	3	1736	37	3.00	0.00	0.28	0.22
70.	1	1742	0	2.89	0.00	0.34	0.00
80.	4	1752	17	2.94	0.03	0.48	0.11
90.	9	1756	29	2.99	0.05	0.49	0.33
100.	26	1738	35	2.97	0.02	0.42	0.23
110.	73	1731	36	2.97	0.04	0.38	0.15
120.	45	1722	39	2.95	0.05	0.42	0.19
130.	46	1706	35	2.96	0.04	0.46	0.16
140.	28	1705	26	2.95	0.04	0.45	0.14
150.	10	1696	42	2.93	0.04	0.42	0.18
160.	9	1667	26	2.92	0.04	0.63	0.23
170.	2	1628	49	2.91	0.03	0.38	0.36
180.	1	1714	0	1.81	0.00	0.32	0.00
190.	1	1662	0	2.86	0.00	0.55	0.00
200.	2	1705	64	2.94	0.12	0.28	0.23
210.	0	0	0	0.00	0.00	0.00	0.00
220.	0	0	0	0.00	0.00	0.00	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 260
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1488
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	1	1994	0	2.57	0.00	0.54	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	3	1981	6	2.59	0.03	0.73	0.15
80.	2	1967	36	2.59	0.02	0.60	0.30
90.	4	1979	33	2.59	0.02	0.41	0.19
100.	22	1977	33	8.27	****	0.44	0.18
110.	43	1954	38	2.60	0.03	0.41	0.16
120.	54	1947	32	2.60	0.04	0.42	0.18
130.	50	1942	37	2.59	0.04	0.43	0.20
140.	40	1922	42	2.58	0.06	0.49	0.20
150.	26	1923	38	2.58	0.03	0.46	0.18
160.	17	1920	74	2.59	0.03	0.44	0.26
170.	3	1925	49	2.70	0.11	0.36	0.22
180.	1	1905	0	2.60	0.00	0.27	0.00
190.	3	1875	12	2.56	0.01	0.44	0.04
200.	3	1927	23	2.62	0.02	0.24	0.14
210.	2	1927	29	2.06	0.66	0.24	0.02
220.	3	2011	67	2.49	0.19	0.08	0.08
230.	0	0	0	0.00	0.00	0.00	0.00
240.	1	1931	0	2.65	0.00	0.02	0.00

NUMBER OF PARTICLES = 278
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1488
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.1 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	3	1777	138	2.75	0.01	0.55	0.26
60.	2	1832	225	2.70	0.06	0.21	0.03
70.	3	1911	80	2.75	0.01	0.41	0.27
80.	5	1950	33	2.76	0.05	0.54	0.27
90.	8	1904	119	2.77	0.03	0.33	0.15
100.	12	1871	107	2.76	0.05	0.37	0.27
110.	28	1954	53	7.21	****	0.34	0.20
120.	33	1879	112	2.73	0.05	0.34	0.23
130.	20	1892	93	2.76	0.04	0.29	0.22
140.	15	1864	102	2.73	0.04	0.29	0.32
150.	12	1827	89	2.76	0.05	0.30	0.34
160.	10	1833	104	2.73	0.06	0.27	0.36
170.	11	1882	92	2.74	0.03	0.15	0.20
180.	5	1914	51	2.76	0.05	0.22	0.32
190.	6	1863	120	2.73	0.05	0.08	0.05
200.	3	1835	35	2.58	0.09	0.02	0.00
210.	5	1854	78	2.80	0.02	0.18	0.07
220.	3	1932	25	2.76	0.09	0.04	0.04
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 184
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**KINETIC ANALYSIS
AND COMBUSTION PARAMETERS**

Data and Analysis Compilation
for PSOC-1488, Dietz Coal

Summary of Combustion Parameters for PSOC-1488		
Char oxidation rate parameters $q = A \exp(-E/RT_p) P^n$	A E n	Chars burned at their diffusion limited rates (zone 3) in both 6 and 12 mole-% oxygen.
Product ratio parameters $CO/CO_2 = A_c \exp(-E_c/RT_p)$	A_c E_c	5×10^8 * 60 * kcal / mole
Burning mode parameter $\rho/\rho_o = (m/m_o)^\alpha$ $d/d_o = (m/m_o)^{(1-\alpha)/3}$	α	0.25
Char structural parameters $\omega = d_o / d_c$ (linear swelling factor) $\rho_{c,o} \equiv mc/Vc$ at $z = 6.5$ cm (initial char particle carbon density)	ω ρ_{c,o}	1.04 0.41 gm / cm ³
<p>As an example, this parameter set yields a combustion rate, q, of 0.0072 gm/sq.cm-sec in a gas with a temperature of 1600 K containing 6 mole-% oxygen</p> <p>These product ratio parameters yield an average of 7 mole-% carbon dioxide in the 6 mole-% oxygen environment and 1 mole-% carbon dioxide in the 12 mole-% oxygen environment</p> <p>* These particular parameters should be regarded as empirical parameters, useful for the prediction of burning rates. They do not necessarily have fundamental significance and/or are not necessarily unique for this data set.</p>

Measured Carbon Conversions in the CCL
for PSOC-1488

**CALCULATIONS OF THE COAL CHAR REACTIVITY INDEX, τ_{50} ,
FOR VARIOUS ENVIRONMENTS
PRESENT IN PULVERIZED-COAL COMBUSTION SYSTEMS**

Data and Analysis Compilation
for PSOC-1488, Dietz Coal

Compilation of Data and Kinetic Analyses for

**Illinois #6 Bituminous Coal
(hvB)**

PSOC-1493D

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- **Chemical analysis of size-fractionated raw coal and partially reacted chars**
- **Time resolved measurements of the partitioning of elemental coal constituents between the gas and solid phases**
- **Mode of particle burning**
- **Statistical analyses of elemental composition measurements and derived quantities**
- **Optical measurements of single-particle temperature distributions**
- **Optical measurements of single-particle sizes, temperatures, and velocities**
- **Kinetic analysis and combustion parameters**
- **Calculations of the coal char reactivity index, τ_{50} , for various environments present in pulverized-coal combustion systems**

**SAMPLE HISTORY, GEOLOGIC INFORMATION AND
CHEMICAL ANALYSIS OF BULK, RAW COAL**

Data and Analysis Compilation
for PSOC-1493, Illinois #6 Coal

SAMPLE HISTORY

PENN STATE NUMBER	PSOC-1493
COLLECTED BY	PENNSYLVANIA STATE UNIVERSITY
COLLECTION DATE	9/1/85
COLLECTOR'S NUMBER	
REPORTED RANK	HIGH VOLATILE B BITUMINOUS (HVBB)
SAMPLE TYPE	CHANNEL WHOLE SEAM
OTHER SAMPLE INFORMATION	
SAMPLE RESERVE	900
SEAM NAME	ILLINOIS #6
ALTERNATE SEAM NAME	HERRIN
TOTAL SEAM THICKNESS	5 FT. 6 IN.
THICKNESS OF SEAM SAMPLED	5 FT. 6 IN.
PORTION RECOVERED IN CORE	
DIAMETER OF CORE	

SAMPLE LOCATION

COUNTRY	U.S.A.
STATE	ILLINOIS
COUNTY	PERRY
TOWNSHIP	SIX MILE PRAIRIE
NEAREST TOWN	CUTLER
COAL PROVINCE	INTERIOR
COAL REGION	EASTERN
COAL FIELD	

GEOLOGIC INFORMATION

SYSTEM (AGE)	PENNSYLVANIAN
SERIES	
GROUP	
FORMATION	CARBONDALE
OVERBURDEN LITHOLOGY	SHALE
FLOOR LITHOLOGY	CLAY

SEAM STRATA INFORMATION

<u>THICKNESS</u>	<u>LITHOTYPE</u>
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SEAM NAME	ILLINOIS #6	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	ILLINOIS

CHEMICAL DATA 1

PROXIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF (PAFF)	DMMF (PARR-G)	DMMF (DIR MM)
% MOISTURE	9.43					
% ASH	13.74	15.17				
% VOLATILE MATTER	34.34	37.91	44.69	42.91	42.93	
% FIXED CARBON	42.50	46.92	55.31	57.09	57.07	

CALORIFIC VALUE (GROSS BTU/LB)	DRY	AS REC'D MOIST.	EQUIL MOIST.
MM-FREE, DIRECT			
MM-CONTAINING	11963	10835	10637
MM-FREE (PARR)	14484	12832	12550
MM-FREE (MOD.P)	14485	12707	12430
BEST MM FREE		12707	12430
NET CV, DMMF BTU/LB	14011		
ASH-FREE	14102		

MOTT-SPOONER DIFFERENCE =

ASSOCIATED ANALYSES	DRY	MMF
% EQUILIBRIUM MOISTURE	11.08	13.70
% TOTAL SULFUR	4.98	

RANK CALCULATIONS

APPARENT RANK (AS REC'D MOIST)	HIGH VOLATILE C BITUMINOUS (HVCB)
ASTM RANK (EQUIL. MOIST.)	HIGH VOLATILE C BITUMINOUS (HVCB)
REFLECTANCE RANK CATEGORY	HIGH VOLATILE C BITUMINOUS (HVCB)
INTERNATIONAL RANK	
AS REC'D MOIST.	
EQUIL. MOIST	
REPORTED RANK	HIGH VOLATILE B BITUMINOUS (HVBB)

SEAM NAME	ILLINOIS #6	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	ILLINOIS

CHEMICAL DATA 2

ULTIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF(PARR) (19.12 % MM)
% ASH	13.74	15.17		
% CARBON	59.98	66.23	78.07	81.89
% HYDROGEN	*3.78	4.17	4.92	5.16
% NITROGEN	1.15	1.27	1.50	1.57
% SULFUR	4.51	4.98	5.87	
% CHLORINE	0.03	0.03	0.04	0.04
% OXYGEN (DIFF)	*7.38	8.15	9.61	11.35

SULFUR FORMS	% PYRITIC	% SULFATIC	% ORGANIC	% TOTAL
DRY	2.61	0.04	2.33	4.98
DAF	3.08	0.05	2.75	5.87
OPTICAL				

ELEMENTAL ANALYSIS	DRY	DMMF (MOD.P) (18.38 % MM)	DMMF(DIR.) (% MM)
% CARBON	66.07	80.96	
% HYDROGEN	4.44	5.44	
% NITROGEN	1.27	1.57	
% ORGANIC SULFUR	2.33	2.85	
% OXYGEN (DIFF)	7.50	9.16	
% CHLORINE	0.03	0.04	
% MINERAL MATTER (INCLUDES 4.88 % FES2)	18.38		

ATOM RATIOS (DMMF)	PARR	MOD.PAR	DIRECT
ATOMIC H/C	0.756	0.807	
ATOMIC O/C	0.104	0.104	

MISC. CHEMICAL DATA	DRY	OF DMMF COAL	OF DMMF OXYGEN
% O AS COOH			
% O AS OH			
% S AS SO4, IN ASH			
% CARBONATE AS CO2	0.57		
% CHLORINE	0.06		

INFRA-RED ANALYSIS

(*)- EXCLUDES MOISTURE

SEAM NAME	ILLINOIS #6	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	ILLINOIS

CHEMICAL DATA 3

% MOISTURE IN COAL = 2.37

% HIGH TEMPERATURE ASH = 14.30 AT 750 DEGREES C

TRACE ELEMENT ANALYSIS	PPM HTA	PPM TOTAL COAL	MAJOR ELEMENT ANALYSIS	OXIDE % OF HTA	ELEMENT % OF TOTAL DRY COAL
AG			SI02	41.20	2.75
B			AL203	15.70	1.19
BA	540	77	TI02	0.76	0.07
BE	9	1	FE203	23.90	2.39
BI			MG0	0.90	0.08
CE			CA0	7.39	0.76
CO			NA20	0.40	0.04
CR	130	19	K20	1.70	0.20
CU	120	17	P205	0.26	0.02
GA			S03	7.90	0.45
GE					
LA					
LI					
MN	430	61			
MO			<u>VOLATILES</u>	<u>PPM TOTAL COAL</u>	
NI	60	9			
NB			AS		
PB			BR		
RB	100	14	CD		
SC			CL		
SN			F		
SR	170	24	HG		
TH			SB		
U			SE		
V	220	31			
Y					
YB					
ZN	440	63			
ZR	150	21			

SEAM NAME	ILLINOIS #6	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	ILLINOIS

MINERALOGICAL DATA

TOTAL MINERAL MATTER

% MM-PARR	19.12
% MM-MODIFIED PARR	18.38
% MM-KMC	
% MM-DIRECT	
% MM-BEST AVAILABLE	18.38
VOL % MM-PARR	10.23

MINERAL COMPOSITION

NONE

SEAM NAME	ILLINOIS #6	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	ILLINOIS

PETROGRAPHIC DATA

MACERAL COMPOSITION WHITE ANALYSIS ONLY

	<u>DRY</u> <u>VOLUME %</u>	<u>DMMF</u> <u>VOLUME %</u>	<u>DRY</u> <u>WEIGHT %</u>
VITRINITE (CALC.)	77.6	86.4	69.9
INERTINITE (CALC.)	11.0	12.2	9.9
LIPTINITE (CALC.)	1.3	1.4	1.1
MINERAL MATTER (CALC.)	10.2		19.1
VITRINOIDS			
VITRINITE	77.6	86.4	69.9
PSEUDOVITRINITE	0.0	0.0	0.0
FUSINITE	3.2	3.6	2.9
SEMI-FUSINITE	4.8	5.4	4.4
MACRINITE	0.4	0.5	0.4
MICRINITE	2.4	2.7	2.2
SCLEROTINITE	0.0	0.0	0.0
SPORINITE			
CUTINITE			
EXINITE (ANAL.)	1.1	1.2	1.0
RESINITE	0.2	0.2	0.2
SUBERINITE			
EXUDATINITE			
FLUORINITE			
BITUMINITE			
ALGINITE	0.0	0.0	0.0
LIPTODETRINITE			
MINERAL MATTER (ANAL.)			
INERTINITE (ANAL.)			
LIPTODETRINITE (ANAL.)			

<u>REFLECTANCE DATA</u>	<u>HIGH</u>	<u>LOW</u>	<u>RANGE</u>	<u>MEAN MAX</u>	<u>STAND.DEV.</u>
(%, IN OIL)					
VITRINITE	0.68	0.42	0.26	0.53	0.06
PSEUDOVITRINITE					
VITRINOIDS					

**CHEMICAL ANALYSES OF SIZE-FRACTIONATED RAW COAL
AND PARTIALLY REACTED CHARS**

Data and Analysis Compilation
for PSOC-1493, Illinois #6 Coal

**Organic Elemental Analysis and Percent Ash of Illinois #6 Coal
and its Partially Reacted Chars**

Initial particle size range: 75 - 106 μm

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	69.45	4.54	11.83	1.406	5.56	11.44
6.4	66.59	0.74	3.07	1.08	3.45	26.85
12.7	69.82	0.49	3.71	1.05	2.12	28.54
19.1	65.90	0.35	2.83	1.02	2.13	32.12
25.4	60.83	0.34	4.87	0.91	2.06	35.16

12 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	68.11	4.32	12.21	1.32	4.86	11.1
6.4	69.67	0.76	3.64	1	3.84	25.19
12.7	62.42	1.16	6.12	0.91	3.34	29.38
19.1	60.06	0.39	3.89	0.82	1.73	41.2
25.4	41.71	0.14	11.4	0.51	1.13	58.02

* Data taken in November 1987

**Organic Elemental Analysis and Percent Ash of Illinois #6 Coal
and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	69.46	4.50	12.33	1.14	5.50	11.2
6.4	66.58	1.12	6.86	1.21	4.57	23.8
12.7	67.96	0.43	5.44	1.12	3.98	22.7
19.1	69.73	1.03	4.87	1.09	3.17	22.7
25.4	63.22	0.49	4.82	1.11	3.02	28.2

12 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	71.87	4.73	12.45	1.25	4.5	10.9
6.4	63.20	0.39	4.43	1.07	4.07	28.3
12.7	63.43	0.36	4.43	0.80	3.54	25.6
19.1	59.50	0.44	5.67	0.77	2.50	36.1
19.1	56.10	0.20	4.65	0.50	2.22	42.3
25.4	46.86	0.24	6.77	0.55	1.93	49.8

* Data taken in November 1987

**Ash Content of Illinois #6 Coal and its
Partially Reacted Chars**

Initial particle size range: 75 - 106 μm

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	3.54	1.43	0.087	4.36	0.722	0.022	0.197	0.094
6.4	10.5	4.05	0.221	7.33	1.45	0.195	0.343	0.204
12.7	11.6	4.55	0.252	7.05	1.52	0.033	0.386	0.229
19.1	13.3	5.12	0.278	6.64	1.87	<0.01	0.510	0.187
25.4	14.1	5.64	0.291	6.79	2.08	<0.01	0.402	0.226

12 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	3.69	1.44	0.088	4.05	0.670	<0.01	0.161	0.099
6.4	9.45	3.64	0.203	6.97	2.67	0.655	0.459	0.192
12.7	10.7	4.67	0.261	8.06	1.59	<0.01	0.43	0.198
19.1	16.79	6.5	0.342	8.70	4.21	0.506	0.598	0.284
25.4	22.6	9.27	0.481	13.55	3.86	<0.01	1.02	0.433

* Data taken in November 1987

**Ash Content of Illinois #6 Coal and its
Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	3.8	1.6	0.084	2.7	0.51	--	0.18	0.05
6.4	9.1	3.4	0.180	6.9	1.13	--	0.39	0.10
12.7	9.5	3.8	0.214	4.7	0.84	--	0.44	0.11
19.1	10.0	3.8	0.200	4.2	1.00	--	0.47	0.13
25.4	11.6	4.4	0.233	5.4	1.37	--	0.54	0.14

12 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	3.70	1.60	0.086	3.34	0.51	--	0.16	0.05
6.4	8.50	3.4	0.184	8.1	1.07	--	0.40	0.12
12.7	12.2	4.5	0.256	5.0	0.85	--	0.33	0.11
19.1	15.4	5.8	0.296	7.7	2.08	--	0.54	0.19
19.1	17.9	6.6	0.326	8.4	2.88	--	0.63	0.14
25.4	19.0	8.0	0.408	10.3	3.28	--	0.74	0.19

* Data taken in November 1987

**TIME RESOLVED MEASUREMENTS OF THE
PARTITIONING OF ELEMENTAL COAL CONSTITUENTS
BETWEEN THE GAS AND SOLID PHASES**

Data and Analysis Compilation
for PSOC-1493, Illinois #6 Coal

MODE OF PARTICLE BURNING

Data and Analysis Compilation
for PSOC-1493, Illinois #6 Coal

**Fractional Mass Remaining and Apparent Density
of Illinois #6 Coal and its Partially Reacted Chars**

Initial particle size range: 75 - 106 μ m

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m _O	1.0	0.35	0.31	0.28	0.26
Fractional burnoff, daf	0.0	0.71	0.75	0.81	0.82
Apparent density, g/cc	1.21	0.47	0.49	0.46	0.45

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m _O	1.0	0.39	0.31	0.22	0.15
Fractional burnoff, daf	0.0	0.67	0.75	0.90	0.93
Apparent density, g/cc	1.21	0.52	0.53	0.39	0.43

**Fractional Mass Remaining and Apparent Density
of Illinois #6 Coal and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μ m

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m _O	1.0	0.49	0.44	0.43	0.38
Fractional burnoff, daf	0.0	0.58	0.62	0.67	0.69
Apparent density, g/cc	1.21	--	--	--	--

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m _O	1.0	0.50	0.36	0.28	0.22
Fractional burnoff, daf	0.0	0.58	0.70	0.84	0.87
Apparent density, g/cc	1.21	--	--	--	--

**STATISTICAL ANALYSES
OF ELEMENTAL COMPOSITION MEASUREMENTS
AND DERIVED QUANTITIES**

- **Raw Coal Composition**
- **Overall Combustion Conversion vs. Residence Time**
- **Elemental Partitioning between Gas and Solid Phases**

Data and Analysis Compilation
for PSOC-1493, Illinois #6 Coal

Average Initial Mass Percents and Statistics						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 6% O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	3.613	0.221	4	0.061	0.351	0.644
Al ₂ O ₃	1.433	0.070	4	0.049	0.112	0.206
TiO ₂	0.088	0.004	4	0.042	0.006	0.011
Fe ₂ O ₃	4.200	0.577	4	0.137	0.919	1.686
CaO	0.696	0.143	4	0.206	0.228	0.418
Na ₂ O	0.096	0.020	4	0.208	0.032	0.059
K ₂ O	0.179	0.055	4	0.310	0.088	0.162
MgO	0.011	0.022	4	2.000	0.034	0.063
Σ Oxides	10.314					
C	68.613	1.715	3	0.025	4.261	9.829
H	4.733	0.537	3	0.113	1.334	3.076
O	10.473	2.686	3	0.256	6.672	15.389
N	1.353	0.065	4	0.048	0.103	0.190
S	5.228	0.385	4	0.074	0.613	1.125
Ash-s	11.830	1.321	4	0.112	2.102	3.858
Ash-l	11.270	0.546	4	0.048	0.869	1.595

Residual Total Mass (m/m₀) as a Function of Residence Time						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 6% O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.50	0.34	0.35	0.40	0.46	0.42
72	0.39	0.31	0.31	0.35	0.43	0.39
95	0.32	0.27	0.28	0.31	0.34	0.35
117	0.25	0.26	0.25	0.30	0.31	0.32

Residual Total Mass (m/m0) with Statistics						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 6% O ₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	8	1.00	0.000	0.000
47	0.35	0.007	2	0.29	0.061	0.307
72	0.31	0.002	2	0.25	0.022	0.109
95	0.28	0.006	2	0.21	0.052	0.260
117	0.26	0.002	4	0.18	0.002	0.005

Residual Elemental Mass as a Function of Residence Time						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 6% O ₂		
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.01	0.88	0.99	0.61	0.73	0.74
72	1.01	0.90	0.99	0.53	0.68	0.75
95	1.02	0.88	0.99	0.44	0.74	0.54
117	1.00	0.85	1.00	0.41	0.76	0.60
	K ₂ O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.67	0.34	0.05	0.10	0.28	0.23
72	0.68	0.32	0.03	0.11	0.24	0.13
95	0.79	0.26	0.02	0.07	0.21	0.11
117	0.57	0.23	0.02	0.12	0.17	0.10

Elemental Mass Release (Normalized) and Statistics						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 6% O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.079	4	0.079	0.126	0.230
47	-0.014	0.082	4	0.081	0.180	0.415
72	-0.005	0.080	4	0.079	0.172	0.397
95	-0.015	0.083	4	0.082	0.181	0.418
117	0.004	0.076	4	0.077	0.121	0.222
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	4	0.071	0.113	0.207
47	0.014	0.072	4	0.073	0.159	0.366
72	0.005	0.071	4	0.071	0.153	0.352
95	0.015	0.073	4	0.074	0.160	0.368
117	-0.004	0.068	4	0.068	0.108	0.199
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	4	0.071	0.113	0.207
47	0.119	0.065	4	0.073	0.142	0.327
72	0.098	0.064	4	0.071	0.138	0.319
95	0.124	0.065	4	0.074	0.142	0.327
117	0.153	0.059	4	0.069	0.094	0.172
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.146	4	0.146	0.233	0.427
47	0.391	0.090	4	0.148	0.194	0.448
72	0.474	0.077	4	0.146	0.166	0.382
95	0.564	0.064	4	0.148	0.139	0.321
117	0.588	0.059	4	0.144	0.094	0.173

Elemental Mass Release (Normalized) and Statistics (con't)						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 6% O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.212	4	0.212	0.337	0.618
47	0.273	0.154	4	0.213	0.333	0.768
72	0.316	0.145	4	0.212	0.312	0.719
95	0.259	0.158	4	0.213	0.340	0.784
117	0.239	0.146	4	0.192	0.232	0.427
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.214	4	0.214	0.341	0.626
47	0.261	0.159	4	0.215	0.343	0.791
72	0.255	0.160	4	0.214	0.344	0.793
95	0.464	0.115	4	0.215	0.249	0.574
117	0.401	0.108	4	0.180	0.171	0.314
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.314	4	0.314	0.500	0.918
47	0.331	0.211	4	0.315	0.454	1.047
72	0.324	0.213	4	0.314	0.458	1.055
95	0.213	0.248	4	0.315	0.534	1.231
117	0.427	0.228	4	0.397	0.362	0.665
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	2.001	4	2.001	3.183	5.843
47	-5.328	12.661	4	2.001	27.242	62.834
72	0.039	1.923	4	2.001	4.138	9.543
95	1.000	0.000	#NUM!	#NUM!	#NUM!	#NUM!
117	1.000	0.000	#NUM!	#NUM!	#NUM!	#NUM!

Elemental Mass Release (Normalized) and Statistics (con't)						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 6% O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.661	0.025	3	0.073	0.184	0.924
72	0.681	0.023	3	0.071	0.167	0.835
95	0.735	0.020	3	0.074	0.145	0.728
117	0.774	0.017	3	0.074	0.042	0.096
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.124	3	0.124	0.308	0.710
47	0.945	0.007	3	0.125	0.050	0.253
72	0.968	0.004	3	0.124	0.030	0.148
95	0.980	0.003	3	0.126	0.019	0.095
117	0.982	0.002	3	0.127	0.006	0.013
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.261	3	0.261	0.649	1.497
47	0.898	0.027	3	0.262	0.197	0.986
72	0.889	0.029	3	0.261	0.213	1.066
95	0.926	0.020	3	0.262	0.143	0.718
117	0.881	0.019	3	0.157	0.046	0.107
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	4	0.071	0.113	0.207
47	0.721	0.020	4	0.073	0.045	0.103
72	0.757	0.017	4	0.071	0.037	0.086
95	0.792	0.015	4	0.074	0.034	0.078
117	0.828	0.013	4	0.075	0.021	0.038

Elemental Mass Release (Normalized) and Statistics (con't)						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 6% O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.089	4	0.089	0.142	0.260
47	0.770	0.021	4	0.091	0.046	0.105
72	0.873	0.011	4	0.089	0.024	0.056
95	0.888	0.010	4	0.092	0.022	0.052
117	0.900	0.009	4	0.092	0.015	0.027
Ash-l						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	4	0.071	0.113	0.207
47	0.169	0.061	4	0.073	0.134	0.308
72	0.207	0.056	4	0.071	0.122	0.281
95	0.214	0.058	4	0.074	0.127	0.294
117	0.204	0.054	4	0.068	0.086	0.158
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.122	4	0.122	0.195	0.357
47	0.234	0.095	4	0.124	0.206	0.474
72	0.265	0.090	4	0.123	0.194	0.448
95	0.200	0.099	4	0.124	0.215	0.496
117	0.172	0.093	4	0.112	0.147	0.270
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	4	0.071	0.113	0.207
47	0.721	0.020	4	0.073	0.045	0.103
72	0.757	0.017	4	0.071	0.037	0.086
95	0.792	0.015	4	0.074	0.034	0.078
117	0.828	0.013	4	0.075	0.021	0.038

Average Initial Mass Percents and Statistics						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 12% O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95\%$	$\delta \pm 99\%$
SiO ₂	3.613	0.221	4	0.061	0.351	0.644
Al ₂ O ₃	1.433	0.070	4	0.049	0.112	0.206
TiO ₂	0.088	0.004	4	0.042	0.006	0.011
Fe ₂ O ₃	4.200	0.577	4	0.137	0.919	1.686
CaO	0.696	0.143	4	0.206	0.228	0.418
Na ₂ O	0.096	0.020	4	0.208	0.032	0.059
K ₂ O	0.179	0.055	4	0.310	0.088	0.162
MgO	0.011	0.022	4	2.000	0.034	0.063
Σ Oxides	10.314					
C	68.613	1.715	3	0.025	4.261	9.829
H	4.733	0.537	3	0.113	1.334	3.076
O	10.473	2.686	3	0.256	6.672	15.389
N	1.353	0.065	4	0.048	0.103	0.190
S	5.228	0.385	4	0.074	0.613	1.125
Ash-s	11.830	1.321	4	0.112	2.102	3.858
Ash-l	11.270	0.546	4	0.048	0.869	1.595

Residual Total Mass (m/m₀) as a Function of Residence Time						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 12% O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.41	0.38	0.39	0.43	0.47	0.46
72	0.27	0.34	0.31	0.34	0.40	0.40
95	0.21	0.22	0.22	0.26	0.30	0.27
117	0.14	0.16	0.15	0.18	0.21	0.19

Residual Total Mass (m/m0) with Statistics						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 12% O ₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	14	1.00	0.000	0.000
47	0.39	0.012	5	0.34	0.015	0.025
72	0.31	0.032	3	0.25	0.080	0.185
95	0.22	0.005	3	0.15	0.013	0.030
117	0.15	0.010	3	0.07	0.026	0.059

Residual Elemental Mass as a Function of Residence Time						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 12% O ₂		
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.03	0.91	1.00	0.65	1.51	0.79
72	0.91	0.91	1.00	0.59	0.70	0.63
95	1.00	0.84	0.98	0.45	1.30	0.63
117	0.95	0.83	0.98	0.49	0.84	0.68
	K ₂ O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.01	0.40	0.06	0.14	0.29	0.29
72	0.74	0.28	0.07	0.18	0.21	0.20
95	0.72	0.19	0.02	0.08	0.13	0.07
117	0.86	0.09	0.00	0.16	0.06	0.03

Elemental Mass Release (Normalized) and Statistics						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 12% O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.079	4	0.079	0.126	0.230
47	-0.031	0.087	4	0.085	0.137	0.251
72	0.094	0.119	3	0.132	0.281	0.647
95	0.000	0.083	4	0.083	0.179	0.414
117	0.052	0.091	3	0.096	0.209	0.481
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	4	0.071	0.113	0.207
47	-0.001	0.077	4	0.077	0.121	0.221
72	0.003	0.127	3	0.127	0.300	0.692
95	0.024	0.073	4	0.075	0.159	0.367
117	0.020	0.089	3	0.091	0.207	0.478
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	4	0.071	0.113	0.207
47	0.087	0.071	4	0.077	0.110	0.202
72	0.088	0.116	3	0.127	0.274	0.633
95	0.159	0.063	4	0.075	0.137	0.316
117	0.167	0.076	3	0.091	0.176	0.407
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.146	4	0.146	0.233	0.427
47	0.345	0.098	4	0.150	0.155	0.284
72	0.413	0.106	4	0.180	0.238	0.550
95	0.554	0.066	4	0.148	0.143	0.329
117	0.511	0.060	4	0.122	0.134	0.308

Elemental Mass Release (Normalized) and Statistics (con't)						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 12% O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.212	4	0.212	0.337	0.618
47	-0.512	0.323	4	0.214	0.513	0.942
72	0.301	0.165	4	0.237	0.365	0.841
95	-0.302	0.277	4	0.213	0.597	1.378
117	0.160	0.201	4	0.240	0.437	1.009
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.214	4	0.214	0.341	0.626
47	0.213	0.170	4	0.217	0.270	0.496
72	0.371	0.150	4	0.239	0.332	0.765
95	0.365	0.137	4	0.216	0.295	0.681
117	0.319	0.109	4	0.161	0.241	0.555
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.314	4	0.314	0.500	0.918
47	-0.013	0.320	4	0.316	0.509	0.934
72	0.264	0.244	4	0.332	0.532	1.226
95	0.280	0.227	4	0.315	0.489	1.127
117	0.136	0.173	4	0.201	0.378	0.873
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	2.001	4	2.001	3.183	5.843
47	-23.038	48.097	4	2.001	76.521	140.464
72	1.000	0.000	#NUM!	#NUM!	#NUM!	#NUM!
95	-9.129	20.265	4	2.001	43.601	100.566
117	1.000	14.258	4	#DIV/0!	22.685	41.641

Elemental Mass Release (Normalized) and Statistics (con't)						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 12% O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.599	0.031	3	0.077	0.073	0.168
72	0.722	0.035	3	0.127	0.088	0.203
95	0.812	0.014	3	0.075	0.035	0.081
117	0.908	0.010	3	0.111	0.025	0.058
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.124	3	0.124	0.308	0.710
47	0.937	0.008	3	0.128	0.020	0.045
72	0.925	0.012	3	0.163	0.030	0.070
95	0.982	0.002	3	0.126	0.006	0.013
117	0.996	0.001	3	0.327	0.004	0.008
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.261	3	0.261	0.649	1.497
47	0.863	0.036	3	0.263	0.089	0.206
72	0.821	0.050	3	0.282	0.125	0.289
95	0.920	0.021	3	0.262	0.052	0.120
117	0.835	0.020	3	0.121	0.050	0.115
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	4	0.071	0.113	0.207
47	0.708	0.023	4	0.077	0.035	0.065
72	0.794	0.026	3	0.127	0.062	0.143
95	0.870	0.010	4	0.075	0.021	0.049
117	0.943	0.007	4	0.116	0.015	0.035

Elemental Mass Release (Normalized) and Statistics (con't)						
Illinois #6 bituminous (hvbb) 75-106 μm				PSOC-1493d 12% O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.089	4	0.089	0.142	0.260
47	0.710	0.027	4	0.094	0.043	0.079
72	0.805	0.027	3	0.138	0.063	0.145
95	0.929	0.007	4	0.092	0.014	0.033
117	0.967	0.005	4	0.141	0.010	0.024
Ash-I						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	4	0.071	0.113	0.207
47	0.146	0.066	4	0.077	0.103	0.189
72	0.230	0.098	3	0.127	0.232	0.534
95	0.213	0.059	4	0.075	0.128	0.296
117	0.220	0.071	3	0.091	0.165	0.381
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.122	4	0.122	0.195	0.357
47	0.160	0.106	4	0.126	0.167	0.307
72	0.229	0.125	4	0.162	0.284	0.655
95	0.287	0.089	4	0.125	0.192	0.444
117	0.285	0.082	4	0.115	0.185	0.427
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	4	0.071	0.113	0.207
47	0.708	0.023	4	0.077	0.035	0.065
72	0.794	0.026	3	0.127	0.062	0.143
95	0.870	0.010	4	0.075	0.021	0.049
117	0.943	0.007	4	0.116	0.015	0.035

Average Initial Mass Percents and Statistics						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 6% O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95\%$	$\delta \pm 99\%$
SiO ₂	4.233	0.592	6	0.140	0.621	0.974
Al ₂ O ₃	1.678	0.206	6	0.123	0.216	0.339
TiO ₂	0.092	0.009	6	0.102	0.010	0.015
Fe ₂ O ₃	3.554	0.574	8	0.162	0.480	0.710
CaO	0.559	0.214	4	0.382	0.340	0.624
Na ₂ O	0.039	0.013	4	0.336	0.021	0.039
K ₂ O	0.135	0.086	4	0.640	0.137	0.252
MgO	0.110	0.037	2	0.334	0.330	1.655
Σ Oxides	10.401					
C	67.860	2.018	8	0.030	1.687	2.496
H	4.576	0.122	8	0.027	0.102	0.151
O	11.889	1.277	7	0.107	1.181	1.790
N	1.265	0.064	8	0.051	0.053	0.079
S	5.222	0.513	6	0.098	0.538	0.844
Ash-s	11.848	2.067	8	0.174	1.729	2.557
Ash-l	11.115	0.278	6	0.025	0.292	0.457

Residual Total Mass (m/m₀) as a Function of Residence Time						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 6% O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.45	0.47	0.49	0.51	0.48	0.47
72	0.40	0.45	0.44	0.43	0.47	0.49
95	0.34	0.42	0.44	0.46	0.45	0.49
117	0.33	0.36	0.38	0.39	0.43	0.39

Residual Total Mass (m/m0) with Statistics						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 6% O ₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	28	1.00	0.000	0.000
47	0.48	0.027	4	0.41	0.043	0.078
72	0.43	0.020	4	0.37	0.032	0.059
95	0.42	0.053	4	0.36	0.084	0.153
117	0.37	0.030	4	0.30	0.048	0.088

Residual Elemental Mass as a Function of Residence Time						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 6% O ₂		
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.03	0.94	0.97	0.93	0.97	1.22
72	0.96	1.00	0.97	0.57	0.65	1.20
95	0.98	0.91	0.94	0.49	0.75	1.38
117	1.00	0.93	0.96	0.56	0.90	1.31
	K ₂ O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.39	0.47	0.06	0.26	0.38	0.33
72	1.40	0.43	0.04	0.20	0.38	0.33
95	1.45	0.43	0.09	0.17	0.36	0.25
117	1.47	0.34	0.04	0.15	0.32	0.21

Elemental Mass Release (Normalized) and Statistics						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 6% O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.148	6	0.148	0.156	0.244
47	-0.033	0.164	6	0.159	0.190	0.314
72	0.036	0.150	6	0.156	0.173	0.287
95	0.016	0.192	5	0.195	0.234	0.388
117	-0.004	0.155	5	0.154	0.185	0.307
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.133	6	0.133	0.139	0.218
47	0.027	0.140	6	0.144	0.163	0.270
72	0.027	0.137	6	0.141	0.158	0.262
95	0.057	0.172	5	0.183	0.213	0.353
117	0.039	0.138	5	0.143	0.166	0.275
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.113	6	0.113	0.119	0.187
47	0.060	0.119	6	0.126	0.139	0.231
72	0.001	0.123	6	0.123	0.142	0.236
95	0.095	0.154	5	0.170	0.221	0.405
117	0.072	0.121	5	0.130	0.147	0.244
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.169	8	0.169	0.141	0.209
47	0.067	0.166	8	0.178	0.147	0.223
72	0.432	0.100	8	0.175	0.088	0.133
95	0.508	0.104	7	0.211	0.104	0.163
117	0.443	0.088	7	0.158	0.086	0.135

Elemental Mass Release (Normalized) and Statistics (con't)						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 6% O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.386	4	0.386	0.614	1.127
47	0.028	0.379	4	0.390	0.603	1.106
72	0.354	0.251	4	0.389	0.399	0.733
95	0.255	0.303	4	0.406	0.481	0.883
117	0.101	0.266	4	0.295	0.422	0.775
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.340	4	0.340	0.541	0.993
47	-0.224	0.422	4	0.345	0.671	1.232
72	-0.204	0.413	4	0.343	0.657	1.207
95	-0.379	0.500	4	0.363	0.796	1.461
117	-0.307	0.427	4	0.327	0.680	1.248
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.642	4	0.642	1.021	1.874
47	-0.391	0.896	4	0.644	1.425	2.615
72	-0.403	0.902	4	0.643	1.435	2.635
95	-0.453	0.950	4	0.654	1.511	2.774
117	-0.469	0.830	4	0.565	1.320	2.424
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.338	2	0.338	3.037	15.213
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 6% O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	8	0.071	0.059	0.087
47	0.535	0.042	6	0.090	0.042	0.066
72	0.570	0.037	7	0.085	0.036	0.057
95	0.572	0.062	5	0.145	0.088	0.162
117	0.659	0.038	6	0.111	0.044	0.073
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	8	0.071	0.059	0.087
47	0.943	0.005	6	0.090	0.005	0.008
72	0.960	0.003	7	0.085	0.003	0.005
95	0.906	0.014	5	0.145	0.019	0.036
117	0.961	0.006	7	0.143	0.006	0.009
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.118	7	0.118	0.110	0.166
47	0.743	0.034	6	0.131	0.034	0.053
72	0.803	0.025	7	0.127	0.025	0.039
95	0.829	0.030	5	0.173	0.035	0.058
117	0.851	0.022	6	0.145	0.023	0.035
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	8	0.071	0.059	0.088
47	0.620	0.034	6	0.090	0.035	0.054
72	0.620	0.032	7	0.085	0.032	0.050
95	0.641	0.052	5	0.145	0.074	0.136
117	0.678	0.035	6	0.109	0.041	0.067

Elemental Mass Release (Normalized) and Statistics (con't)						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 6% O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.110	6	0.110	0.116	0.181
47	0.675	0.040	6	0.124	0.047	0.078
72	0.673	0.039	6	0.120	0.046	0.076
95	0.747	0.042	5	0.167	0.061	0.112
117	0.788	0.030	5	0.141	0.036	0.060
Ash-l						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	6	0.071	0.074	0.116
47	-0.031	0.093	5	0.090	0.113	0.187
72	0.123	0.074	5	0.085	0.089	0.148
95	0.149	0.123	4	0.145	0.185	0.339
117	0.070	0.097	5	0.105	0.142	0.261
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.182	8	0.182	0.152	0.225
47	0.001	0.190	8	0.190	0.168	0.254
72	0.094	0.170	8	0.187	0.149	0.226
95	0.073	0.205	7	0.221	0.203	0.319
117	0.142	0.165	7	0.192	0.150	0.227
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	8	0.071	0.059	0.088
47	0.620	0.034	6	0.090	0.035	0.054
72	0.620	0.032	7	0.085	0.032	0.050
95	0.641	0.052	5	0.145	0.074	0.136
117	0.678	0.035	6	0.109	0.041	0.067

Average Initial Mass Percents and Statistics						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 12% O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	4.233	0.592	6	0.140	0.621	0.974
Al ₂ O ₃	1.678	0.206	6	0.123	0.216	0.339
TiO ₂	0.092	0.009	6	0.102	0.010	0.015
Fe ₂ O ₃	3.554	0.574	8	0.162	0.480	0.710
CaO	0.605	0.170	4	0.282	0.271	0.498
Na ₂ O	0.046	0.008	4	0.172	0.012	0.023
K ₂ O	0.162	0.033	4	0.203	0.052	0.096
MgO	0.110	0.037	2	0.342	0.337	1.687
Σ Oxides	10.481					
C	67.860	2.018	8	0.030	1.687	2.496
H	4.576	0.122	8	0.027	0.102	0.151
O	11.889	1.277	7	0.107	1.181	1.790
N	1.265	0.064	8	0.051	0.053	0.079
S	5.222	0.513	6	0.098	0.538	0.844
Ash-s	11.848	2.067	8	0.174	1.729	2.557
Ash-l	11.115	0.278	6	0.025	0.292	0.457

Residual Total Mass (m/m₀) as a Function of Residence Time						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 12% O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.46	0.50	0.49	0.50	0.52	0.45
72	0.31	0.35	0.37	0.36	0.40	0.43
95	0.22	0.25	0.27	0.30	0.32	0.28
117	0.18	0.22	0.21	0.23	0.25	0.22

Residual Total Mass (m/m0) with Statistics						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 12% O2		
	Mean (mf)	σ	n	Mean (daf)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	1.00	0.000	28	1.00	0.000	0.000
47	0.49	0.020	4	0.42	0.031	0.058
72	0.35	0.029	4	0.28	0.046	0.084
95	0.26	0.033	8	0.18	0.028	0.041
117	0.21	0.021	4	0.12	0.034	0.062

Residual Elemental Mass as a Function of Residence Time						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 12% O2		
	SiO2	TiO2	Al2O3	Fe2O3	CaO	Na2O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.98	0.97	0.99	1.11	0.86	1.28
72	1.00	0.96	0.93	0.49	0.49	0.83
95	1.02	0.88	0.96	0.59	1.06	0.94
117	0.94	0.93	1.00	0.61	1.13	0.87
	K2O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.20	0.47	0.04	0.24	0.37	0.32
72	0.70	0.32	0.03	0.13	0.22	0.23
95	0.94	0.22	0.02	0.11	0.13	0.12
117	0.95	0.14	0.01	0.12	0.09	0.08

Elemental Mass Release (Normalized) and Statistics						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 12% O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.148	6	0.148	0.156	0.244
47	0.021	0.151	6	0.154	0.173	0.287
72	0.002	0.170	6	0.170	0.201	0.333
95	-0.020	0.200	7	0.196	0.196	0.308
117	0.061	0.157	5	0.167	0.190	0.315
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.133	6	0.133	0.139	0.218
47	0.013	0.137	6	0.139	0.157	0.261
72	0.071	0.145	5	0.157	0.173	0.287
95	0.042	0.176	7	0.184	0.172	0.269
117	0.002	0.148	5	0.148	0.182	0.302
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.113	6	0.113	0.119	0.187
47	0.025	0.117	6	0.120	0.136	0.225
72	0.036	0.136	5	0.141	0.164	0.271
95	0.123	0.150	7	0.171	0.137	0.208
117	0.072	0.128	5	0.137	0.183	0.336
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.169	8	0.169	0.141	0.209
47	-0.111	0.193	8	0.174	0.169	0.257
72	0.513	0.092	7	0.189	0.084	0.127
95	0.412	0.124	8	0.212	0.104	0.154
117	0.394	0.103	7	0.170	0.103	0.162

Elemental Mass Release (Normalized) and Statistics (con't)						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 12% O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.286	4	0.286	0.455	0.835
47	0.138	0.249	4	0.289	0.396	0.727
72	0.514	0.145	4	0.298	0.231	0.423
95	-0.063	0.333	5	0.313	0.491	0.900
117	-0.134	0.274	4	0.241	0.435	0.799
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.179	4	0.179	0.284	0.522
47	-0.278	0.234	4	0.183	0.373	0.684
72	0.167	0.164	4	0.197	0.261	0.480
95	0.064	0.205	5	0.219	0.246	0.409
117	0.131	0.163	4	0.187	0.259	0.475
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.209	4	0.209	0.333	0.610
47	-0.202	0.256	4	0.213	0.407	0.747
72	0.296	0.159	4	0.225	0.252	0.463
95	0.065	0.229	5	0.245	0.282	0.468
117	0.046	0.188	4	0.197	0.298	0.548
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.346	2	0.346	3.108	15.569
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 12% O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	8	0.071	0.059	0.087
47	0.534	0.038	7	0.082	0.035	0.053
72	0.676	0.035	6	0.109	0.041	0.068
95	0.779	0.032	8	0.146	0.027	0.040
117	0.855	0.019	6	0.129	0.022	0.037
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	8	0.071	0.059	0.087
47	0.961	0.003	7	0.082	0.003	0.004
72	0.973	0.003	6	0.109	0.003	0.006
95	0.982	0.003	8	0.146	0.002	0.003
117	0.989	0.001	6	0.132	0.002	0.003
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.118	7	0.118	0.110	0.166
47	0.764	0.030	7	0.125	0.029	0.046
72	0.871	0.019	6	0.145	0.020	0.031
95	0.887	0.020	8	0.174	0.017	0.026
117	0.881	0.017	5	0.140	0.020	0.033
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	8	0.071	0.059	0.088
47	0.628	0.030	7	0.082	0.028	0.043
72	0.781	0.024	6	0.110	0.028	0.046
95	0.870	0.019	8	0.146	0.016	0.024
117	0.909	0.012	5	0.128	0.014	0.023

Elemental Mass Release (Normalized) and Statistics (con't)						
Illinois #6 bituminous (hvbb) 106-125 μm				PSOC-1493d 12% O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.110	6	0.110	0.116	0.181
47	0.682	0.037	6	0.117	0.043	0.072
72	0.765	0.032	5	0.138	0.039	0.065
95	0.883	0.020	7	0.168	0.018	0.027
117	0.923	0.013	5	0.165	0.015	0.026
Ash-I						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	6	0.071	0.074	0.116
47	-0.095	0.089	6	0.082	0.106	0.175
72	0.202	0.087	5	0.109	0.126	0.232
95	0.085	0.133	8	0.146	0.119	0.180
117	0.062	0.113	5	0.120	0.168	0.308
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.182	8	0.182	0.152	0.225
47	0.054	0.176	8	0.186	0.154	0.233
72	0.135	0.173	7	0.200	0.156	0.237
95	0.201	0.177	8	0.222	0.148	0.219
117	0.176	0.146	7	0.178	0.145	0.228
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	8	0.071	0.059	0.088
47	0.628	0.030	7	0.082	0.028	0.043
72	0.781	0.024	6	0.110	0.028	0.046
95	0.870	0.019	8	0.146	0.016	0.024
117	0.909	0.012	5	0.128	0.014	0.023

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE TEMPERATURE DISTRIBUTIONS**

Data and Analysis Compilation
for PSOC-1493, Illinois #6 Coal

6 mole-% Oxygen
Environment

12 mole-% Oxygen
Environment

ILLINOIS #6 COAL CHAR

COAL TYPE: Illinois #6, psoc-1493, 10kgc133. 7-06-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	1	1374.3	0.0	2.09	0.00	1.408	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1445.4	0.0	2.20	0.00	0.524	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	2	1548.3	22.9	2.35	0.14	1.062	0.180
1600.0	1	1581.6	0.0	2.34	0.00	0.026	0.000
1650.0	2	1667.6	8.1	2.50	0.04	0.724	0.431
1700.0	20	1709.4	11.9	2.48	0.27	0.832	0.348
1750.0	83	1752.9	14.6	2.57	0.03	0.861	1.064
1800.0	32	1790.6	11.4	2.58	0.02	0.482	0.223
1850.0	3	1825.8	0.0	2.58	0.01	0.616	0.140
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 145
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Illinois #6, psoc-1493, 15kgc133. 7-06-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	1	1504.7	0.0	2.34	0.00	0.509	0.000
1550.0	2	1559.0	16.4	2.46	0.01	0.669	0.873
1600.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1650.0	25	1659.8	13.4	2.72	0.05	0.938	0.352
1700.0	64	1699.9	13.4	2.71	0.18	0.787	0.366
1750.0	62	1741.4	12.0	2.75	0.02	0.777	0.328
1800.0	4	1786.4	9.6	2.76	0.01	0.584	0.468
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 158
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Illinois #6, psoc-1493, 20kgcl33. 7-06-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	2	1479.3	3.9	2.66	0.20	0.717	0.557
1550.0	8	1554.0	12.7	2.87	0.04	1.208	0.495
1600.0	31	1599.9	12.9	2.91	0.03	0.959	0.421
1650.0	86	1649.8	13.4	2.89	0.17	0.853	0.370
1700.0	32	1693.9	14.0	2.91	0.05	0.762	0.183
1750.0	1	1731.9	0.0	2.96	0.00	0.880	0.000
1800.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 160
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Illinois #6, psoc 1493, 10kgcl42. 7-06-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1652.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	1	1412.8	0.0	2.22	0.00	0.519	0.000
1450.0	1	1434.6	0.0	2.14	0.00	0.098	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	1	1529.8	0.0	2.05	0.00	1.137	0.000
1600.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1650.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1700.0	1	1680.5	0.0	2.22	0.00	2.144	0.000
1750.0	3	1752.9	8.4	2.38	0.25	0.718	0.316
1800.0	5	1816.2	8.5	2.53	0.03	1.015	0.312
1850.0	66	1853.6	14.3	2.55	0.03	0.877	0.306
1900.0	54	1896.9	13.4	2.54	0.06	0.886	0.314
1950.0	39	1946.1	16.0	2.55	0.07	0.873	0.627
2000.0	4	1981.7	4.7	2.55	0.02	0.625	0.182
2050.0	1	2025.1	0.0	1.51	0.00	0.381	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 176
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Illinois #6, psoc-1493, 15kgcl42. 7-06-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1430.6	0.0	2.50	0.00	0.702	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	2	1556.0	10.1	2.54	0.09	0.166	0.011
1600.0	4	1607.8	16.2	2.71	0.05	0.867	0.341
1650.0	13	1648.5	12.6	2.72	0.06	0.660	0.250
1700.0	20	1707.0	13.3	2.73	0.03	0.846	0.383
1750.0	20	1752.4	13.7	2.73	0.03	0.899	0.436
1800.0	40	1801.6	15.0	2.73	0.05	0.857	0.280
1850.0	40	1848.8	14.0	2.68	0.23	0.794	0.297
1900.0	19	1896.2	14.5	2.76	0.03	0.817	0.202
1950.0	4	1942.4	15.0	2.76	0.04	0.897	0.268
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	1	2203.1	0.0	2.80	0.00	0.593	0.000
2250.0	2	2256.1	19.1	2.57	0.16	0.000	0.000

NUMBER OF PARTICLES = 166
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Illinois #6, psoc 1493, 20kgcl42. 7-06-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	2	1470.5	6.4	2.93	0.00	0.834	0.141
1500.0	25	1502.4	14.6	2.91	0.03	0.838	0.456
1550.0	43	1546.1	15.4	2.90	0.06	0.957	0.428
1600.0	19	1593.4	13.4	2.88	0.09	0.739	0.194
1650.0	19	1642.3	11.6	2.91	0.07	0.838	0.323
1700.0	15	1706.8	15.4	2.90	0.05	0.937	0.202
1750.0	18	1747.4	14.8	2.92	0.04	0.847	0.234
1800.0	17	1803.0	14.8	2.91	0.04	0.799	0.319
1850.0	7	1845.7	13.4	2.92	0.03	0.751	0.180
1900.0	4	1887.1	8.2	2.86	0.04	1.036	0.264
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	1	2013.2	0.0	2.57	0.00	0.875	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 170
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE SIZES, TEMPERATURES, AND VELOCITIES**

Data and Analysis Compilation
for PSOC-1493, Illinois #6 Coal

COAL TYPE: PSOC-1493
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	1	1725	0	2.57	0.00	1.76	0.00
90.	3	1767	2	2.56	0.03	1.34	0.18
100.	13	1742	60	2.55	0.04	1.19	0.28
110.	12	1705	103	2.51	0.13	1.05	0.22
120.	9	1750	33	2.43	0.39	0.90	0.18
130.	22	1760	26	2.57	0.03	0.73	0.19
140.	15	1720	79	2.53	0.09	0.68	0.17
150.	22	1748	53	2.55	0.08	0.65	0.18
160.	10	1747	65	2.55	0.07	0.49	0.23
170.	12	1762	25	2.57	0.02	0.46	0.14
180.	5	1778	16	2.58	0.01	0.39	0.11
190.	10	1768	26	2.59	0.02	0.32	0.07
200.	2	1726	65	2.52	0.07	0.29	0.02
210.	4	1754	46	2.59	0.04	0.25	0.16
220.	0	0	0	0.00	0.00	0.00	0.00
230.	1	1753	0	2.55	0.00	0.27	0.00
240.	1	1771	0	2.55	0.00	0.27	0.00

NUMBER OF PARTICLES = 142
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1493
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.1 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	6	1735	32	2.77	0.02	1.25	0.33
90.	12	1687	47	2.70	0.10	1.16	0.39
100.	19	1709	33	2.72	0.08	1.13	0.40
110.	15	1712	27	2.74	0.02	1.06	0.26
120.	15	1731	40	2.75	0.03	0.80	0.17
130.	22	1703	32	2.74	0.03	0.82	0.18
140.	18	1708	33	2.66	0.33	0.64	0.11
150.	19	1705	43	2.74	0.07	0.59	0.23
160.	5	1708	33	2.73	0.03	0.62	0.07
170.	7	1694	21	2.75	0.03	0.58	0.19
180.	3	1718	18	2.73	0.01	0.47	0.04
190.	3	1737	8	2.75	0.01	0.34	0.06
200.	5	1709	51	2.74	0.02	0.44	0.22
210.	2	1618	161	2.54	0.28	0.36	0.21
220.	0	0	0	0.00	0.00	0.00	0.00
230.	2	1730	65	2.74	0.00	0.38	0.16
240.	1	1737	0	2.77	0.00	0.23	0.00

NUMBER OF PARTICLES = 154
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1493
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.4 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	2	1552	18	2.89	0.05	1.90	0.17
80.	2	1630	36	2.91	0.03	2.57	0.17
90.	12	1625	54	2.92	0.04	1.40	0.25
100.	14	1631	54	2.90	0.05	1.13	0.26
110.	14	1655	35	2.92	0.03	1.06	0.20
120.	15	1641	40	2.91	0.04	0.90	0.12
130.	23	1651	32	2.89	0.09	0.86	0.17
140.	23	1655	34	2.92	0.04	0.74	0.11
150.	23	1643	44	2.90	0.05	0.68	0.12
160.	7	1661	28	2.89	0.02	0.63	0.09
170.	10	1618	54	2.88	0.12	0.52	0.11
180.	4	1630	14	2.90	0.03	0.59	0.13
190.	3	1661	20	2.39	0.72	0.53	0.17
200.	1	1629	0	2.89	0.00	0.43	0.00
210.	1	1655	0	2.93	0.00	0.64	0.00
220.	1	1623	0	2.89	0.00	0.31	0.00
230.	2	1656	27	2.89	0.00	0.43	0.03
240.	3	1637	5	2.93	0.03	0.35	0.10

NUMBER OF PARTICLES = 160
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1493
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	1	1931	0	2.55	0.00	3.90	0.00
70.	1	1943	0	2.57	0.00	2.41	0.00
80.	4	1815	81	2.47	0.15	1.66	0.29
90.	10	1887	52	2.55	0.02	1.38	0.29
100.	13	1887	40	2.55	0.05	1.16	0.19
110.	20	1878	61	2.53	0.12	1.10	0.30
120.	21	1889	45	2.54	0.03	0.91	0.16
130.	36	1858	100	2.53	0.10	0.82	0.18
140.	16	1873	120	2.53	0.11	0.65	0.17
150.	17	1886	52	2.53	0.10	0.61	0.13
160.	14	1886	38	2.56	0.03	0.62	0.05
170.	7	1910	39	2.50	0.13	0.59	0.12
180.	7	1879	50	2.52	0.04	0.55	0.10
190.	4	1926	56	2.26	0.43	0.47	0.08
200.	3	1915	51	2.53	0.01	0.40	0.04
210.	2	1924	73	2.54	0.02	0.41	0.07
220.	0	0	0	0.00	0.00	0.00	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 176
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1493
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.1 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	2	1716	43	2.82	0.02	1.87	0.07
70.	6	1879	202	2.75	0.04	1.46	0.37
80.	5	1820	109	2.77	0.03	1.23	0.52
90.	19	1801	56	2.74	0.04	1.09	0.16
100.	32	1781	119	2.72	0.06	0.86	0.26
110.	12	1819	75	2.74	0.03	0.89	0.10
120.	16	1795	111	2.72	0.07	0.79	0.14
130.	19	1769	95	2.72	0.07	0.71	0.17
140.	20	1767	85	2.74	0.04	0.59	0.13
150.	12	1806	75	2.70	0.16	0.68	0.15
160.	6	1899	156	2.69	0.11	0.50	0.11
170.	6	1789	66	2.73	0.03	0.66	0.25
180.	5	1802	51	2.73	0.02	0.46	0.10
190.	1	1641	0	2.77	0.00	0.34	0.00
200.	0	0	0	0.00	0.00	0.00	0.00
210.	2	1810	59	2.10	0.91	0.49	0.14
220.	0	0	0	0.00	0.00	0.00	0.00
230.	2	1864	7	2.50	0.19	0.51	0.03
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 165
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1493
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.4 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	1	1557	0	2.74	0.00	2.40	0.00
70.	3	1569	51	2.90	0.04	1.39	0.66
80.	9	1562	80	2.93	0.02	1.32	0.39
90.	17	1643	146	2.91	0.09	1.20	0.29
100.	21	1630	128	2.92	0.03	1.04	0.23
110.	16	1696	79	2.90	0.08	0.84	0.26
120.	26	1677	115	2.88	0.08	0.78	0.23
130.	24	1652	112	2.92	0.04	0.80	0.18
140.	17	1598	98	2.91	0.04	0.72	0.13
150.	13	1578	107	2.89	0.05	0.60	0.19
160.	11	1635	102	2.88	0.07	0.59	0.12
170.	6	1676	103	2.87	0.03	0.64	0.16
180.	2	1553	57	2.89	0.00	0.57	0.23
190.	1	1744	0	2.86	0.00	0.59	0.00
200.	1	1508	0	2.93	0.00	0.28	0.00
210.	1	1817	0	2.93	0.00	0.54	0.00
220.	1	1816	0	2.93	0.00	0.40	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 170
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**KINETIC ANALYSIS
AND COMBUSTION PARAMETERS**

Data and Analysis Compilation
for PSOC-1493, Illinois #6 Coal

Summary of Combustion Parameters for PSOC-1493D			
Char oxidation rate parameters $q = A \exp(-E/RT_p) P^n$	A	22.4	gm-C / cm ² -s-atm ⁿ
	E	22.5	kcal / mole
	n	0.5 *	
Product ratio parameters $CO/CO_2 = A_c \exp(-E_c/RT_p)$	A _c	2.5 x 10 ⁸ *	
	E _c	60 *	kcal / mole
Burning mode parameter $\rho/\rho_o = (m/m_o)^\alpha$ $d/d_o = (m/m_o)^{(1-\alpha)/3}$	α	0.45**	
Char structural parameters $\omega = d_o / d_c$ (linear swelling factor) $\rho_{c,o} = m_c/V_c$ at $z = 6.5$ cm (initial char particle carbon density)	ω	1.06**	
	$\rho_{c,o}$	0.385**	gm / cm ³
<p>As an example, this parameter set yields a combustion rate, q, of 0.0041 gm/sq.cm-s for a 100 μm particle in a gas with $T_g = 1600$ K containing 6 mole-% oxygen</p> <p>These product ratio parameters yield 3 mole-% carbon dioxide at 1900 K and 17 mole-% carbon dioxide at 1700 K</p> <p>* These particular parameters should be regarded as empirical parameters that are useful for the prediction of burning rates. They do not necessarily have fundamental significance and/or are not necessarily unique for this data set.</p> <p>** Measured for 75 - 106 μm particles</p>

**CALCULATIONS OF THE COAL CHAR REACTIVITY INDEX, τ_{50} ,
FOR VARIOUS ENVIRONMENTS
PRESENT IN PULVERIZED-COAL COMBUSTION SYSTEMS**

Data and Analysis Compilation
for PSOC-1493, Illinois #6 Coal

Compilation of Data and Kinetic Analyses for

**Hiawatha Bituminous Coal
(Utah, hvC)**

PSOC-1502D

TABLE OF CONTENTS

- **Sample history, geologic information and chemical analysis of bulk, raw coal**
- **Chemical analysis of size-fractionated raw coal and partially reacted chars**
- **Measurements of total surface area evolution**
- **Time resolved measurements of the partitioning of elemental coal constituents between the gas and solid phases**
- **Mode of particle burning**
- **Statistical analyses of elemental composition measurements and derived quantities**
- **Optical measurements of single-particle temperature distributions**
- **Optical measurements of single-particle sizes, temperatures, and velocities**
- **Kinetic analysis and combustion parameters**
- **Calculations of the coal char reactivity index, τ_{50} , for various environments present in pulverized-coal combustion systems**

**SAMPLE HISTORY, GEOLOGIC INFORMATION AND
CHEMICAL ANALYSIS OF BULK, RAW COAL**

Data and Analysis Compilation
for PSOC-1502, Hiawatha Coal

SAMPLE HISTORY

PENN STATE NUMBER	PSOC-1502
COLLECTED BY	PENNSYLVANIA STATE UNIVERSITY
COLLECTION DATE	9/30/85
COLLECTOR'S NUMBER	
REPORTED RANK	HIGH VOLATILE C BITUMINOUS (HVCB)
SAMPLE TYPE	CHANNEL WORKING SECTION
OTHER SAMPLE INFORMATION	
SAMPLE RESERVE	900
SEAM NAME	HIAWATHA
ALTERNATE SEAM NAME	
TOTAL SEAM THICKNESS	12 FT. 0 IN.
THICKNESS OF SEAM SAMPLED	7 FT. 2 IN.
PORTION RECOVERED IN CORE	
DIAMETER OF CORE	

SAMPLE LOCATION

COUNTRY	U.S.A.
STATE	UTAH
COUNTY	SEVIER
TOWNSHIP	
NEAREST TOWN	EMERY
COAL PROVINCE	ROCKY MOUNTAIN
COAL REGION	UINTA
COAL FIELD	

GEOLOGIC INFORMATION

SYSTEM (AGE)	CRETACEOUS
SERIES	
GROUP	MESAVERDE
FORMATION	BLACKHAWK
OVERBURDEN LITHOLOGY	
FLOOR LITHOLOGY	

SEAM STRATA INFORMATION

<u>THICKNESS</u>	<u>LITHOTYPE</u>
------------------	------------------

SEAM NAME	HIAWATHA	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	UTAH

CHEMICAL DATA 1

PROXIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF (PAFF)	DMMF (PARR-G)	DMMF (DIR MM)
% MOISTURE	8.72					
% ASH	8.20	8.98				
% VOLATILE MATTER	37.20	40.75	44.77	44.24	43.92	
% FIXED CARBON	45.89	50.27	55.23	55.76	56.08	

CALORIFIC VALUE (GROSS BTU/LB)	DRY	AS REC'D MOIST.	EQUIL MOIST.
MM-FREE, DIRECT			
MM-CONTAINING	12650	11547	11513
MM-FREE (PARR)	14024	12678	12637
MM-FREE (MOD.P)	14082	12708	12666
BEST MM FREE		12708	12666
NET CV, DMMF BTU/LB	13587		
ASH-FREE	13898		

MOTT-SPOONER DIFFERENCE =

ASSOCIATED ANALYSES	DRY	MMF
% EQUILIBRIUM MOISTURE	8.99	9.99
% TOTAL SULFUR	0.51	

RANK CALCULATION

APPARENT RANK (AS REC'D MOIST)	HIGH VOLATILE C BITUMINOUS (HVCB)
ASTM RANK (EQUIL. MOIST.)	HIGH VOLATILE C BITUMINOUS (HVCB)
REFLECTANCE RANK CATEGORY	
INTERNATIONAL RANK	
AS REC'D MOIST.	
EQUIL. MOIST	
REPORTED RANK	HIGH VOLATILE C BITUMINOUS (HVCB)

SEAM NAME	HIAWATHA	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	UTAH

CHEMICAL DATA 2

ULTIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF(PARR) (9.98 % MM)
% ASH	8.20	8.98		
% CARBON	66.50	72.85	80.04	80.93
% HYDROGEN	*4.37	4.79	5.26	5.32
% NITROGEN	1.02	1.12	1.23	1.24
% SULFUR	0.47	0.51	0.56	
% CHLORINE	0.01	0.01	0.02	0.02
% OXYGEN (DIFF)	*10.71	11.73	12.89	12.49

SULFUR FORMS	% PYRITIC	% SULFATIC	% ORGANIC	% TOTAL
DRY	0.15	0.00	0.36	0.51
DAF	0.16	0.00	0.40	0.56
OPTICAL				

ELEMENTAL ANALYSIS	DRY	DMMF (MOD.P) (10.23 % MM)	DMMF(DIR.) (% MM)
% CARBON	72.55	80.81	
% HYDROGEN	4.67	5.20	
% NITROGEN	1.12	1.24	
% ORGANIC SULFUR	0.36	0.40	
% OXYGEN (DIFF)	11.07	12.32	
% CHLORINE	0.01	0.02	
% MINERAL MATTER (INCLUDES 0.28 % FES2)	10.23		

ATOM RATIOS (DMMF)	PARR	MOD.PAR	DIRECT
ATOMIC H/C	0.790	0.773	
ATOMIC O/C	0.116	0.128	

MISC. CHEMICAL DATA	DRY	OF DMMF COAL	OF DMMF OXYGEN
% O AS COOH			
% O AS OH			
% S AS SO4, IN ASH			
% CARBONATE AS CO2	1.10		
% CHLORINE	0.03		

INFRA-RED ANALYSIS

(*)- EXCLUDES MOISTURE

SEAM NAME	HIAWATHA	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	UTAH

CHEMICAL DATA 3

% MOISTURE IN COAL = 4.04
 % HIGH TEMPERATURE ASH = 8.20 AT 750 DEGREES C

TRACE ELEMENT ANALYSIS	PPM HTA	PPM TOTAL COAL	MAJOR ELEMENT ANALYSIS	OXIDE % OF HTA	ELEMENT % OF TOTAL DRY COAL
AG			SI02	49.60	1.90
B			AL203	10.50	0.46
BA	630	52	TI02	0.84	0.04
BE	< 2	0	FE203	6.04	0.35
BI			MG0	2.25	0.11
CE			CA0	17.60	1.03
CO			NA20	2.38	0.14
CR	65	5	K20	0.06	0.00
CU	90	7	P205	0.35	0.01
GA			S03	8.90	0.29
GE					
LA					
LI					
MN	230	19			
MO			<u>VOLATILES</u>	<u>PPM TOTAL COAL</u>	
NI	35	3			
NB			AS		
PB			BR		
RB	6	0	CD		
SC			CL		
SN			F		
SR	1440	118	HG		
TH			SB		
U			SE		
V	90	7			
Y					
YB					
ZN	30	2			
ZR	390	32			

SEAM NAME	HIAWATHA	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	UTAH

MINERALOGICAL DATA

TOTAL MINERAL MATTER

% MM-PARR	9.98
% MM-MODIFIED PARR	10.23
% MM-KMC	
% MM-DIRECT	
% MM-BEST AVAILABLE	10.23
VOL % MM-PARR	5.07

MINERAL COMPOSITION

NONE

SEAM NAME	HIAWATHA	COUNTRY	U.S.A.
APPARENT RANK	HIGH VOLATILE C BITUMINOUS (HVCB)	STATE	UTAH

PETROGRAPHIC DATA

PETROGRAPHIC DATA NOT AVAILABLE

PHYSICAL PROPERTIES

HARDGROVE GRINDABILITY	39.3
VICKER'S MICROHARDNESS	
FREE SWELLING INDEX	0.5
GRAY KING COKE TYPE	

<u>ASH FUSION ANALYSIS (DEGREES F)</u>	<u>REDUCING</u>	<u>OXIDIZING</u>
INITIAL DEFORMATION TEMPERATURE	2060	2065
SOFTENING TEMPERATURE	2105	2175
HEMISPHERE TEMPERATURE	2195	2330
FLUID TEMPERATURE	2310	2490

ANALYSIS LOG

<u>ANALYSIS</u>	<u>DATE</u>	<u>PERFORMED BY</u>
A.R. MOIST		
EQUIL. MOIST.		
PROXIMATE		
ULTIMATE		
SULFUR FORMS		
FSI	3/24/86	COAL PETROGRAPHY LABORATORIES-PSU
PLASTOMETER		
DIRECT MM		
GRAY-KING		

**CHEMICAL ANALYSES OF SIZE-FRACTIONATED RAW COAL
AND PARTIALLY REACTED CHARS**

Data and Analysis Compilation
for PSOC-1502, Hiawatha Coal

**Organic Elemental Analysis and Percent Ash of Hiawatha Coal
and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	73.13	4.84	12.28	1.12	0.40	7.09
6.4	81.78	1.63	1.61	1.20	0.50	10.5
12.7	82.42	0.66	<0.01	1.14	0.51	15.3
19.1	77.96	0.52	<0.01	0.98	0.53	22.8
25.4	73.21	0.54	1.91	1.08	0.45	22.3

12 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	73.53	4.87	12.94	1.13	0.36	6.81
6.4	79.67	1.67	3.87	1.14	0.57	14.4
12.7	81.42	0.56	1.04	0.99	0.57	20.5
19.1	65.23	0.26	2.01	0.73	0.81	35.4
25.4	53.60	0.37	3.22	0.80	0.94	52.0

* Data taken in July 1989

**Ash Content of Hiawatha Coal and its
Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	2.96	0.855	0.076	0.392	0.579	0.044	<0.004	0.128
6.4	4.35	1.36	0.157	0.517	1.12	0.288	0.017	0.277
12.7	7.06	2.08	0.185	0.822	2.60	0.582	0.006	0.273
19.1	9.75	2.76	0.211	1.33	3.81	0.788	<0.004	0.585
25.4	9.19	2.59	0.238	1.01	3.18	0.600	0.038	0.386

12 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	2.91	0.845	0.076	0.358	0.633	0.086	0.014	0.136
6.4	6.73	1.90	0.153	0.836	1.82	0.414	<0.004	0.343
12.7	9.73	2.85	0.225	1.01	1.88	0.232	<0.004	0.330
19.1	15.7	4.65	0.349	2.02	4.08	1.52	0.021	0.254
25.4	24.1	7.00	0.408	2.60	8.40	1.86	0.004	0.878

* Data taken in July 1989

**MEASUREMENTS OF
TOTAL SURFACE AREA EVOLUTION**

Data and Analysis Compilation
for PSOC-1502, Hiawatha Coal

Surface area evolution for PSOC-1502, Hiawatha Coal
Combustion in 6 mole-% oxygen

Surface area evolution for PSOC-1502, Hiawatha Coal
Combustion in 12 mole-% oxygen

**TIME RESOLVED MEASUREMENTS OF THE
PARTITIONING OF ELEMENTAL COAL CONSTITUENTS
BETWEEN THE GAS AND SOLID PHASES**

Data and Analysis Compilation
for PSOC-1502, Hiawatha Coal

MODE OF PARTICLE BURNING

Data and Analysis Compilation
for PSOC-1502, Hiawatha Coal

Fractional Mass Remaining and Apparent Density of Hiawatha Coal and its Partially Reacted Chars

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.46	0.39	0.30	0.29
Fractional burnoff, daf	0.0	0.56	0.64	0.75	0.76
Apparent density, g/cc	1.29	0.47	0.48	0.44	0.44

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.45	0.29	0.18	0.12
Fractional burnoff, daf	0.0	0.58	0.75	0.88	0.94
Apparent density, g/cc	1.29	0.51	0.51	0.60	0.72

**STATISTICAL ANALYSES
OF ELEMENTAL COMPOSITION MEASUREMENTS
AND DERIVED QUANTITIES**

- **Raw Coal Composition**
- **Overall Combustion Conversion vs. Residence Time**
- **Elemental Partitioning between Gas and Solid Phases**

Data and Analysis Compilation
for PSOC-1502, Hiawatha Coal

Average Initial Mass Percents and Statistics						
	Hiawatha (hvcb) 106-125 μm			PSOC-1502d 6 % O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	2.923	0.073	3	0.025	0.182	0.419
Al ₂ O ₃	0.848	0.021	3	0.025	0.053	0.121
TiO ₂	0.076	0.002	3	0.025	0.005	0.011
Fe ₂ O ₃	0.369	0.023	3	0.061	0.056	0.129
CaO	0.615	0.037	3	0.060	0.092	0.212
Na ₂ O	0.133	0.008	3	0.063	0.021	0.048
K ₂ O	0.009	0.008	3	0.892	0.021	0.048
MgO	0.072	0.025	3	0.351	0.063	0.145
Σ Oxides	5.046					
C	73.457	1.836	3	0.025	4.562	10.523
H	5.040	0.321	3	0.064	0.797	1.838
O	12.250	0.705	3	0.058	1.753	4.043
N	1.153	0.049	3	0.043	0.123	0.283
S	0.390	0.026	3	0.068	0.066	0.152
Ash-s	7.003	0.659	3	0.094	1.637	3.776
Ash-l	6.900	0.173	3	0.025	0.429	0.988

Residual Total Mass (m/m₀) as a Function of Residence Time						
	Hiawatha (hvcb) 106-125 μm			PSOC-1502d 6 % O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.45	0.67	0.62	0.48	0.61	0.66
72	0.35	0.41	0.41	0.41	0.58	0.45
95	0.28	0.30	0.31	0.36	0.34	0.30
117	0.22	0.32	0.33	0.32	0.32	0.31

Residual Total Mass (m/m0) with Statistics						
Hiawatha (hvcb) 106-125 μm				PSOC-1502d 6 % O ₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	9	1.00	0.000	0.000
47	0.58	0.119	3	0.56	0.296	0.682
72	0.39	0.036	4	0.36	0.058	0.106
95	0.30	0.013	3	0.25	0.032	0.074
117	0.29	0.062	4	0.24	0.098	0.180

Residual Elemental Mass as a Function of Residence Time						
Hiawatha (hvcb) 106-125 μm				PSOC-1502d 6 % O ₂		
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.86	1.20	0.93	0.81	1.06	1.21
72	0.94	0.95	0.96	0.87	1.65	0.80
95	0.99	0.83	0.96	1.07	1.84	1.30
117	0.90	0.90	0.88	0.79	1.49	0.83
	K ₂ O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.06	0.65	0.19	0.08	0.60	0.74
72	0.25	0.44	0.05	0.00	0.39	0.51
95	0.00	0.31	0.03	0.00	0.25	0.40
117	1.17	0.29	0.03	0.04	0.27	0.33

Elemental Mass Release (Normalized) and Statistics						
Hiawatha (hvcb) 106-125 μm				PSOC-1502d 6 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.136	0.187	3	0.217	0.465	1.073
72	0.058	0.110	4	0.117	0.248	0.572
95	0.012	0.082	3	0.083	0.204	0.471
117	0.097	0.204	4	0.226	0.445	1.027
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.069	0.202	3	0.217	0.502	1.157
72	0.043	0.112	4	0.117	0.252	0.581
95	0.035	0.080	3	0.083	0.199	0.460
117	0.122	0.199	4	0.226	0.433	0.998
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	-0.205	0.261	3	0.217	0.649	1.497
72	0.046	0.111	4	0.117	0.251	0.579
95	0.174	0.069	3	0.083	0.171	0.394
117	0.096	0.203	4	0.224	0.441	1.017
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.079	3	0.079	0.196	0.452
47	0.187	0.178	3	0.220	0.443	1.023
72	0.132	0.106	4	0.122	0.240	0.554
95	-0.067	0.096	3	0.090	0.239	0.551
117	0.214	0.184	4	0.234	0.404	0.932

Elemental Mass Release (Normalized) and Statistics (con't)						
Hiawatha (hvcb) 106-125 μm				PSOC-1502d 6 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.078	3	0.078	0.195	0.449
47	-0.058	0.232	3	0.219	0.577	1.330
72	-0.650	0.200	4	0.121	0.455	1.050
95	-0.837	0.165	3	0.090	0.410	0.945
117	-0.487	0.344	4	0.231	0.754	1.739
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.080	3	0.080	0.200	0.460
47	-0.206	0.266	3	0.220	0.660	1.522
72	0.201	0.098	4	0.123	0.223	0.515
95	-0.300	0.119	3	0.092	0.296	0.682
117	0.168	0.199	4	0.240	0.440	1.015
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.894	3	0.894	2.220	5.120
47	-0.057	0.969	3	0.917	2.408	5.555
72	0.749	0.225	3	0.898	0.559	1.289
95	1.000	0.000	#NUM!	#NUM!	#NUM!	#NUM!
117	-0.170	0.257	4	0.220	0.557	1.285
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.354	3	0.354	0.880	2.029
47	-1.322	0.950	3	0.409	2.360	5.444
72	-2.153	1.154	3	0.366	2.837	6.544
95	-2.243	1.157	3	0.357	2.875	6.631
117	-1.394	1.222	3	0.510	2.950	6.803

Elemental Mass Release (Normalized) and Statistics (con't)						
Hiawatha (hvcb) 106-125 μm				PSOC-1502d 6 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.354	0.140	3	0.217	0.348	0.803
72	0.562	0.051	4	0.117	0.115	0.266
95	0.685	0.026	3	0.083	0.065	0.150
117	0.714	0.065	4	0.226	0.141	0.326
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.081	3	0.081	0.201	0.464
47	0.812	0.041	3	0.220	0.103	0.237
72	0.949	0.006	4	0.123	0.014	0.033
95	0.969	0.003	3	0.092	0.007	0.016
117	0.969	0.007	4	0.228	0.015	0.035
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.076	3	0.076	0.189	0.437
47	0.924	0.017	3	0.219	0.041	0.096
72	1.000	0.000	#NUM!	#NUM!	#NUM!	#NUM!
95	1.000	0.000	#NUM!	#NUM!	#NUM!	#NUM!
117	0.955	0.010	4	0.220	0.021	0.049
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.396	0.131	3	0.217	0.325	0.750
72	0.614	0.045	4	0.117	0.101	0.234
95	0.748	0.021	3	0.083	0.052	0.120
117	0.732	0.060	4	0.225	0.131	0.302

Elemental Mass Release (Normalized) and Statistics (con't)						
Hiawatha (hvcb) 106-125 μm				PSOC-1502d 6 % O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.084	3	0.084	0.209	0.483
47	0.256	0.165	3	0.222	0.410	0.945
72	0.490	0.064	4	0.125	0.146	0.337
95	0.597	0.038	3	0.095	0.095	0.219
117	0.672	0.077	4	0.234	0.169	0.389
Ash-l						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.117	0.192	3	0.217	0.476	1.098
72	0.135	0.101	4	0.117	0.228	0.525
95	0.021	0.081	3	0.083	0.202	0.467
117	0.071	0.210	4	0.226	0.457	1.054
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.107	3	0.107	0.265	0.611
47	0.056	0.218	3	0.231	0.542	1.250
72	0.327	0.095	3	0.141	0.221	0.510
95	0.135	0.100	3	0.115	0.247	0.571
117	0.104	0.212	4	0.237	0.468	1.078
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.396	0.131	3	0.217	0.325	0.750
72	0.614	0.045	4	0.117	0.101	0.234
95	0.748	0.021	3	0.083	0.052	0.120
117	0.732	0.060	4	0.225	0.131	0.302

Average Initial Mass Percents and Statistics						
	Hiawatha (hvcb) 106-125 μm			PSOC-1502d 12 % O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	2.923	0.073	3	0.025	0.182	0.419
Al ₂ O ₃	0.848	0.021	3	0.025	0.053	0.121
TiO ₂	0.076	0.002	3	0.025	0.005	0.011
Fe ₂ O ₃	0.369	0.023	3	0.061	0.056	0.129
CaO	0.615	0.037	3	0.060	0.092	0.212
Na ₂ O	0.133	0.008	3	0.063	0.021	0.048
K ₂ O	0.009	0.008	3	0.892	0.021	0.048
MgO	0.072	0.025	3	0.351	0.063	0.145
Σ Oxides	5.046					
C	73.457	1.836	3	0.025	4.562	10.523
H	5.040	0.321	3	0.064	0.797	1.838
O	12.250	0.705	3	0.058	1.753	4.043
N	1.153	0.049	3	0.043	0.123	0.283
S	0.390	0.026	3	0.068	0.066	0.152
Ash-s	7.003	0.659	3	0.094	1.637	3.776
Ash-l	6.900	0.173	3	0.025	0.429	0.988

Residual Total Mass (m/m₀) as a Function of Residence Time						
	Hiawatha (hvcb) 106-125 μm			PSOC-1502d 12 % O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.46	0.43	0.45	0.49	0.56	0.48
72	0.28	0.30	0.30	0.34	0.32	0.34
95	0.16	0.19	0.18	0.22	0.20	0.19
117	0.11	0.12	0.12	0.19	0.14	0.13

Residual Total Mass (m/m0) with Statistics						
Hiawatha (hvcb) 106-125 μm				PSOC-1502d 12 % O₂		
	Mean (mf)	σ	n	Mean (daf)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	1.00	0.000	9	1.00	0.000	0.000
47	0.45	0.014	3	0.42	0.034	0.079
72	0.29	0.013	3	0.25	0.032	0.073
95	0.18	0.012	4	0.12	0.019	0.035
117	0.12	0.005	4	0.06	0.008	0.016

Residual Elemental Mass as a Function of Residence Time						
Hiawatha (hvcb) 106-125 μm				PSOC-1502d 12 % O₂		
	SiO₂	TiO₂	Al₂O₃	Fe₂O₃	CaO	Na₂O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.03	0.90	1.00	1.01	1.33	1.15
72	0.97	0.87	0.98	0.80	0.89	0.72
95	0.95	0.82	0.97	0.97	1.18	0.34
117	0.97	0.64	0.98	0.83	1.61	0.78
	K₂O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.00	0.49	0.15	0.14	0.44	0.65
72	0.00	0.32	0.03	0.02	0.25	0.43
95	0.40	0.16	0.01	0.03	0.11	0.37
117	0.05	0.09	0.01	0.03	0.08	0.28

Elemental Mass Release (Normalized) and Statistics						
Hiawatha (hvcb) 106-125 μm				PSOC-1502d 12 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	-0.030	0.080	3	0.077	0.198	0.456
72	0.029	0.081	3	0.083	0.201	0.463
95	0.048	0.094	3	0.098	0.216	0.499
117	0.026	0.073	3	0.075	0.171	0.394
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	-0.003	0.077	3	0.077	0.192	0.444
72	0.020	0.082	3	0.083	0.203	0.467
95	0.027	0.096	3	0.098	0.221	0.509
117	0.025	0.073	3	0.075	0.172	0.396
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.095	0.070	3	0.077	0.174	0.400
72	0.133	0.072	3	0.083	0.179	0.413
95	0.182	0.081	3	0.098	0.186	0.428
117	0.363	0.051	3	0.080	0.120	0.277
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.079	3	0.079	0.196	0.452
47	-0.013	0.086	3	0.085	0.213	0.492
72	0.202	0.072	3	0.090	0.179	0.412
95	0.030	0.101	3	0.104	0.235	0.543
117	0.168	0.068	3	0.082	0.162	0.374

Elemental Mass Release (Normalized) and Statistics (con't)						
Hiawatha (hvcb) 106-125 μm				PSOC-1502d 12 % O2		
CaO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.078	3	0.078	0.195	0.449
47	-0.325	0.112	3	0.084	0.277	0.640
72	0.108	0.080	3	0.090	0.199	0.459
95	-0.177	0.123	3	0.104	0.285	0.656
117	-0.615	0.119	3	0.073	0.278	0.640
Na2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.080	3	0.080	0.200	0.460
47	-0.151	0.099	3	0.086	0.246	0.568
72	0.278	0.066	3	0.092	0.164	0.379
95	0.662	0.036	3	0.106	0.083	0.191
117	0.222	0.054	3	0.070	0.126	0.291
K2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.894	3	0.894	2.220	5.120
47	1.000	0.000	#NUM!	#NUM!	#NUM!	#NUM!
72	1.000	0.000	#NUM!	#NUM!	#NUM!	#NUM!
95	0.601	0.358	3	0.896	0.888	2.047
117	0.949	0.237	3	4.684	0.589	1.359
MgO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.354	3	0.354	0.880	2.029
47	-1.573	0.915	3	0.355	2.272	5.242
72	0.060	0.335	3	0.357	0.833	1.921
95	-2.744	1.350	3	0.361	3.335	7.692
117	-2.052	0.898	3	0.294	2.223	5.127

Elemental Mass Release (Normalized) and Statistics (con't)						
Hiawatha (hvcb) 106-125 μm				PSOC-1502d 12 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.515	0.037	3	0.077	0.093	0.215
72	0.677	0.027	3	0.083	0.067	0.154
95	0.843	0.016	3	0.098	0.036	0.082
117	0.914	0.008	3	0.091	0.019	0.043
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.081	3	0.081	0.201	0.464
47	0.852	0.013	3	0.087	0.032	0.074
72	0.968	0.003	3	0.092	0.007	0.017
95	0.991	0.001	3	0.106	0.002	0.005
117	0.991	0.001	3	0.081	0.002	0.004
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.076	3	0.076	0.189	0.437
47	0.859	0.012	3	0.082	0.029	0.067
72	0.975	0.002	3	0.088	0.005	0.012
95	0.971	0.003	3	0.103	0.007	0.016
117	0.969	0.002	3	0.076	0.006	0.013
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.558	0.034	3	0.077	0.085	0.196
72	0.750	0.021	3	0.083	0.052	0.119
95	0.888	0.011	3	0.098	0.025	0.059
117	0.918	0.007	3	0.081	0.016	0.036

Elemental Mass Release (Normalized) and Statistics (con't)						
Hiawatha (hvcb) 106-125 μm				PSOC-1502d 12 % O2		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.084	3	0.084	0.209	0.483
47	0.346	0.059	3	0.090	0.146	0.337
72	0.574	0.040	3	0.095	0.101	0.232
95	0.632	0.040	3	0.109	0.093	0.215
117	0.715	0.025	3	0.089	0.061	0.140
Ash-l						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.066	0.072	3	0.077	0.179	0.413
72	0.133	0.072	3	0.083	0.179	0.413
95	0.090	0.090	3	0.098	0.207	0.476
117	0.110	0.067	3	0.075	0.158	0.364
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.107	3	0.107	0.265	0.611
47	0.199	0.089	3	0.111	0.221	0.510
72	0.083	0.106	3	0.115	0.262	0.605
95	0.126	0.111	3	0.127	0.263	0.606
117	0.128	0.080	3	0.092	0.192	0.443
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.558	0.034	3	0.077	0.085	0.196
72	0.750	0.021	3	0.083	0.052	0.119
95	0.888	0.011	3	0.098	0.025	0.059
117	0.918	0.007	3	0.081	0.016	0.036

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE TEMPERATURE DISTRIBUTIONS**

Data and Analysis Compilation
for PSOC-1502, Hiawatha Coal

6 mole-% Oxygen
Environment

12 mole-% Oxygen
Environment

HIAWATHA COAL CHAR

COAL TYPE: Hiawatha, psoc 1502, 10kgcl33. 7-06-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	1	1374.5	0.0	2.27	0.00	0.974	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1650.0	4	1643.9	14.9	2.27	0.16	0.596	0.239
1700.0	4	1704.3	6.2	2.40	0.14	0.905	0.481
1750.0	156	1760.8	11.5	2.59	0.09	0.759	0.346
1800.0	104	1786.2	9.4	2.60	0.04	0.697	0.275
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 269
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Hiawatha, psoc 1502, 15kgcl33. 7-06-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	1	1528.1	0.0	2.30	0.00	1.204	0.000
1600.0	1	1575.3	0.0	2.63	0.00	1.168	0.000
1650.0	2	1658.7	22.6	2.56	0.13	0.346	0.337
1700.0	40	1711.2	10.4	2.74	0.07	0.989	0.387
1750.0	233	1747.5	11.5	2.77	0.03	0.734	0.293
1800.0	21	1785.9	7.8	2.76	0.04	0.597	0.608
1850.0	1	1825.1	0.0	2.68	0.00	0.626	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 299
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Hiawatha, psoc1502, 20kgcl33. 7-06-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	1	1593.8	0.0	2.96	0.00	1.307	0.000
1650.0	25	1655.8	13.3	2.87	0.11	0.855	0.397
1700.0	217	1705.6	12.3	2.93	0.05	0.749	0.238
1750.0	55	1739.2	12.5	2.91	0.21	0.564	0.216
1800.0	2	1781.9	1.6	2.82	0.20	0.449	0.400
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 300
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Hiawatha, psoc1502, 10kgcl42. 7-06-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1652.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1443.2	0.0	1.97	0.00	0.977	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1650.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1700.0	1	1697.4	0.0	2.23	0.00	0.383	0.000
1750.0	1	1745.2	0.0	2.14	0.00	0.135	0.000
1800.0	2	1811.1	1.4	2.49	0.21	0.271	0.149
1850.0	4	1867.6	4.9	2.54	0.07	0.883	0.057
1900.0	147	1910.0	10.6	2.58	0.04	0.795	0.211
1950.0	105	1938.6	11.7	2.55	0.22	0.694	0.232
2000.0	8	2004.1	10.3	2.22	0.42	0.678	0.373
2050.0	1	2056.2	0.0	2.32	0.00	0.507	0.000
2100.0	2	2102.3	10.1	64.42	89.02	0.683	0.650
2150.0	3	2151.4	4.7	43.67	59.19	0.275	0.070
2200.0	2	2193.8	20.3	2.07	0.19	2.069	2.221
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 277
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Hiawatha, psoc 1502, 15kgc142. 7-06-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	1	1514.9	0.0	2.52	0.00	0.070	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	3	1609.9	10.2	2.56	0.18	0.524	0.075
1650.0	12	1645.1	12.1	2.78	0.02	0.278	0.213
1700.0	3	1693.5	6.8	2.66	0.08	0.275	0.273
1750.0	13	1759.4	7.2	2.70	0.14	0.345	0.169
1800.0	14	1807.1	14.6	2.75	0.05	0.368	0.247
1850.0	36	1857.5	13.9	2.72	0.10	0.611	0.301
1900.0	149	1902.7	12.3	2.75	0.05	0.646	0.335
1950.0	37	1944.8	13.1	2.70	0.20	0.642	0.581
2000.0	5	1990.6	11.2	2.75	0.06	0.436	0.256
2050.0	1	2046.6	0.0	2.74	0.00	0.385	0.000
2100.0	2	2100.7	29.6	2.30	0.06	1.153	0.307
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	1	2179.3	0.0	2.07	0.00	0.427	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 277
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Hiawatha, psoc1502, 20kgc142. 7-06-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	2	1519.1	1.4	2.95	0.02	0.326	0.196
1550.0	12	1558.7	11.0	2.81	0.36	0.247	0.126
1600.0	47	1605.4	12.4	2.80	0.30	0.462	0.297
1650.0	29	1647.4	16.6	2.91	0.04	0.723	0.209
1700.0	13	1703.7	13.8	2.88	0.08	0.522	0.265
1750.0	15	1750.0	16.0	2.92	0.08	0.577	0.271
1800.0	26	1798.0	13.5	2.89	0.11	0.474	0.244
1850.0	26	1854.3	16.2	2.92	0.07	0.761	0.426
1900.0	18	1896.4	14.7	2.93	0.12	0.539	0.245
1950.0	3	1937.2	4.0	2.78	0.15	0.379	0.369
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	1	2229.6	0.0	2.25	0.00	0.131	0.000

NUMBER OF PARTICLES = 192
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE SIZES, TEMPERATURES, AND VELOCITIES**

Data and Analysis Compilation
for PSOC-1502, Hiawatha Coal

COAL TYPE: HIAWATHA COAL, 106 - 125 micron:
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	2	1737	47	2.36	0.28	2.27	0.77
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	1	1777	0	2.60	0.00	1.32	0.00
100.	10	1739	122	2.58	0.11	1.39	0.37
110.	15	1769	40	2.54	0.14	0.99	0.27
120.	29	1778	11	2.60	0.03	0.89	0.21
130.	24	1777	16	2.60	0.04	0.84	0.26
140.	51	1770	16	2.58	0.05	0.77	0.19
150.	34	1772	14	2.59	0.03	0.66	0.17
160.	23	1771	15	2.60	0.04	0.61	0.15
170.	16	1765	13	2.61	0.03	0.69	0.20
180.	12	1766	20	2.60	0.05	0.49	0.17
190.	15	1762	14	2.60	0.04	0.52	0.17
200.	13	1736	44	2.57	0.13	0.57	0.18
210.	7	1760	15	2.59	0.03	0.46	0.10
220.	4	1744	30	2.58	0.04	0.40	0.15
230.	0	0	0	0.00	0.00	0.00	0.00
240.	3	1755	19	2.60	0.02	0.42	0.20

NUMBER OF PARTICLES = 259
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0:00 TO 10:00

COAL TYPE: HIAWATHA COAL, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	2	1767	22	2.71	0.00	3.26	0.06
70.	1	1758	0	2.68	0.00	1.75	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	3	1786	18	2.76	0.04	0.62	0.38
100.	11	1755	22	2.78	0.03	1.01	0.25
110.	27	1742	18	2.76	0.06	0.99	0.29
120.	45	1749	20	2.76	0.04	0.87	0.34
130.	37	1750	16	2.77	0.03	0.78	0.22
140.	50	1745	19	2.76	0.04	0.71	0.23
150.	39	1743	17	2.76	0.05	0.68	0.21
160.	26	1731	47	2.74	0.10	0.62	0.19
170.	30	1741	19	2.76	0.03	0.56	0.13
180.	8	1735	27	2.75	0.05	0.57	0.17
190.	4	1721	24	2.75	0.04	0.66	0.28
200.	4	1705	79	2.75	0.07	0.63	0.37
210.	4	1740	17	2.76	0.02	0.40	0.11
220.	3	1694	10	2.68	0.11	0.81	0.20
230.	2	1743	25	2.77	0.00	0.32	0.16
240.	1	1702	0	2.71	0.00	0.81	0.00

NUMBER OF PARTICLES = 297
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0:00 TO 10:00

COAL TYPE: HIAWATHA COAL, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	1	1722	0	2.93	0.00	0.99	0.00
90.	2	1748	36	2.87	0.09	1.24	0.28
100.	11	1711	32	2.90	0.14	0.97	0.33
110.	18	1717	22	2.94	0.05	0.86	0.19
120.	63	1709	21	2.93	0.05	0.86	0.27
130.	65	1711	23	2.94	0.06	0.69	0.23
140.	47	1710	22	2.92	0.08	0.65	0.18
150.	27	1701	21	2.93	0.03	0.64	0.16
160.	28	1702	25	2.86	0.27	0.58	0.19
170.	12	1708	21	2.91	0.07	0.60	0.27
180.	10	1687	26	2.90	0.07	0.74	0.39
190.	3	1721	48	2.89	0.10	0.54	0.35
200.	5	1686	8	2.90	0.04	0.59	0.17
210.	5	1680	25	2.84	0.07	0.65	0.38
220.	1	1670	0	2.93	0.00	0.54	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 298
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0:00 TO 10:00

COAL TYPE: HIAWATHA COAL, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	1	2095	0	****	0.00	1.14	0.00
100.	9	1919	38	2.37	0.53	1.31	0.28
110.	12	1957	76	2.57	0.12	0.92	0.32
120.	35	1920	25	2.61	0.03	0.84	0.24
130.	63	1922	33	2.58	0.08	0.76	0.19
140.	65	1919	23	2.55	0.17	0.72	0.18
150.	37	1920	60	5.93	****	0.67	0.15
160.	25	1925	27	2.52	0.21	0.67	0.11
170.	11	1918	32	2.44	0.31	0.61	0.12
180.	7	1976	79	2.40	0.36	0.46	0.15
190.	2	1932	23	2.49	0.08	0.49	0.05
200.	4	1982	98	2.36	0.17	0.42	0.13
210.	2	2018	128	2.00	0.74	0.30	0.11
220.	1	1443	0	1.97	0.00	0.98	0.00
230.	2	1930	0	2.60	0.04	0.26	0.14
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 276
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0:00 TO 10:00

COAL TYPE: HIAWATHA COAL, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.05 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	2	1917	5	2.80	0.04	1.93	0.49
60.	2	1907	13	2.77	0.04	2.07	1.29
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	5	1889	144	2.72	0.19	0.79	0.41
100.	19	1881	115	2.71	0.15	0.62	0.24
110.	40	1877	98	2.71	0.19	0.62	0.25
120.	47	1891	78	2.74	0.05	0.62	0.22
130.	45	1895	71	2.73	0.12	0.58	0.21
140.	34	1872	63	2.75	0.05	0.56	0.20
150.	31	1872	68	2.72	0.11	0.58	0.22
160.	16	1855	68	2.73	0.08	0.46	0.28
170.	10	1882	47	2.71	0.08	0.46	0.24
180.	8	1860	56	2.73	0.09	0.52	0.27
190.	2	1713	116	2.79	0.06	0.08	0.03
200.	3	1839	100	2.75	0.03	0.23	0.21
210.	3	1841	60	2.64	0.15	0.21	0.04
220.	1	1764	0	2.77	0.00	0.13	0.00
230.	2	1847	33	2.83	0.00	0.04	0.02
240.	1	1904	0	2.80	0.00	0.15	0.00

NUMBER OF PARTICLES = 271
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: HIAWATHA COAL, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	2	1736	193	2.93	0.00	1.59	1.26
60.	0	0	0	0.00	0.00	0.00	0.00
70.	1	1591	0	2.86	0.00	0.27	0.00
80.	1	1904	0	3.07	0.00	0.69	0.00
90.	3	1710	88	2.84	0.12	0.52	0.41
100.	6	1798	105	2.85	0.14	0.54	0.21
110.	18	1773	110	2.94	0.06	0.60	0.24
120.	26	1735	136	2.92	0.08	0.53	0.20
130.	33	1711	100	2.92	0.06	0.60	0.22
140.	25	1704	113	2.91	0.06	0.52	0.35
150.	23	1698	92	2.89	0.10	0.64	0.27
160.	24	1690	101	2.89	0.08	0.58	0.27
170.	3	1752	119	2.70	0.12	0.56	0.40
180.	7	1816	110	2.85	0.07	0.56	0.33
190.	5	1615	29	2.35	0.73	0.10	0.08
200.	3	1683	25	2.91	0.03	0.44	0.09
210.	3	1898	264	2.60	0.28	0.12	0.05
220.	2	1710	163	2.76	0.15	0.26	0.02
230.	0	0	0	0.00	0.00	0.00	0.00
240.	3	1629	80	2.81	0.06	0.31	0.36

NUMBER OF PARTICLES = 188
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1502
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	2	1737	47	2.36	0.28	2.27	0.77
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	1	1777	0	2.60	0.00	1.32	0.00
100.	10	1739	122	2.58	0.11	1.39	0.37
110.	15	1769	40	2.54	0.14	0.99	0.27
120.	29	1778	11	2.60	0.03	0.89	0.21
130.	24	1777	16	2.60	0.04	0.84	0.26
140.	51	1770	16	2.58	0.05	0.77	0.19
150.	34	1772	14	2.59	0.03	0.66	0.17
160.	23	1771	15	2.60	0.04	0.61	0.15
170.	16	1765	13	2.61	0.03	0.69	0.20
180.	12	1766	20	2.60	0.05	0.49	0.17
190.	15	1762	14	2.60	0.04	0.52	0.17
200.	13	1736	44	2.57	0.13	0.57	0.18
210.	7	1760	15	2.59	0.03	0.46	0.10
220.	4	1744	30	2.58	0.04	0.40	0.15
230.	0	0	0	0.00	0.00	0.00	0.00
240.	3	1755	19	2.60	0.02	0.42	0.20

NUMBER OF PARTICLES = 259
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1502
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.1 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	2	1767	22	2.71	0.00	3.26	0.06
70.	1	1758	0	2.68	0.00	1.75	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	3	1786	18	2.76	0.04	0.62	0.38
100.	11	1755	22	2.78	0.03	1.01	0.25
110.	27	1742	18	2.76	0.06	0.99	0.29
120.	45	1749	20	2.76	0.04	0.87	0.34
130.	37	1750	16	2.77	0.03	0.78	0.22
140.	50	1745	19	2.76	0.04	0.71	0.23
150.	39	1743	17	2.76	0.05	0.68	0.21
160.	26	1731	47	2.74	0.10	0.62	0.19
170.	30	1741	19	2.76	0.03	0.56	0.13
180.	8	1735	27	2.75	0.05	0.57	0.17
190.	4	1721	24	2.75	0.04	0.66	0.28
200.	4	1705	79	2.75	0.07	0.63	0.37
210.	4	1740	17	2.76	0.02	0.40	0.11
220.	3	1694	10	2.68	0.11	0.81	0.20
230.	2	1743	25	2.77	0.00	0.32	0.16
240.	1	1702	0	2.71	0.00	0.81	0.00

NUMBER OF PARTICLES = 297
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1502
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	1	1722	0	2.93	0.00	0.99	0.00
90.	2	1748	36	2.87	0.09	1.24	0.28
100.	11	1711	32	2.90	0.14	0.97	0.33
110.	18	1717	22	2.94	0.05	0.86	0.19
120.	63	1709	21	2.93	0.05	0.86	0.27
130.	65	1711	23	2.94	0.06	0.69	0.23
140.	47	1710	22	2.92	0.08	0.65	0.18
150.	27	1701	21	2.93	0.03	0.64	0.16
160.	28	1702	25	2.86	0.27	0.58	0.19
170.	12	1708	21	2.91	0.07	0.60	0.27
180.	10	1687	26	2.90	0.07	0.74	0.39
190.	3	1721	48	2.89	0.10	0.54	0.35
200.	5	1686	8	2.90	0.04	0.59	0.17
210.	5	1680	25	2.84	0.07	0.65	0.38
220.	1	1670	0	2.93	0.00	0.54	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 298
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1502
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	1	2095	0	****	0.00	1.14	0.00
100.	9	1919	38	2.37	0.53	1.31	0.28
110.	12	1957	76	2.57	0.12	0.92	0.32
120.	35	1920	25	2.61	0.03	0.84	0.24
130.	63	1922	33	2.58	0.08	0.76	0.19
140.	65	1919	23	2.55	0.17	0.72	0.18
150.	37	1920	60	5.93	****	0.67	0.15
160.	25	1925	27	2.52	0.21	0.67	0.11
170.	11	1918	32	2.44	0.31	0.61	0.12
180.	7	1976	79	2.40	0.36	0.46	0.15
190.	2	1932	23	2.49	0.08	0.49	0.05
200.	4	1982	98	2.36	0.17	0.42	0.13
210.	2	2018	128	2.00	0.74	0.30	0.11
220.	1	1443	0	1.97	0.00	0.98	0.00
230.	2	1930	0	2.60	0.04	0.26	0.14
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 276
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1502
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.1 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	2	1917	5	2.80	0.04	1.93	0.49
60.	2	1907	13	2.77	0.04	2.07	1.29
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	5	1889	144	2.72	0.19	0.79	0.41
100.	19	1881	115	2.71	0.15	0.62	0.24
110.	40	1877	98	2.71	0.19	0.62	0.25
120.	47	1891	78	2.74	0.05	0.62	0.22
130.	45	1895	71	2.73	0.12	0.58	0.21
140.	34	1872	63	2.75	0.05	0.56	0.20
150.	31	1872	68	2.72	0.11	0.58	0.22
160.	16	1855	68	2.73	0.08	0.46	0.28
170.	10	1882	47	2.71	0.08	0.46	0.24
180.	8	1860	56	2.73	0.09	0.52	0.27
190.	2	1713	116	2.79	0.06	0.08	0.03
200.	3	1839	100	2.75	0.03	0.23	0.21
210.	3	1841	60	2.64	0.15	0.21	0.04
220.	1	1764	0	2.77	0.00	0.13	0.00
230.	2	1847	33	2.83	0.00	0.04	0.02
240.	1	1904	0	2.80	0.00	0.15	0.00

NUMBER OF PARTICLES = 271
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1502
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	2	1736	193	2.93	0.00	1.59	1.26
60.	0	0	0	0.00	0.00	0.00	0.00
70.	1	1591	0	2.86	0.00	0.27	0.00
80.	1	1904	0	3.07	0.00	0.69	0.00
90.	3	1710	88	2.84	0.12	0.52	0.41
100.	6	1798	105	2.85	0.14	0.54	0.21
110.	18	1773	110	2.94	0.06	0.60	0.24
120.	26	1735	136	2.92	0.08	0.53	0.20
130.	33	1711	100	2.92	0.06	0.60	0.22
140.	25	1704	113	2.91	0.06	0.52	0.35
150.	23	1698	92	2.89	0.10	0.64	0.27
160.	24	1690	101	2.89	0.08	0.58	0.27
170.	3	1752	119	2.70	0.12	0.56	0.40
180.	7	1816	110	2.85	0.07	0.56	0.33
190.	5	1615	29	2.35	0.73	0.10	0.08
200.	3	1683	25	2.91	0.03	0.44	0.09
210.	3	1898	264	2.60	0.28	0.12	0.05
220.	2	1710	163	2.76	0.15	0.26	0.02
230.	0	0	0	0.00	0.00	0.00	0.00
240.	3	1629	80	2.81	0.06	0.31	0.36

NUMBER OF PARTICLES = 188
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**KINETIC ANALYSIS
AND COMBUSTION PARAMETERS**

Data and Analysis Compilation
for PSOC-1502, Hiawatha Coal

Summary of Combustion Parameters for PSOC-1502D		
Char oxidation rate parameters $q = A \exp(-E/RT_p) P^n$	A E n	chars reacted at their diffusion limited rates in both the 6 and 12 mole-% oxygen environments
Product ratio parameters $CO/CO_2 = A_c \exp(-E_c/RT_p)$	A_c E_c	3×10^8 * 60 * kcal / mole
Burning mode parameter $\rho/\rho_o = (m/m_o)^\alpha$ $d/d_o = (m/m_o)^{(1-\alpha)/3}$	α	0.1
Char structural parameters $\omega = d_o / d_c$ (linear swelling factor) $\rho_{c,o} = mc/V_c$ at $z = 6.5$ cm (Initial char particle carbon density)	ω ρ_{c,o}	1.16 0.44 gm / cm ³
<p>As an example, this parameter set yields a combustion rate, q, of 0.00704 gm/sq.cm-s for a 100 μm particle in a gas with $T_g = 1600$ K containing 6 mole-% oxygen</p> <p>These product ratio parameters yield 2.6 mole-% carbon dioxide at 1900 K and 14.7 mole-% carbon dioxide at 1700 K</p> <p>* These particular parameters should be regarded as empirical parameters, useful for the prediction of burning rates. They do not necessarily have fundamental significance and/or are not necessarily unique for this data set.</p>

Measured Carbon Conversions in the CCL
for PSOC-1502D

**CALCULATIONS OF THE COAL CHAR REACTIVITY INDEX, τ_{50} ,
FOR VARIOUS ENVIRONMENTS
PRESENT IN PULVERIZED-COAL COMBUSTION SYSTEMS**

Data and Analysis Compilation
for PSOC-1502, Hiawatha Coal

Compilation of Data and Kinetic Analyses for

**Beulah Zap Lignite
(N. Dakota)**

PSOC-1507D

TABLE OF CONTENTS

- **Sample history, geologic information and chemical analysis of bulk, raw coal**
- **Chemical analysis of size-fractionated raw coal and partially reacted chars**
- **Time resolved measurements of the partitioning of elemental coal constituents between the gas and solid phases**
- **Mode of particle burning**
- **Statistical analyses of elemental composition measurements and derived quantities**
- **Optical measurements of single-particle temperature distributions**
- **Optical measurements of single-particle sizes, temperatures, and velocities**
- **Kinetic analysis and combustion parameters**
- **Calculations of the coal char reactivity index, τ_{50} , for various environments present in pulverized-coal combustion systems**

**SAMPLE HISTORY, GEOLOGIC INFORMATION AND
CHEMICAL ANALYSIS OF BULK, RAW COAL**

Data and Analysis Compilation
for PSOC-1507, Beulah Zap Lignite

SAMPLE HISTORY

PENN STATE NUMBER	PSOC-1507
COLLECTED BY	PENNSYLVANIA STATE UNIVERSITY
COLLECTION DATE	7/2/85
COLLECTOR'S NUMBER	
REPORTED RANK	LIGNITE
SAMPLE TYPE	CHANNEL WHOLE SEAM
OTHER SAMPLE INFORMATION	UPPER & LOWER BEULAH SEAM COMBINED
SAMPLE RESERVE	300
SEAM NAME	BEULAH
ALTERNATE SEAM NAME	ZAP
TOTAL SEAM THICKNESS	12 FT. 1 IN.
THICKNESS OF SEAM SAMPLED	12 FT. 1 IN.
PORTION RECOVERED IN CORE	
DIAMETER OF CORE	

SAMPLE LOCATION

COUNTRY	U.S.A.
STATE	NORTH DAKOTA
COUNTY	MERCER
TOWNSHIP	
NEAREST TOWN	ZAP
COAL PROVINCE	NORTHERN GREAT PLAINS
COAL REGION	FORT UNION
COAL FIELD	

GEOLOGIC INFORMATION

SYSTEM (AGE)	TERTIARY
SERIES	PALEOCENE
GROUP	
FORMATION	FORT UNION
OVERBURDEN LITHOLOGY	
FLOOR LITHOLOGY	BLACK SHALE

SEAM STRATA INFORMATION

<u>THICKNESS</u>	<u>LITHOTYPE</u>
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SEAM NAME	BEULAH	COUNTRY	U.S.A.
APPARENT RANK	LIGNITE A (LIGA)	STATE	NORTH DAKOTA

CHEMICAL DATA 1

PROXIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF (PAFF)	DMMF (PARR-G)	DMMF (DIR MM)
% MOISTURE	33.57					
% ASH	8.30	12.49				
% VOLATILE MATTER	27.08	40.77	46.59	45.73	45.29	
% FIXED CARBON	31.06	46.75	53.42	54.27	55.71	

CALORIFIC VALUE (GROSS BTU/LB)	DRY	AS REC'D MOIST.	EQUIL MOIST.
MM-FREE, DIRECT			
MM-CONTAINING	10627	7060	6792
MM-FREE (PARR)	12313	7747	7423
MM-FREE (MOD.P)	12375	7734	7412
BEST MM FREE		7734	7412
NET CV, DMMF BTU/LB	11899		
ASH-FREE	12144		

MOTT-SPOONER DIFFERENCE =

ASSOCIATED ANALYSES	DRY	MMF
% EQUILIBRIUM MOISTURE	36.09	42.10
% TOTAL SULFUR	1.43	

RANK CALCULATIONS

APPARENT RANK (AS REC'D MOIST)	LIGNITE A (LIGA)
ASTM RANK (EQUIL. MOIST.)	LIGNITE A (LIGA)
REFLECTANCE RANK CATEGORY	
INTERNATIONAL RANK	
AS REC'D MOIST.	
EQUIL. MOIST	
REPORTED RANK	LIGNITE

SEAM NAME	BEULAH	COUNTRY	U.S.A.
APPARENT RANK	LIGNITE A (LIGA)	STATE	NORTH DAKOTA

CHEMICAL DATA 2

ULTIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF(PARR) (14.28 % MM)
% ASH	8.30	12.49		
% CARBON	41.59	62.61	71.55	73.04
% HYDROGEN	*2.93	4.41	5.04	5.14
% NITROGEN	0.55	0.83	0.95	0.97
% SULFUR	0.95	1.43	1.63	
% CHLORINE	0.01	0.02	0.02	0.02
% OXYGEN (DIFF)	*12.09	18.21	20.81	20.83

SULFUR FORMS	% PYRITIC	% SULFATIC	% ORGANIC	% TOTAL
DRY	0.02	0.01	1.40	1.43
DAF	0.02	0.01	1.60	1.63
OPTICAL				

ELEMENTAL ANALYSIS	DRY	DMMF (MOD.P) (14.13 % MM)	DMMF(DIR.) (% MM)
% CARBON	62.44	72.71	
% HYDROGEN	4.25	4.95	
% NITROGEN	0.83	0.97	
% ORGANIC SULFUR	1.40	1.63	
% OXYGEN (DIFF)	16.95	19.73	
% CHLORINE	0.02	0.02	
% MINERAL MATTER (INCLUDES 0.04 % FES2)	14.13		

ATOM RATIOS (DMMF)	PARR	MOD.PAR	DIRECT
ATOMIC H/C	0.846	0.817	
ATOMIC O/C	0.214	0.237	

MISC. CHEMICAL DATA	DRY	OF DMMF COAL	OF DMMF OXYGEN
% O AS COOH			
% O AS OH			
% S AS SO4, IN ASH			
% CARBONATE AS CO2			
% CHLORINE	0.04		

INFRA-RED ANALYSIS

(*)- EXCLUDES MOISTURE

SEAM NAME	BEULAH	COUNTRY	U.S.A.
APPARENT RANK	LIGNITE A (LIGA)	STATE	NORTH DAKOTA

CHEMICAL DATA 3

% MOISTURE IN COAL = 21.00
 % HIGH TEMPERATURE ASH = 8.68 AT 750 DEGREES C

TRACE ELEMENT ANALYSIS	PPM HTA	PPM TOTAL COAL	MAJOR ELEMENT ANALYSIS	OXIDE % OF HTA	ELEMENT % OF TOTAL DRY COAL
AG			SI02	19.70	0.80
B			AL203	9.34	0.43
BA	6570	570	TI02	0.37	0.02
BE	7	1	FE203	12.90	0.78
BI			MG0	5.33	0.28
CE			CA0	23.20	1.44
CO			NA20	5.87	0.38
CR	65	6	K20	0.69	0.05
CU	100	9	P205	0.34	0.01
GA			S03	20.00	0.69
GE					
LA					
LI					
MN	1400	122			
MO			<u>VOLATILES</u>	<u>PPM TOTAL COAL</u>	
NI	45	4			
NB			AS		
PB			BR		
RB	40	3	CD		
SC			CL		
SN			F		
SR	4900	425	HG		
TH			SB		
U			SE		
V	85	7			
Y					
YB					
ZN	40	3			
ZR	190	16			

SEAM NAME	BEULAH	COUNTRY	U.S.A.
APPARENT RANK	LIGNITE A (LIGA)	STATE	NORTH DAKOTA

MINERALOGICAL DATA

TOTAL MINERAL MATTER

% MM-PARR	14.28
% MM-MODIFIED PARR	14.13
% MM-KMC	
% MM-DIRECT	
% MM-BEST AVAILABLE	14.13
VOL % MM-PARR	7.43

MINERAL COMPOSITION

NONE

SEAM NAME	BEULAH	COUNTRY	U.S.A.
APPARENT RANK	LIGNITE A (LIGA)	STATE	NORTH DAKOTA

PETROGRAPHIC DATA

PETROGRAPHIC DATA NOT AVILABLE

PHYSICAL PROPERTIES

HARDGROVE GRINDABILITY	
VICKER'S MICROHARDNESS	
FREE SWELLING INDEX	0.0
GRAY KING COKE TYPE	

<u>ASH FUSION ANALYSIS (DEGREES F)</u>	<u>REDUCING</u>	<u>OXIDIZING</u>
INITIAL DEFORMATION TEMPERATURE	2330	2320
SOFTENING TEMPERATURE	2350	2340
HEMISPHERE TEMPERATURE	2360	2370
FLUID TEMPERATURE	2370	2420

ANALYSIS LOG

<u>ANALYSIS</u>	<u>DATE</u>	<u>PERFORMED BY</u>
A.R. MOIST		
EQUIL. MOIST.		
PROXIMATE		
ULTIMATE		
SULFUR FORMS		
FSI	4/29/86	COAL PETROGRAPHY LABORATORIES-PSU
PLASTOMETER		
DIRECT MM		
GRAY-KING		

**CHEMICAL ANALYSES OF SIZE-FRACTIONATED RAW COAL
AND PARTIALLY REACTED CHARS**

Data and Analysis Compilation
for PSOC-1507, Beulah Zap Lignite

**Organic Elemental Analysis and Percent Ash of Beulah Lignite
and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	57.32	4.02	27.01	0.86	1.82	14.1
6.4	68.63	0.72	8.11	0.96	1.37	30.96
12.7	61.84	0.57	9.21	0.76	3.34	34.81
19.1	52.20	0.47	8.91	0.57	3.42	45.49
25.4	38.21	0.46	11.01	0.51	0.45	56.07

12 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	56.11	4.00	24.31	0.87	1.87	14.04
6.4	67.09	1.10	11.18	0.86	2.23	26.88
12.7	45.61	0.49	11.10	0.48	0.60	49.55
19.1	21.27	0.57	11.79	0.36	0.13	74.83
25.4	10.88	0.50	11.4	0.29	0.07	84.77

* Data taken in September 1988

**Ash Content of Beulah Lignite and its
Partially Reacted Chars**

Initial particle size range: 106 - 125 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	2.06	0.944	0.047	1.74	--	--	--	--
6.4	4.54	2.06	0.101	5.68	--	--	--	--
12.7	5.53	2.61	0.149	5.74	--	--	--	--
19.1	8.28	3.67	0.174	6.38	--	--	--	--
25.4	11.5	4.71	0.222	6.95	--	--	--	--

12 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	2.22	1.01	0.049	1.63	--	--	--	--
6.4	4.87	2.05	0.097	3.23	--	--	--	--
12.7	8.67	3.86	0.182	6.70	--	--	--	--
19.1	13.9	6.15	0.274	10.2	--	--	--	--
25.4	19.0	7.77	0.360	10.5	--	--	--	--

* Data taken in September 1988

**TIME RESOLVED MEASUREMENTS OF THE
PARTITIONING OF ELEMENTAL COAL CONSTITUENTS
BETWEEN THE GAS AND SOLID PHASES**

Data and Analysis Compilation
for PSOC-1507, Beulah Zap Lignite

MODE OF PARTICLE BURNING

Data and Analysis Compilation
for PSOC-1507, Beulah Zap Lignite

Fractional Mass Remaining and Apparent Density of Beulah Lignite and its Partially Reacted Chars

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.47	0.36	0.25	0.20
Fractional burnoff, daf	0.0	0.60	0.72	0.87	0.90
Apparent density, g/cc	1.23	0.74	0.70	0.64	0.73

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.47	0.24	0.15	0.12
Fractional burnoff, daf	0.0	0.59	0.87	0.96	0.98
Apparent density, g/cc	1.23	0.77	0.71	1.02	1.24

**STATISTICAL ANALYSES
OF ELEMENTAL COMPOSITION MEASUREMENTS
AND DERIVED QUANTITIES**

- **Raw Coal Composition**
- **Overall Combustion Conversion vs. Residence Time**
- **Elemental Partitioning between Gas and Solid Phases**

Data and Analysis Compilation
for PSOC-1507, Beulah Zap Lignite

Average Initial Mass Percents and Statistics						
	Beulah lignite 106-125 μm				PSOC-1507d 6 % O ₂	
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	2.140	0.113	2	0.053	1.016	5.092
Al ₂ O ₃	0.977	0.047	2	0.048	0.419	2.101
TiO ₂	0.048	0.001	2	0.029	0.013	0.064
Fe ₂ O ₃	1.685	0.078	2	0.046	0.699	3.501
CaO	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Na ₂ O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
K ₂ O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
MgO	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Σ Oxides	#DIV/0!					
C	56.715	1.418	2	0.025	12.739	63.821
H	4.010	0.100	2	0.025	0.901	4.512
O	25.660	1.909	2	0.074	17.153	85.936
N	0.865	0.022	2	0.025	0.194	0.973
S	1.845	0.046	2	0.025	0.414	2.076
Ash-s	13.675	0.431	2	0.032	3.875	19.415
Ash-l	14.070	0.352	2	0.025	3.160	15.833

Residual Total Mass (m/m ₀) as a Function of Residence Time						
	Beulah lignite 106-125 μm				PSOC-1507d 6 % O ₂	
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.46	0.47	0.47	0.48	0.59	0.45
72	0.36	0.39	0.37	0.32	0.44	0.40
95	0.19	0.26	0.27	0.28	0.31	0.31
117	0.18	0.19	0.21	0.22	0.24	0.25

Residual Total Mass (m/m0) with Statistics						
Beulah lignite 106-125 μm				PSOC-1507d 6 % O₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	8	1.00	0.000	0.000
47	0.47	0.007	4	0.40	0.012	0.022
72	0.36	0.028	7	0.28	0.026	0.039
95	0.25	0.041	5	0.16	0.051	0.084
117	0.20	0.017	4	0.10	0.027	0.050

Residual Elemental Mass as a Function of Residence Time						
Beulah lignite 106-125 μm				PSOC-1507d 6 % O₂		
	SiO₂	TiO₂	Al₂O₃	Fe₂O₃	CaO	Na₂O
t (ms)						
0	1.00	1.00	1.00	1.00	#DIV/0!	#DIV/0!
47	1.00	0.99	0.99	1.58	#DIV/0!	#DIV/0!
72	0.93	1.12	0.97	1.23	#DIV/0!	#DIV/0!
95	0.95	0.89	0.93	0.93	#DIV/0!	#DIV/0!
117	1.06	0.91	0.95	0.81	#DIV/0!	#DIV/0!
	K₂O	C	H	O	N	S
t (ms)						
0	#DIV/0!	1.00	1.00	1.00	1.00	1.00
47	#DIV/0!	0.57	0.08	0.15	0.52	0.35
72	#DIV/0!	0.39	0.05	0.13	0.32	0.65
95	#DIV/0!	0.23	0.03	0.09	0.16	0.46
117	#DIV/0!	0.13	0.02	0.08	0.12	0.05

Elemental Mass Release (Normalized) and Statistics						
Beulah lignite 106-125 μm				PSOC-1507d 6 % O2		
SiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.073	2	0.073	0.654	3.275
47	0.003	0.074	2	0.074	0.653	3.269
72	0.067	0.100	5	0.107	0.146	0.269
95	0.045	0.172	5	0.181	0.258	0.474
117	-0.061	0.114	3	0.107	0.269	0.621
Al2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.009	0.072	2	0.072	0.630	3.158
72	0.034	0.102	5	0.105	0.148	0.273
95	0.073	0.167	5	0.180	0.249	0.457
117	0.048	0.102	3	0.108	0.242	0.559
TiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.011	0.072	2	0.072	0.629	3.151
72	-0.122	0.118	5	0.105	0.173	0.317
95	0.106	0.161	5	0.180	0.240	0.441
117	0.087	0.098	3	0.108	0.233	0.537
Fe2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.584	0.115	2	0.072	1.008	5.048
72	-0.230	0.129	5	0.105	0.189	0.347
95	0.066	0.168	5	0.180	0.251	0.461
117	0.186	0.090	3	0.110	0.215	0.495

Elemental Mass Release (Normalized) and Statistics (con't)						
Beulah lignite 106-125 μm				PSOC-1507d 6 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Beulah lignite 106-125 μm				PSOC-1507d 6 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.431	0.041	2	0.072	0.362	1.812
72	0.606	0.041	5	0.105	0.061	0.111
95	0.773	0.041	5	0.180	0.061	0.112
117	0.867	0.016	3	0.121	0.040	0.092
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.916	0.006	2	0.072	0.054	0.269
72	0.949	0.005	5	0.105	0.008	0.015
95	0.971	0.005	5	0.180	0.008	0.014
117	0.977	0.003	3	0.113	0.006	0.014
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.090	2	0.090	0.805	4.035
47	0.851	0.014	2	0.091	0.120	0.600
72	0.870	0.015	4	0.119	0.024	0.044
95	0.914	0.016	4	0.188	0.025	0.045
117	0.915	0.010	3	0.117	0.024	0.056
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.478	0.038	2	0.072	0.332	1.662
72	0.682	0.033	5	0.105	0.049	0.090
95	0.837	0.029	5	0.180	0.044	0.080
117	0.882	0.013	3	0.115	0.033	0.075

Average Initial Mass Percents and Statistics						
Beulah lignite 106-125 μm				PSOC-1507d 12 % O ₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	2.140	0.113	2	0.053	1.016	5.092
Al ₂ O ₃	0.977	0.047	2	0.048	0.419	2.101
TiO ₂	0.048	0.001	2	0.029	0.013	0.064
Fe ₂ O ₃	1.685	0.078	2	0.046	0.699	3.501
CaO	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Na ₂ O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
K ₂ O	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
MgO	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
Σ Oxides	#DIV/0!					
C	56.715	1.418	2	0.025	12.739	63.821
H	4.010	0.100	2	0.025	0.901	4.512
O	25.660	1.909	2	0.074	17.153	85.936
N	0.865	0.022	2	0.025	0.194	0.973
S	1.845	0.046	2	0.025	0.414	2.076
Ash-s	13.675	0.431	2	0.032	3.875	19.415
Ash-l	14.070	0.352	2	0.025	3.160	15.833

Residual Total Mass (m/m ₀) as a Function of Residence Time						
Beulah lignite 106-125 μm				PSOC-1507d 12 % O ₂		
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.45	0.44	0.48	0.49	0.61	0.52
72	0.21	0.25	0.25	0.26	0.25	0.28
95	0.10	0.15	0.16	0.18	0.18	0.19
117	0.10	0.11	0.13	0.13	0.16	0.17

Residual Total Mass (m/m0) with Statistics						
Beulah lignite 106-125 μm				PSOC-1507d 12 % O ₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	8	1.00	0.000	0.000
47	0.47	0.025	7	0.41	0.023	0.035
72	0.24	0.026	4	0.13	0.041	0.075
95	0.15	0.034	4	0.04	0.053	0.098
117	0.12	0.014	4	0.02	0.021	0.039

Residual Elemental Mass as a Function of Residence Time						
Beulah lignite 106-125 μm				PSOC-1507d 12 % O ₂		
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O
t (ms)						
0	1.00	1.00	1.00	1.00	#DIV/0!	#DIV/0!
47	1.06	0.94	0.98	0.89	#DIV/0!	#DIV/0!
72	0.98	0.92	0.96	0.96	#DIV/0!	#DIV/0!
95	0.95	0.84	0.92	0.89	#DIV/0!	#DIV/0!
117	1.05	0.89	0.94	0.74	#DIV/0!	#DIV/0!
	K ₂ O	C	H	O	N	S
t (ms)						
0	#DIV/0!	1.00	1.00	1.00	1.00	1.00
47	#DIV/0!	0.55	0.13	0.20	0.46	0.56
72	#DIV/0!	0.19	0.03	0.10	0.13	0.08
95	#DIV/0!	0.05	0.02	0.07	0.06	0.01
117	#DIV/0!	0.02	0.01	0.05	0.04	0.00

Elemental Mass Release (Normalized) and Statistics						
Beulah lignite 106-125 μm				PSOC-1507d 12 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.073	2	0.073	0.654	3.275
47	-0.058	0.096	4	0.090	0.212	0.490
72	0.019	0.126	3	0.129	0.297	0.684
95	0.048	0.229	4	0.241	0.504	1.163
117	-0.054	0.137	4	0.130	0.314	0.725
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.023	0.087	4	0.089	0.191	0.440
72	0.043	0.122	3	0.128	0.286	0.659
95	0.078	0.221	4	0.240	0.487	1.122
117	0.056	0.123	4	0.130	0.282	0.651
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.059	0.083	4	0.089	0.184	0.424
72	0.082	0.117	3	0.128	0.274	0.632
95	0.164	0.201	4	0.240	0.441	1.018
117	0.110	0.116	4	0.130	0.265	0.611
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.108	0.079	4	0.089	0.174	0.402
72	0.037	0.123	3	0.128	0.287	0.663
95	0.113	0.213	4	0.240	0.468	1.079
117	0.260	0.099	3	0.133	0.228	0.527

Elemental Mass Release (Normalized) and Statistics (con't)						
Beulah lignite 106-125 μm				PSOC-1507d 12 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Beulah lignite 106-125 μm				PSOC-1507d 12 % O2		
C						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.449	0.049	4	0.089	0.107	0.248
72	0.805	0.025	3	0.128	0.058	0.134
95	0.945	0.013	4	0.240	0.029	0.067
117	0.977	0.004	3	0.158	0.009	0.021
H						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.872	0.011	4	0.089	0.025	0.057
72	0.970	0.004	3	0.128	0.009	0.020
95	0.979	0.005	4	0.240	0.011	0.025
117	0.985	0.002	3	0.137	0.005	0.011
O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.090	2	0.090	0.805	4.035
47	0.797	0.021	3	0.104	0.050	0.115
72	0.895	0.015	3	0.139	0.035	0.081
95	0.933	0.017	4	0.246	0.037	0.085
117	0.947	0.008	3	0.146	0.019	0.043
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.537	0.041	4	0.089	0.090	0.208
72	0.866	0.017	3	0.128	0.040	0.093
95	0.939	0.015	4	0.240	0.032	0.074
117	0.960	0.006	3	0.139	0.013	0.030

Elemental Mass Release (Normalized) and Statistics (con't)						
Beulah lignite 106-125 μm				PSOC-1507d 12 % O2		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.437	0.050	4	0.089	0.110	0.253
72	0.921	0.010	3	0.128	0.024	0.054
95	0.990	0.002	4	0.240	0.005	0.013
117	0.995	0.001	3	0.155	0.002	0.004
Ash-l						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.111	0.079	4	0.089	0.174	0.400
72	0.147	0.109	3	0.128	0.255	0.587
95	0.221	0.187	4	0.240	0.411	0.948
117	0.285	0.094	3	0.132	0.217	0.501
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.242	0.067	4	0.089	0.148	0.341
72	0.024	0.125	3	0.128	0.291	0.672
95	0.205	0.191	4	0.240	0.420	0.968
117	0.261	0.097	3	0.132	0.224	0.517
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.537	0.041	4	0.089	0.090	0.208
72	0.866	0.017	3	0.128	0.040	0.093
95	0.939	0.015	4	0.240	0.032	0.074
117	0.960	0.006	3	0.139	0.013	0.030

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE TEMPERATURE DISTRIBUTIONS**

Data and Analysis Compilation
for PSOC-1507, Beulah Zap Lignite

6 mole-% Oxygen
Environment

12 mole-% Oxygen
Environment

BEULAH COAL CHAR

COAL TYPE: Beulah r1, psoc1507, 10kgc133. 8-15-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	1	1512.8	0.0	2.34	0.00	0.891	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	2	1588.8	4.6	2.43	0.06	0.646	0.067
1650.0	3	1650.5	18.2	2.45	0.05	0.397	0.122
1700.0	33	1717.2	6.9	2.56	0.03	0.752	0.242
1750.0	221	1745.7	12.0	2.56	0.10	0.575	0.149
1800.0	21	1794.4	12.9	2.51	0.22	0.513	0.202
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 281
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: beulah r1, psoc1507, 15kgc133. 8-15-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1426.0	0.0	2.47	0.00	0.485	0.000
1500.0	1	1487.9	0.0	2.45	0.00	0.038	0.000
1550.0	7	1556.8	10.5	2.56	0.04	0.441	0.137
1600.0	4	1590.8	10.7	2.60	0.05	0.465	0.157
1650.0	6	1650.6	18.8	2.63	0.04	0.463	0.208
1700.0	66	1713.4	9.5	2.74	0.05	0.596	0.159
1750.0	169	1744.8	13.0	2.75	0.14	0.476	0.152
1800.0	10	1793.0	12.2	2.75	0.07	0.436	0.228
1850.0	4	1841.4	13.7	2.76	0.04	0.194	0.105
1900.0	1	1894.8	0.0	2.68	0.00	0.028	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 269
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Beulah r1, psoc1507, 20kgc133. 8-15-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	1	1413.2	0.0	2.65	0.00	0.374	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	2	1512.1	16.6	2.71	0.00	0.682	0.025
1550.0	6	1543.9	13.8	2.74	0.06	0.426	0.113
1600.0	4	1606.3	13.4	2.76	0.03	0.172	0.044
1650.0	15	1653.0	16.8	2.86	0.09	0.432	0.256
1700.0	110	1707.6	12.3	2.90	0.20	0.548	0.529
1750.0	121	1745.6	13.6	2.92	0.21	0.371	0.148
1800.0	15	1792.8	13.7	2.94	0.06	0.247	0.219
1850.0	2	1856.3	18.7	2.76	0.06	0.036	0.027
1900.0	2	1893.1	12.6	2.85	0.02	0.017	0.010
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 278
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: beulah r2, psoc1507, 10kgc142. 8-15-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1652.0 K
 SAMPLING HEIGHT: ~~19.05~~ 12.7 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	2	1358.0	23.6	2.28	0.11	0.639	0.552
1400.0	1	1401.7	0.0	2.30	0.00	0.281	0.000
1450.0	4	1451.7	13.4	2.32	0.09	0.386	0.062
1500.0	1	1524.2	0.0	2.38	0.00	0.441	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	2	1587.0	10.1	2.20	0.22	0.878	0.402
1650.0	3	1659.7	13.2	2.42	0.03	0.687	0.245
1700.0	4	1707.6	12.7	2.40	0.10	0.513	0.248
1750.0	1	1748.7	0.0	2.20	0.00	1.039	0.000
1800.0	3	1798.1	7.2	2.30	0.18	1.060	0.475
1850.0	5	1857.8	6.2	2.48	0.04	0.665	0.151
1900.0	18	1911.1	11.2	2.54	0.10	0.933	0.354
1950.0	67	1949.8	12.6	2.57	0.05	0.835	0.306
2000.0	48	1992.7	13.8	2.58	0.03	0.838	0.341
2050.0	6	2038.7	12.3	2.58	0.02	0.788	0.302
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 165
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Beulah r2, psoc1507, 15kgcl42. 8-15-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	1	1385.6	0.0	2.47	0.00	0.374	0.000
1450.0	1	1461.1	0.0	2.55	0.00	0.246	0.000
1500.0	1	1521.7	0.0	2.45	0.00	0.119	0.000
1550.0	8	1555.9	9.4	2.58	0.07	0.536	0.143
1600.0	7	1591.7	9.7	2.61	0.07	0.462	0.200
1650.0	11	1643.8	15.0	2.64	0.10	0.358	0.302
1700.0	3	1699.9	15.6	2.74	0.02	0.387	0.259
1750.0	4	1745.0	13.0	2.63	0.13	0.396	0.419
1800.0	11	1803.6	13.0	2.57	0.50	0.473	0.369
1850.0	11	1850.7	12.7	2.69	0.06	0.938	0.574
1900.0	23	1902.2	15.3	2.70	0.12	0.869	0.416
1950.0	33	1949.3	15.9	2.67	0.24	0.693	0.446
2000.0	40	1995.8	12.0	2.76	0.03	0.750	0.325
2050.0	5	2038.0	7.7	2.73	0.03	0.653	0.506
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	1	2135.9	0.0	2.65	0.00	0.625	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 160
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: beulah r2, psoc1507, 20kgcl42. 8-15-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	1	1279.2	0.0	2.63	0.00	0.560	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	4	1463.8	4.4	2.68	0.02	0.576	0.377
1500.0	24	1504.4	12.2	2.77	0.08	0.652	0.318
1550.0	18	1541.9	12.3	2.76	0.10	0.505	0.256
1600.0	15	1601.8	12.4	2.82	0.10	0.239	0.186
1650.0	15	1649.5	14.4	2.87	0.05	0.486	0.440
1700.0	7	1693.9	13.5	2.66	0.42	0.501	0.325
1750.0	10	1755.8	14.8	2.88	0.04	0.660	0.608
1800.0	9	1800.5	13.8	2.71	0.35	0.444	0.497
1850.0	9	1844.9	14.1	2.75	0.13	0.381	0.274
1900.0	7	1912.9	11.8	2.88	0.06	0.651	0.503
1950.0	13	1946.3	13.5	12.52	33.16	0.635	0.322
2000.0	10	1991.8	15.0	2.82	0.19	0.769	0.322
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	1	2174.8	0.0	2.74	0.00	1.602	0.000
2200.0	1	2184.7	0.0	2.63	0.00	0.872	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 144
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE SIZES, TEMPERATURES, AND VELOCITIES**

Data and Analysis Compilation
for PSOC-1507, Beulah Zap Lignite

COAL TYPE: PSOC-1507
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	0	0	0	0.00	0.00	0.00	0.00
100.	3	1733	8	2.59	0.03	1.13	0.14
110.	36	1745	44	2.56	0.05	0.76	0.17
120.	62	1747	26	2.57	0.03	0.62	0.17
130.	64	1747	20	2.56	0.03	0.58	0.13
140.	65	1740	27	2.55	0.13	0.54	0.13
150.	26	1739	15	2.57	0.04	0.53	0.17
160.	10	1731	36	2.44	0.30	0.45	0.06
170.	6	1703	53	2.55	0.05	0.43	0.11
180.	4	1743	22	2.59	0.01	0.38	0.14
190.	1	1736	0	2.60	0.00	0.37	0.00
200.	1	1726	0	2.47	0.00	0.44	0.00
210.	1	1738	0	2.57	0.00	0.48	0.00
220.	0	0	0	0.00	0.00	0.00	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	1	1799	0	1.53	0.00	0.18	0.00

NUMBER OF PARTICLES = 280
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1507
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.10 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	1	1860	0	2.80	0.00	0.27	0.00
70.	2	1783	67	2.77	0.00	0.82	0.72
80.	3	1750	5	2.78	0.01	0.76	0.23
90.	5	1750	12	2.77	0.02	0.66	0.12
100.	23	1755	30	2.77	0.04	0.53	0.22
110.	52	1745	28	2.77	0.02	0.54	0.18
120.	70	1728	42	2.74	0.05	0.48	0.14
130.	54	1731	30	2.75	0.04	0.48	0.12
140.	33	1699	78	2.71	0.08	0.47	0.15
150.	14	1716	38	2.73	0.06	0.44	0.13
160.	3	1678	95	2.62	0.11	0.39	0.19
170.	3	1647	61	2.64	0.05	0.50	0.22
180.	0	0	0	0.00	0.00	0.00	0.00
190.	3	1736	7	1.90	0.55	0.30	0.09
200.	0	0	0	0.00	0.00	0.00	0.00
210.	1	1690	0	2.71	0.00	0.26	0.00
220.	1	1690	0	2.43	0.00	0.57	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	1	1487	0	2.45	0.00	0.04	0.00

NUMBER OF PARTICLES = 269
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1507
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.4 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	1	1763	0	3.00	0.00	0.71	0.00
70.	1	1764	0	2.96	0.00	0.39	0.00
80.	5	1748	45	2.94	0.06	0.50	0.32
90.	10	1740	24	2.94	0.01	0.54	0.23
100.	46	1740	28	2.95	0.03	0.40	0.13
110.	66	1726	46	2.94	0.06	0.45	0.19
120.	56	1721	57	2.91	0.17	0.41	0.20
130.	36	1709	50	2.89	0.22	0.41	0.16
140.	22	1712	51	2.90	0.13	0.34	0.15
150.	15	1689	81	2.85	0.10	0.37	0.20
160.	6	1648	110	2.83	0.12	0.37	0.16
170.	4	1682	19	2.59	0.42	0.52	0.11
180.	4	1701	43	2.53	0.65	0.34	0.18
190.	2	1738	16	2.39	0.76	0.28	0.10
200.	1	1707	0	2.89	0.00	0.30	0.00
210.	1	1690	0	2.96	0.00	0.44	0.00
220.	0	0	0	0.00	0.00	0.00	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 276
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1507
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	8	1994	30	2.59	0.04	1.23	0.29
60.	15	1954	135	2.57	0.04	1.08	0.32
70.	13	1942	90	2.55	0.04	1.00	0.38
80.	24	1944	51	2.55	0.08	0.86	0.26
90.	36	1943	70	2.56	0.05	0.78	0.28
100.	21	1938	46	2.54	0.12	0.81	0.25
110.	12	1873	182	2.54	0.08	0.71	0.22
120.	9	1882	141	2.53	0.08	0.59	0.09
130.	8	1864	150	2.53	0.08	0.50	0.17
140.	4	1757	198	2.44	0.12	0.80	0.53
150.	3	1438	26	2.27	0.02	0.36	0.06
160.	2	1652	392	2.40	0.28	0.35	0.14
170.	1	1960	0	2.55	0.00	0.43	0.00
180.	2	1777	259	2.34	0.41	0.75	0.58
190.	0	0	0	0.00	0.00	0.00	0.00
200.	3	1919	12	2.32	0.22	0.44	0.16
210.	1	1852	0	2.45	0.00	0.58	0.00
220.	0	0	0	0.00	0.00	0.00	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 162
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1507
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.1 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	11	1957	88	2.75	0.03	0.89	0.43
60.	29	1933	108	2.74	0.04	1.00	0.45
70.	24	1911	101	2.73	0.08	0.69	0.34
80.	16	1943	57	2.71	0.06	0.65	0.27
90.	17	1872	139	2.72	0.06	0.47	0.22
100.	8	1841	149	2.67	0.10	0.48	0.24
110.	8	1857	130	2.66	0.15	0.52	0.27
120.	12	1750	170	2.67	0.07	0.37	0.27
130.	11	1655	182	2.59	0.08	0.36	0.15
140.	2	1903	48	2.71	0.00	0.40	0.03
150.	7	1691	153	2.34	0.55	0.43	0.18
160.	2	1844	45	2.45	0.10	0.71	0.20
170.	1	1838	0	2.55	0.00	0.91	0.00
180.	1	1833	0	2.74	0.00	0.70	0.00
190.	1	1955	0	2.83	0.00	0.06	0.00
200.	1	1739	0	2.40	0.00	1.07	0.00
210.	1	1965	0	1.39	0.00	0.00	0.00
220.	0	0	0	0.00	0.00	0.00	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 152
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1507
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.4 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	12	1809	181	2.91	0.03	0.84	0.39
60.	22	1719	130	2.88	0.12	0.79	0.45
70.	13	1799	206	2.89	0.10	0.58	0.34
80.	11	1747	177	2.88	0.03	0.78	0.35
90.	17	1669	167	2.73	0.27	0.45	0.38
100.	14	1664	127	2.84	0.08	0.29	0.29
110.	5	1668	204	2.68	0.19	0.39	0.31
120.	12	1540	92	2.74	0.07	0.52	0.22
130.	15	1625	168	2.66	0.26	0.32	0.25
140.	6	1564	181	2.75	0.11	0.39	0.20
150.	5	1712	178	2.67	0.04	0.52	0.10
160.	1	1512	0	2.63	0.00	0.34	0.00
170.	2	1704	201	2.79	0.20	0.32	0.18
180.	0	0	0	0.00	0.00	0.00	0.00
190.	2	1856	97	2.74	0.08	0.83	0.00
200.	2	1812	223	****	****	0.07	0.03
210.	0	0	0	0.00	0.00	0.00	0.00
220.	0	0	0	0.00	0.00	0.00	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 139
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**KINETIC ANALYSIS
AND COMBUSTION PARAMETERS**

Data and Analysis Compilation
for PSOC-1507, Beulah Zap Lignite

Summary of Combustion Parameters for PSOC-1507D		
Char oxidation rate parameters $q = A \exp(-E/RT_p) P^n$	A E n	Chars reacted at their diffusion-limit rates (zone 3) in both 6 and 12 mole-% oxygen
Product ratio parameters $CO/CO_2 = A_c \exp(-E_c/RT_p)$	A_c E_c	no carbon dioxide production
Burning mode parameter $\rho/\rho_o = (m/m_o)^\alpha$ $d/d_o = (m/m_o)^{(1-\alpha)/3}$	α	0.2
Char structural parameters $\omega = \bar{d}(z = 6.4 \text{ cm}) / \bar{d}_{\text{coal}}$ (linear swelling factor) $\rho_{c,o} \equiv mc/V_c \text{ at } z = 6.5 \text{ cm}$ (Initial char particle carbon density)	ω $\rho_{c,o}$	0.92 0.63 gm / cm ³
As an example, this parameter set yields a combustion rate, q , of 0.0075 gm/sq.cm-sec for a 100 μ m particle in a gas with a temperature of 1600 K containing 6 mole-% oxygen

Measured Carbon Conversions in the CCL
for PSOC-1507

**CALCULATIONS OF THE COAL CHAR REACTIVITY INDEX, τ_{50} ,
FOR VARIOUS ENVIRONMENTS
PRESENT IN PULVERIZED-COAL COMBUSTION SYSTEMS**

Data and Analysis Compilation
for PSOC-1507, Beulah Zap Lignite

Compilation of Data and Kinetic Analyses for

Pocahontas #3 Bituminous Coal
(W. Virginia, lvb)

PSOC-1508D

TABLE OF CONTENTS

- **Sample history, geologic information and chemical analysis of bulk, raw coal**
- **Chemical analysis of size-fractionated raw coal and partially reacted chars**
- **Time resolved measurements of the partitioning of elemental coal constituents between the gas and solid phases**
- **Mode of particle burning**
- **Statistical analyses of elemental composition measurements and derived quantities**
- **Optical measurements of single-particle temperature distributions**
- **Optical measurements of single-particle sizes, temperatures, and velocities**
- **Kinetic analysis and combustion parameters**
- **Calculations of the coal char reactivity index, τ_{50} , for various environments present in pulverized-coal combustion systems**

**SAMPLE HISTORY, GEOLOGIC INFORMATION AND
CHEMICAL ANALYSIS OF BULK, RAW COAL**

Data and Analysis Compilation
for PSOC-1508, Pocahontas #3 Coal

SAMPLE HISTORY

PENN STATE NUMBER	PSOC-1508
COLLECTED BY	PENNSYLVANIA STATE UNIVERSITY
COLLECTION DATE	11/5/85
COLLECTOR'S NUMBER	
REPORTED RANK	LOW VOLATILE BITUMINOUS (LVB)
SAMPLE TYPE	CHANNEL WHOLE SEAM
OTHER SAMPLE INFORMATION	
SAMPLE RESERVE	
SEAM NAME	POCAHONTAS #3
ALTERNATE SEAM NAME	
TOTAL SEAM THICKNESS	4 FT. 11 IN.
THICKNESS OF SEAM SAMPLED	4 FT. 11 IN.
PORTION RECOVERED IN CORE	
DIAMETER OF CORE	

SAMPLE LOCATION

COUNTRY	U.S.A.
STATE	WEST VIRGINIA
COUNTY	MCDOWELL
TOWNSHIP	
NEAREST TOWN	WELCH
COAL PROVINCE	EASTERN
COAL REGION	APPALACHIAN
COAL FIELD	SOUTHERN

GEOLOGIC INFORMATION

SYSTEM (AGE)	PENNSYLVANIAN
SERIES	
GROUP	POTTSVILLE
FORMATION	POCAHONTAS
OVERBURDEN LITHOLOGY	SILTY SHALE
FLOOR LITHOLOGY	SILTY SHALE

SEAM STRATA INFORMATION

<u>THICKNESS</u>	<u>LITHOTYPE</u>
------------------	------------------

SEAM NAME	POCAHONTAS #3	COUNTRY	U.S.A.
APPARENT RANK	LOW VOLATILE BITUMINOUS (LVB)	STATE	WEST VIRGINIA

CHEMICAL DATA 1

PROXIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF (PAFF)	DMMF (PARR-G)	DMMF (DIR MM)
% MOISTURE	1.14					
% ASH	7.36	7.44				
% VOLATILE MATTER	15.52	15.70	16.96	16.21	15.96	
% FIXED CARBON	75.98	76.86	83.04	83.79	84.04	

CALORIFIC VALUE (GROSS BTU/LB)	DRY	AS REC'D MOIST.	EQUIL MOIST.
MM-FREE, DIRECT			
MM-CONTAINING	14542	14376	14145
MM-FREE (PARR)	15838	15642	15368
MM-FREE (MOD.P)	15885	15658	15383
BEST MM FREE		15685	15383
NET CV, DMMF BTU/LB	15474		
ASH-FREE	15711		

MOTT-SPOONER DIFFERENCE =

ASSOCIATED ANALYSES	DRY	MMF
% EQUILIBRIUM MOISTURE	2.73	2.98
% TOTAL SULFUR	0.64	

RANK CALCULATIONS

APPARENT RANK (AS REC'D MOIST)	LOW VOLATILE BITUMINOUS (LVB)
ASTM RANK (EQUIL. MOIST.)	LOW VOLATILE BITUMINOUS (LVB)
REFLECTANCE RANK CATEGORY	LOW VOLATILE BITUMINOUS (LVB)
INTERNATIONAL RANK	
AS REC'D MOIST.	
EQUIL. MOIST	
REPORTED RANK	LOW VOLATILE BITUMINOUS (LVB)

SEAM NAME	POCAHONTAS #3	COUNTRY	U.S.A.
APPARENT RANK	LOW VOLATILE BITUMINOUS (LVB)	STATE	WEST VIRGINIA

CHEMICAL DATA 2

<u>ULTIMATE ANALYSIS</u>	<u>AS REC'D</u>	<u>DRY</u>	<u>DAF</u>	<u>DMMF(PARR)</u> (8.39 % MM)
% ASH	7.36	7.44		
% CARBON	83.70	84.67	91.48	92.42
% HYDROGEN	*4.00	4.05	4.38	4.42
% NITROGEN	1.01	1.02	1.10	1.11
% SULFUR	0.63	0.64	0.69	
% CHLORINE	0.05	0.05	0.06	0.06
% OXYGEN (DIFF)	*2.10	2.13	2.30	1.99

<u>SULFUR FORMS</u>	<u>% PYRITIC</u>	<u>% SULFATIC</u>	<u>% ORGANIC</u>	<u>% TOTAL</u>
DRY	0.14	0.00	0.50	0.64
DAF	0.15	0.00	0.54	0.69
OPTICAL				

<u>ELEMENTAL ANALYSIS</u>	<u>DRY</u>	<u>DMMF (MOD.P)</u> (8.50 % MM)	<u>DMMF(DIR.)</u> (% MM)
% CARBON	84.50	92.35	
% HYDROGEN	3.95	4.32	
% NITROGEN	1.02	1.11	
% ORGANIC SULFUR	0.50	0.55	
% OXYGEN (DIFF)	1.53	1.62	
% CHLORINE	0.05	0.06	
% MINERAL MATTER (INCLUDES 0.26 % FES2)	8.50		

<u>ATOM RATIOS (DMMF)</u>	<u>PARR</u>	<u>MOD.PAR</u>	<u>DIRECT</u>
ATOMIC H/C	0.575	0.562	
ATOMIC O/C	0.016	0.014	

<u>MISC. CHEMICAL DATA</u>	<u>DRY</u>	<u>OF DMMF COAL</u>	<u>OF DMMF OXYGEN</u>
% O AS COOH			
% O AS OH			
% S AS SO4, IN ASH			
% CARBONATE AS CO2	0.62		
% CHLORINE	0.11		

INFRA-RED ANALYSIS

(*)- EXCLUDES MOISTURE

SEAM NAME	POCAHONTAS #3	COUNTRY	U.S.A.
APPARENT RANK	LOW VOLATILE BITUMINOUS (LVB)	STATE	WEST VIRGINIA

CHEMICAL DATA 3

% MOISTURE IN COAL = 0.22
 % HIGH TEMPERATURE ASH = 7.63 AT 750 DEGREES C

TRACE ELEMENT ANALYSIS	PPM HTA	PPM TOTAL COAL	MAJOR ELEMENT ANALYSIS	OXIDE % OF HTA	ELEMENT % OF TOTAL DRY COAL
AG			SI02	46.50	1.66
B			AL203	24.40	0.99
BA	1800	137	TI02	1.76	0.08
BE	29	2	FE203	8.29	0.44
BI			MG0	1.31	0.06
CE			CA0	7.38	0.40
CO			NA20	1.12	0.06
CR	170	13	K20	0.53	0.03
CU	230	18	P205	0.32	0.01
GA			S03	8.40	0.26
GE					
LA					
LI					
MN	340	26			
MO			<u>VOLATILES</u>	<u>PPM TOTAL COAL</u>	
NI	160	12			
NB			AS		
PB			BR		
RB	25	2	CD		
SC			CL		
SN			F		
SR	1350	103	HG		
TH			SB		
U			SE		
V	210	16			
Y					
YB					
ZN	50	4			
ZR	400	31			

SEAM NAME	POCAHONTAS #3	COUNTRY	U.S.A.
APPARENT RANK	LOW VOLATILE BITUMINOUS (LVB)	STATE	WEST VIRGINIA

MINERALOGICAL DATA

TOTAL MINERAL MATTER

% MM-PARR	8.39
% MM-MODIFIED PARR	8.50
% MM-KMC	
% MM-DIRECT	
% MM-BEST AVAILABLE	8.50
VOL % MM-PARR	4.23

MINERAL COMPOSITION

NONE

SEAM NAME	POCAHONTAS #3	COUNTRY	U.S.A.
APPARENT RANK	LOW VOLATILE BITUMINOUS (LVB)	STATE	WEST VIRGINIA

PETROGRAPHIC DATA

MACERAL COMPOSITION WHITE ANALYSIS ONLY

	<u>DRY VOLUME %</u>	<u>DMMF VOLUME %</u>	<u>DRY WEIGHT %</u>
VITRINITE (CALC.)	74.9	78.2	71.7
INERTINITE (CALC.)	20.9	21.8	20.0
LIPTINITE (CALC.)		0.0	0.0
MINERAL MATTER (CALC.)	4.2		8.4
VITRINOIDS			
VITRINITE	72.2	75.4	69.1
PSEUDOVITRINITE	2.7	2.8	2.6
FUSINITE	5.5	5.7	5.2
SEMI-FUSINITE	11.1	11.6	10.6
MACRINITE	1.0	1.0	0.9
MICRINITE	3.4	3.5	3.2
SCLEROTINITE	0.0	0.0	0.0
SPORINITE	0.0	0.0	0.0
CUTINITE	0.0	0.0	0.0
EXINITE (ANAL.)			
RESINITE	0.0	0.0	0.0
SUBERINITE			
EXUDATINITE			
FLUORINITE			
BITUMINITE			
ALGINITE	0.0	0.0	0.0
LIPTODETRINITE			
MINERAL MATTER (ANAL.)			
INERTINITE (ANAL.)			
LIPTINITE (ANAL.)			

<u>REFLECTANCE DATA</u> (%, IN OIL)	<u>HIGH</u>	<u>LOW</u>	<u>RANGE</u>	<u>MEAN MAX</u>	<u>STAND.DEV.</u>
VITRINITE	1.97	1.71	0.26	1.85	0.05
PSEUDOVITRINITE					
VITRINOIDS					

SEAM NAME	POCAHONTAS #3	COUNTRY	U.S.A.
APPARENT RANK	LOW VOLATILE BITUMINOUS (LVB)	STATE	WEST VIRGINIA

PETROGRAPHIC DATA

CONTINUED

<u>% VITRINOID</u>		<u>VOLUME</u>	<u>% VITRINOID</u>		<u>VOLUME</u>
<u>REFLECTANCE</u>	<u>HALF-TYPE</u>	<u>PERCENT</u>	<u>REFLECTANCE</u>	<u>V-TYPE</u>	<u>PERCENT</u>
1.70-1.74	VHT 1.725	3.00			
1.75-1.79	VHT 1.775	13.00	1.70-1.79	V17	16.00
1.80-1.84	VHT 1.825	32.00			
1.85-1.89	VHT 1.875	37.00	1.80-1.99	V18	69.00
1.90-1.94	VHT 1.925	13.00			
1.95-1.99	VHT 1.975	2.00	1.90-1.99	V19	15.00

PHYSICAL PROPERTIES

HARDGROVE GRINDABILITY	
VICKER'S MICROHARDNESS	
FREE SWELLING INDEX	6.5
GRAY KING COKE TYPE	

GIESELER PLASTICITY DATA

MAXIMUM FLUIDITY	10
MAXIMUM FLUIDITY TEMPERATURE	486
INITIAL SOFTENING TEMPERATURE	460
SOLIDIFICATION TEMPERATURE	504
FLUID TEMPERATURE RANGE	44
PLASTOMETER TYPE	GEISELER - PSU

<u>ASH FUSION ANALYSIS (DEGREES F)</u>	<u>REDUCING</u>	<u>OXIDIZING</u>
INITIAL DEFORMATION TEMPERATURE	2290	2380
SOFTENING TEMPERATURE	2375	2455
HEMISPHERE TEMPERATURE	2470	2495
FLUID TEMPERATURE	2530	2570

**** PENN STATE COAL DATA BASE ****

PSOC-1508

SEAM NAME	POCAHONTAS #3	COUNTRY	U.S.A.
APPARENT RANK	LOW VOLATILE BITUMINOUS (LVB)	STATE	WEST VIRGINIA

ANALYSIS LOG

<u>ANALYSIS</u>	<u>DATE</u>	<u>PERFORMED BY</u>
A.R. MOIST	12/23/85	WARNER LABORATORIES
EQUIL. MOIST.	12/23/85	WARNER LABORATORIES
PROXIMATE	12/23/85	WARNER LABORATORIES
ULTIMATE	12/23/85	WARNER LABORATORIES
SULFUR FORMS	12/23/85	WARNER LABORATORIES
FSI	12/5/85	COAL PETROGRAPHY LABORATORIES-PSU
PLASTOMETER	12/7/85	COAL PETROGRAPHY LBAORATORIES-
PSUDIRECT MM		
GRAY-KING		

**CHEMICAL ANALYSES OF SIZE-FRACTIONATED RAW COAL
AND PARTIALLY REACTED CHARS**

Data and Analysis Compilation
for PSOC-1508, Pocahontas #3 Coal

**Organic Elemental Analysis and Percent Ash of Pocahontas #3 Coal
and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	74.17	3.62	4.19	0.86	0.49	17.12
6.4	79.10	1.79	2.14	0.90	0.39	16.33
12.7	81.04	0.68	0.93	0.83	0.37	17.68
19.1	77.86	0.50	0.63	0.82	0.39	21.14
25.4	79.07	0.40	1.42	0.86	0.39	18.75

12 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	75.00	3.67	4.09	0.85	0.48	17.10
6.4	78.28	1.04	2.48	0.80	0.42	18.84
12.7	82.18	0.43	1.76	0.86	0.39	18.84
19.1	75.86	0.32	4.75	0.80	0.37	23.17
25.4	75.55	0.34	1.37	0.74	0.37	24.54

* Data taken in April 1989

**Ash Content of Pocahontas #3 Coal
and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	8.61	3.82	0.303	0.936	1.47	0.198	0.075	0.140
6.4	8.23	3.95	0.293	0.896	1.55	0.337	0.064	0.161
12.7	8.42	4.16	0.310	0.936	1.83	0.291	0.064	0.173
19.1	10.7	4.81	0.377	1.05	1.92	0.267	0.085	0.189
25.4	9.48	4.43	0.336	1.08	0.798	0.135	0.077	0.174

12 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	8.61	3.82	0.303	0.936	1.47	0.198	0.075	0.140
6.4	9.67	4.48	0.344	1.04	0.963	0.151	0.081	0.18
12.7	10.9	4.63	0.360	0.936	1.44	0.256	0.082	0.174
19.1	12.3	5.57	0.446	1.07	1.12	0.146	0.010	0.215
25.4	12.4	5.71	0.465	1.11	1.20	0.142	0.107	0.217

* Data taken in April 1989

**TIME RESOLVED MEASUREMENTS OF THE
PARTITIONING OF ELEMENTAL COAL CONSTITUENTS
BETWEEN THE GAS AND SOLID PHASES**

Data and Analysis Compilation
for PSOC-1508, Pocahontas #3 Coal

MODE OF PARTICLE BURNING

Data and Analysis Compilation
for PSOC-1508, Pocahontas #3 Coal

**Fractional Mass Remaining and Apparent Density
of Pocahontas #3 Coal and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.83	0.78	0.79	0.74
Fractional burnoff, daf	0.0	0.19	0.24	0.25	0.29
Apparent density, g/cc	1.2	0.68	0.78	0.79	0.77

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.85	0.78	0.68	0.66
Fractional burnoff, daf	0.0	0.17	0.24	0.38	0.40
Apparent density, g/cc	1.2	0.75	0.74	0.65	0.43

**STATISTICAL ANALYSES
OF ELEMENTAL COMPOSITION MEASUREMENTS
AND DERIVED QUANTITIES**

- **Raw Coal Composition**
- **Overall Combustion Conversion vs. Residence Time**
- **Elemental Partitioning between Gas and Solid Phases**

Data and Analysis Compilation
for PSOC-1508, Pocahontas #3 Coal

Average Initial Mass Percents and Statistics						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC-1508d 6 % O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	8.513	0.302	7	0.035	0.279	0.423
Al ₂ O ₃	3.824	0.096	7	0.025	0.088	0.134
TiO ₂	0.298	0.025	7	0.085	0.023	0.035
Fe ₂ O ₃	0.948	0.038	7	0.040	0.035	0.053
CaO	1.689	0.604	7	0.358	0.559	0.846
Na ₂ O	0.126	0.046	7	0.367	0.043	0.065
K ₂ O	0.070	0.011	7	0.161	0.010	0.016
MgO	0.288	0.132	7	0.458	0.122	0.185
Σ Oxides	15.756					
C	75.293	1.882	6	0.025	1.976	3.098
H	3.713	0.093	6	0.025	0.097	0.153
O	4.035	0.908	6	0.225	0.953	1.495
N	0.952	0.135	6	0.142	0.141	0.222
S	0.507	0.027	6	0.054	0.029	0.045
Ash-s	16.210	0.424	5	0.026	0.526	0.873
Ash-l	16.673	0.537	6	0.032	0.564	0.885

Residual Total Mass (m/m₀) as a Function of Residence Time						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC-1508d 6 % O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.83	1.03	0.97	1.02	1.00	1.02
72	0.78	1.01	0.92	0.96	0.94	0.94
95	0.79	0.80	0.80	0.79	0.76	0.79
117	0.74	0.90	0.86	0.89	0.85	0.89

Residual Total Mass (m/m0) with Statistics						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC-1508d 6 % O2		
	Mean (mf)	σ	n	Mean (daf)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	1.00	0.000	22	1.00	0.000	0.000
47	0.94	0.105	3	0.95	0.262	0.604
72	0.90	0.116	3	0.89	0.289	0.667
95	0.79	0.006	4	0.75	0.009	0.017
117	0.83	0.085	3	0.81	0.210	0.485

Residual Elemental Mass as a Function of Residence Time						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC-1508d 6 % O2		
	SiO2	TiO2	Al2O3	Fe2O3	CaO	Na2O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.91	0.93	0.97	0.89	0.87	1.21
72	0.89	0.94	0.98	0.89	0.98	1.24
95	1.00	1.00	1.00	0.88	0.90	1.19
117	0.93	0.94	0.96	0.95	0.39	1.15
	K2O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.87	0.99	0.45	0.50	0.89	0.73
72	0.83	0.97	0.16	0.21	0.78	0.66
95	0.97	0.82	0.11	0.12	0.68	0.61
117	0.92	0.87	0.09	0.29	0.75	0.64

Elemental Mass Release (Normalized) and Statistics						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC-1508d 6 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	7	0.071	0.065	0.099
47	0.088	0.121	4	0.132	0.188	0.346
72	0.106	0.131	4	0.147	0.285	0.657
95	0.004	0.071	7	0.071	0.069	0.108
117	0.073	0.117	4	0.127	0.178	0.326
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	7	0.071	0.065	0.099
47	0.025	0.129	4	0.132	0.201	0.370
72	0.017	0.144	4	0.147	0.313	0.723
95	0.004	0.071	7	0.071	0.069	0.108
117	0.035	0.121	4	0.126	0.184	0.338
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.098	7	0.098	0.091	0.138
47	0.072	0.138	5	0.149	0.202	0.370
72	0.060	0.152	4	0.162	0.229	0.421
95	-0.002	0.099	7	0.099	0.096	0.151
117	0.061	0.139	5	0.148	0.171	0.283
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	7	0.071	0.065	0.099
47	0.109	0.118	4	0.132	0.184	0.338
72	0.108	0.131	4	0.147	0.284	0.656
95	0.123	0.062	7	0.071	0.061	0.095
117	0.052	0.117	4	0.123	0.180	0.330

Elemental Mass Release (Normalized) and Statistics (con't)						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC-1508d 6 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.361	7	0.361	0.334	0.506
47	0.134	0.327	7	0.378	0.326	0.512
72	0.021	0.375	7	0.383	0.377	0.591
95	0.099	0.325	7	0.361	0.316	0.496
117	0.606	0.342	7	0.868	0.333	0.523
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.370	7	0.370	0.342	0.519
47	-0.207	0.467	7	0.387	0.465	0.729
72	-0.242	0.487	7	0.392	0.488	0.766
95	-0.189	0.440	7	0.370	0.428	0.671
117	-0.151	0.477	7	0.414	0.472	0.740
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.168	7	0.168	0.156	0.236
47	0.132	0.175	6	0.202	0.203	0.336
72	0.169	0.176	6	0.212	0.208	0.345
95	0.032	0.163	7	0.169	0.159	0.249
117	0.078	0.194	6	0.211	0.203	0.318
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.460	7	0.460	0.426	0.645
47	-0.103	0.522	7	0.474	0.516	0.809
72	0.088	0.436	7	0.478	0.433	0.679
95	0.266	0.338	7	0.460	0.328	0.515
117	0.610	0.356	7	0.912	0.347	0.544

Elemental Mass Release (Normalized) and Statistics (con't)						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC-1508d 6 % O2		
C						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.071	6	0.071	0.074	0.116
47	0.009	0.131	4	0.132	0.287	0.662
72	0.028	0.143	4	0.147	0.320	0.738
95	0.181	0.058	6	0.071	0.066	0.110
117	0.125	0.108	4	0.124	0.233	0.539
H						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.071	6	0.071	0.074	0.116
47	0.545	0.060	4	0.132	0.132	0.304
72	0.836	0.024	4	0.147	0.054	0.125
95	0.893	0.008	6	0.071	0.009	0.014
117	0.910	0.012	4	0.129	0.018	0.033
O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.231	6	0.231	0.242	0.379
47	0.500	0.128	5	0.256	0.153	0.253
72	0.792	0.055	5	0.264	0.066	0.110
95	0.876	0.029	6	0.231	0.032	0.054
117	0.707	0.044	5	0.151	0.065	0.120
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.150	6	0.150	0.158	0.247
47	0.108	0.167	5	0.187	0.239	0.439
72	0.217	0.155	5	0.198	0.227	0.416
95	0.318	0.103	6	0.150	0.116	0.193
117	0.247	0.133	5	0.176	0.165	0.273

Elemental Mass Release (Normalized) and Statistics (con't)						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC-1508d 6 % O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.074	6	0.074	0.077	0.121
47	0.274	0.097	4	0.134	0.211	0.488
72	0.340	0.098	4	0.148	0.218	0.502
95	0.390	0.045	6	0.074	0.051	0.085
117	0.359	0.080	4	0.126	0.128	0.234
Ash-l						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	6	0.071	0.074	0.116
47	0.076	0.122	4	0.132	0.268	0.617
72	0.042	0.141	4	0.147	0.315	0.727
95	-0.004	0.071	6	0.071	0.081	0.134
117	0.064	0.119	4	0.127	0.187	0.344
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	5	0.071	0.088	0.146
47	0.052	0.125	4	0.132	0.285	0.658
72	0.037	0.141	3	0.147	0.327	0.754
95	-0.042	0.074	5	0.071	0.106	0.194
117	0.024	0.123	4	0.127	0.276	0.636
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.150	6	0.150	0.158	0.247
47	0.108	0.167	5	0.187	0.239	0.439
72	0.217	0.155	5	0.198	0.227	0.416
95	0.318	0.103	6	0.150	0.116	0.193
117	0.247	0.133	5	0.176	0.165	0.273

Average Initial Mass Percents and Statistics						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC1508 12 % O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	8.513	0.302	7	0.035	0.279	0.423
Al ₂ O ₃	3.824	0.096	7	0.025	0.088	0.134
TiO ₂	0.298	0.025	7	0.085	0.023	0.035
Fe ₂ O ₃	0.948	0.038	7	0.040	0.035	0.053
CaO	1.689	0.604	7	0.358	0.559	0.846
Na ₂ O	0.126	0.046	7	0.367	0.043	0.065
K ₂ O	0.070	0.011	7	0.161	0.010	0.016
MgO	0.288	0.132	7	0.458	0.122	0.185
Σ Oxides	15.756					
C	75.293	1.882	6	0.025	1.976	3.098
H	3.713	0.093	6	0.025	0.097	0.153
O	4.035	0.908	6	0.225	0.953	1.495
N	0.952	0.135	6	0.142	0.141	0.222
S	0.507	0.027	6	0.054	0.029	0.045
Ash-s	16.210	0.424	5	0.026	0.526	0.873
Ash-l	16.673	0.537	6	0.032	0.564	0.885

Residual Total Mass (m/m₀) as a Function of Residence Time						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC1508 12 % O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.81	0.88	0.85	0.87	0.89	0.88
72	0.72	0.78	0.83	0.83	0.94	0.88
95	0.66	0.69	0.69	0.67	0.69	0.72
117	0.62	0.69	0.67	0.64	0.69	0.68

Residual Total Mass (m/m0) with Statistics						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC1508 12 % O2		
	Mean (mf)	σ	n	Mean (daf)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	1.00	0.000	22	1.00	0.000	0.000
47	0.85	0.038	3	0.83	0.094	0.216
72	0.78	0.051	3	0.76	0.127	0.293
95	0.68	0.018	3	0.62	0.045	0.105
117	0.66	0.035	3	0.60	0.087	0.201

Residual Elemental Mass as a Function of Residence Time						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC1508 12 % O2		
	SiO2	TiO2	Al2O3	Fe2O3	CaO	Na2O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.96	0.98	0.99	0.93	0.48	1.21
72	0.99	0.94	0.94	0.77	0.66	1.07
95	0.98	1.02	0.99	0.77	0.45	1.16
117	0.96	1.03	0.98	0.77	0.47	1.14
	K2O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.99	0.88	0.24	0.52	0.71	0.70
72	0.92	0.85	0.09	0.34	0.70	0.60
95	0.10	0.68	0.06	0.80	0.57	0.50
117	1.01	0.66	0.06	0.22	0.51	0.47

Elemental Mass Release (Normalized) and Statistics						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC1508 12 % O2		
SiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	7	0.071	0.065	0.099
47	0.038	0.080	6	0.084	0.092	0.153
72	0.005	0.096	5	0.097	0.118	0.195
95	0.019	0.074	6	0.076	0.075	0.117
117	0.041	0.085	6	0.088	0.100	0.166
Al2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	7	0.071	0.065	0.099
47	0.008	0.083	6	0.084	0.095	0.157
72	0.059	0.091	5	0.097	0.111	0.184
95	0.011	0.075	6	0.076	0.076	0.118
117	0.017	0.086	6	0.088	0.102	0.169
TiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.098	7	0.098	0.091	0.138
47	0.023	0.106	6	0.108	0.108	0.169
72	0.061	0.111	6	0.118	0.128	0.213
95	-0.016	0.104	7	0.102	0.103	0.161
117	-0.027	0.112	6	0.109	0.117	0.184
Fe2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	7	0.071	0.065	0.099
47	0.071	0.078	6	0.084	0.089	0.147
72	0.233	0.074	5	0.097	0.091	0.150
95	0.234	0.058	6	0.076	0.058	0.092
117	0.229	0.068	6	0.088	0.080	0.132

Elemental Mass Release (Normalized) and Statistics (con't)						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC1508 12 % O2		
CaO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.361	7	0.361	0.334	0.506
47	0.517	0.176	7	0.364	0.171	0.269
72	0.337	0.243	7	0.367	0.239	0.374
95	0.550	0.163	7	0.362	0.159	0.249
117	0.532	0.160	7	0.342	0.156	0.245
Na2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.370	7	0.370	0.342	0.519
47	-0.211	0.452	7	0.373	0.441	0.691
72	-0.074	0.404	7	0.376	0.396	0.621
95	-0.160	0.431	7	0.371	0.419	0.657
117	-0.135	0.421	7	0.371	0.411	0.645
K2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.168	7	0.168	0.156	0.236
47	0.014	0.172	7	0.174	0.170	0.267
72	0.084	0.166	6	0.181	0.167	0.263
95	0.902	0.017	7	0.171	0.016	0.026
117	-0.013	0.076	5	0.075	0.108	0.198
MgO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.460	7	0.460	0.426	0.645
47	0.557	0.205	7	0.462	0.200	0.313
72	0.310	0.321	7	0.465	0.314	0.492
95	0.656	0.159	7	0.461	0.154	0.242
117	0.676	0.154	7	0.476	0.151	0.236

Elemental Mass Release (Normalized) and Statistics (con't)						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC1508 12 % O2		
C						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	6	0.071	0.074	0.116
47	0.120	0.074	5	0.084	0.090	0.149
72	0.152	0.082	5	0.097	0.121	0.223
95	0.316	0.052	6	0.076	0.061	0.101
117	0.339	0.059	5	0.089	0.084	0.154
H						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	6	0.071	0.074	0.116
47	0.763	0.020	5	0.084	0.024	0.040
72	0.910	0.009	5	0.097	0.013	0.024
95	0.941	0.004	6	0.076	0.005	0.009
117	0.940	0.005	5	0.087	0.008	0.014
O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.231	6	0.231	0.242	0.379
47	0.480	0.122	6	0.235	0.140	0.232
72	0.661	0.081	6	0.240	0.094	0.156
95	0.201	0.185	6	0.232	0.211	0.350
117	0.776	0.175	6	0.784	0.199	0.330
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.150	6	0.150	0.158	0.247
47	0.288	0.111	6	0.157	0.129	0.214
72	0.298	0.115	6	0.164	0.136	0.226
95	0.429	0.087	6	0.152	0.099	0.165
117	0.491	0.087	6	0.171	0.101	0.167

Elemental Mass Release (Normalized) and Statistics (con't)						
Pocahontas #3 bituminous (lv) 106-125 μm				PSOC1508 12 % O2		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.074	6	0.074	0.077	0.121
47	0.298	0.060	5	0.086	0.073	0.122
72	0.402	0.059	5	0.099	0.087	0.160
95	0.504	0.039	6	0.078	0.045	0.075
117	0.526	0.043	5	0.091	0.062	0.113
Ash-l						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	6	0.071	0.074	0.116
47	0.043	0.080	5	0.084	0.098	0.162
72	0.122	0.085	5	0.097	0.126	0.231
95	0.057	0.071	6	0.076	0.084	0.139
117	0.031	0.084	5	0.087	0.122	0.223
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	5	0.071	0.088	0.146
47	0.046	0.080	4	0.084	0.120	0.221
72	0.177	0.079	4	0.097	0.125	0.230
95	0.020	0.074	5	0.076	0.108	0.199
117	0.050	0.084	4	0.089	0.130	0.238
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.150	6	0.150	0.158	0.247
47	0.288	0.111	6	0.157	0.129	0.214
72	0.298	0.115	6	0.164	0.136	0.226
95	0.429	0.087	6	0.152	0.099	0.165
117	0.491	0.087	6	0.171	0.101	0.167

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE TEMPERATURE DISTRIBUTIONS**

Data and Analysis Compilation
for PSOC-1508, Pocahontas #3 Coal

6 mole-% Oxygen
Environment

12 mole-% Oxygen
Environment

POCAHONTAS COAL CHAR

COAL TYPE: Pocahontas, psoc1508, 10kgc133. 7-09-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	1	1297.7	0.0	1.94	0.00	0.852	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	3	1397.5	14.8	2.16	0.12	0.693	0.350
1450.0	1	1462.3	0.0	2.47	0.00	0.403	0.000
1500.0	3	1501.8	8.1	2.34	0.04	0.945	0.116
1550.0	13	1552.4	11.5	2.38	0.04	0.839	0.179
1600.0	6	1599.1	16.9	2.37	0.08	0.600	0.156
1650.0	89	1660.2	10.1	2.51	0.05	0.659	0.215
1700.0	69	1693.5	13.8	2.49	0.16	0.648	0.197
1750.0	19	1753.2	16.4	2.54	0.07	0.948	1.212
1800.0	9	1792.3	10.4	2.37	0.39	0.542	0.082
1850.0	1	1831.2	0.0	2.47	0.00	0.406	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 214
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Pocahontas, psoc1508, 15kgc133. 7-09-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	1	1327.9	0.0	2.38	0.00	0.256	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1472.5	0.0	2.60	0.00	0.398	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	10	1559.9	13.0	2.68	0.07	0.701	0.091
1600.0	88	1606.2	11.2	2.72	0.04	0.639	0.667
1650.0	64	1646.6	13.8	2.72	0.04	0.583	0.129
1700.0	41	1699.2	14.9	2.73	0.04	0.590	0.128
1750.0	25	1748.1	14.3	2.73	0.03	0.671	0.143
1800.0	4	1796.0	14.8	2.65	0.05	0.486	0.117
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 234
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Pocahontas, psoc1508, 20kgcl33. 7-09-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	1	1394.3	0.0	2.74	0.00	0.276	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	15	1509.4	14.0	2.82	0.08	0.572	0.185
1550.0	91	1553.5	13.4	2.89	0.08	0.574	0.167
1600.0	53	1595.0	14.1	2.88	0.11	0.756	1.294
1650.0	39	1650.8	16.2	2.95	0.06	0.622	0.192
1700.0	18	1692.2	9.6	2.91	0.05	0.653	0.240
1750.0	9	1744.3	11.5	2.91	0.05	0.555	0.171
1800.0	1	1783.5	0.0	2.96	0.00	0.394	0.000
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 227
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Pocahontas, psoc1508, 10kgcl42. 7-13-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1653.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	1	1320.3	0.0	2.12	0.00	0.540	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	5	1515.0	7.7	2.24	0.10	0.696	0.185
1550.0	5	1557.6	10.5	2.32	0.04	0.850	0.082
1600.0	8	1598.5	18.7	2.37	0.06	0.662	0.176
1650.0	8	1654.2	13.7	2.41	0.09	0.698	0.257
1700.0	22	1708.8	14.3	2.47	0.06	0.572	0.126
1750.0	86	1753.5	13.4	2.48	0.04	0.654	0.178
1800.0	57	1799.4	13.9	2.46	0.14	0.699	0.201
1850.0	29	1844.9	14.2	2.48	0.06	0.689	0.215
1900.0	16	1893.1	12.6	2.50	0.06	0.727	0.162
1950.0	7	1946.1	11.2	2.53	0.06	0.662	0.193
2000.0	2	1985.1	9.5	2.41	0.13	0.595	0.030
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 246
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Pocahontas, psoc1508, 15kgc142. 7-13-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	8	1548.8	12.9	2.50	0.07	0.634	0.253
1600.0	6	1599.7	15.7	2.63	0.08	0.379	0.129
1650.0	21	1658.3	13.5	2.68	0.03	0.550	0.100
1700.0	60	1697.9	13.4	2.66	0.04	0.576	0.156
1750.0	50	1748.1	14.6	2.68	0.04	0.629	0.213
1800.0	49	1798.0	14.2	2.70	0.05	0.665	0.174
1850.0	25	1846.6	14.6	2.71	0.05	0.674	0.150
1900.0	16	1896.2	16.3	2.71	0.05	0.644	0.156
1950.0	5	1953.6	9.3	2.64	0.03	0.794	0.208
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 240
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Pocahontas, psoc1508, 20kgc142. 7-13-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1429.6	0.0	2.05	0.00	0.991	0.000
1500.0	5	1512.8	6.9	2.72	0.11	0.465	0.090
1550.0	9	1560.7	11.1	2.87	0.04	0.503	0.152
1600.0	28	1607.1	13.0	2.89	0.06	0.635	0.170
1650.0	46	1649.0	15.0	2.89	0.06	0.579	0.145
1700.0	38	1698.9	13.4	2.90	0.09	0.614	0.163
1750.0	45	1752.0	13.4	2.90	0.08	0.694	0.184
1800.0	36	1803.3	14.4	2.95	0.10	0.716	0.191
1850.0	25	1847.1	14.3	2.97	0.06	0.708	0.187
1900.0	3	1897.1	9.5	2.93	0.03	0.572	0.208
1950.0	1	1959.7	0.0	2.86	0.00	0.453	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 237
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE SIZES, TEMPERATURES, AND VELOCITIES**

Data and Analysis Compilation
for PSOC-1508, Pocahontas #3 Coal

COAL TYPE: PSOC-1508, 106 - 125 micron:
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	1	1636	0	2.63	0.00	0.03	0.00
60.	1	1727	0	2.45	0.00	5.91	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	0	0	0	0.00	0.00	0.00	0.00
100.	1	1746	0	2.63	0.00	0.18	0.00
110.	5	1709	42	2.52	0.03	0.76	0.23
120.	7	1669	67	2.46	0.07	0.94	0.27
130.	17	1661	70	2.40	0.29	0.81	0.22
140.	43	1686	63	2.50	0.07	0.67	0.18
150.	37	1664	54	2.50	0.05	0.70	0.22
160.	37	1650	70	2.50	0.09	0.61	0.18
170.	20	1680	48	2.51	0.06	0.73	0.22
180.	20	1676	68	2.51	0.07	0.52	0.15
190.	8	1695	43	2.49	0.05	0.57	0.13
200.	5	1535	159	2.32	0.26	0.70	0.15
210.	4	1653	34	2.15	0.53	0.49	0.14
220.	3	1689	28	2.47	0.04	0.61	0.31
230.	2	1587	134	2.42	0.18	0.64	0.22
240.	2	1669	6	2.46	0.01	0.50	0.09

NUMBER OF PARTICLES = 213
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1508, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	0	0	0	0.00	0.00	0.00	0.00
100.	0	0	0	0.00	0.00	0.00	0.00
110.	3	1628	53	2.72	0.06	0.55	0.09
120.	12	1671	52	2.74	0.04	0.62	0.24
130.	25	1648	64	2.71	0.05	0.69	0.14
140.	43	1655	72	2.72	0.04	0.65	0.12
150.	44	1649	57	2.72	0.04	0.60	0.12
160.	51	1655	45	2.73	0.04	0.53	0.10
170.	29	1634	29	2.71	0.04	0.55	0.13
180.	10	1657	48	2.71	0.07	0.53	0.03
190.	8	1630	70	2.70	0.03	0.53	0.13
200.	4	1624	24	2.66	0.03	0.56	0.06
210.	1	1619	0	2.71	0.00	0.49	0.00
220.	0	0	0	0.00	0.00	0.00	0.00
230.	2	1457	183	2.55	0.23	0.30	0.06
240.	1	1671	0	2.63	0.00	0.76	0.00

NUMBER OF PARTICLES = 233
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1508, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	1	1488	0	2.80	0.00	0.44	0.00
100.	0	0	0	0.00	0.00	0.00	0.00
110.	4	1596	43	2.89	0.06	0.61	0.27
120.	14	1586	29	2.92	0.06	0.70	0.27
130.	28	1614	62	2.89	0.07	0.71	0.17
140.	37	1598	60	2.91	0.07	0.65	0.21
150.	47	1591	61	2.92	0.07	0.58	0.13
160.	32	1587	68	2.91	0.07	0.53	0.14
170.	25	1606	65	2.92	0.06	0.55	0.14
180.	21	1609	56	2.91	0.05	0.54	0.14
190.	5	1550	64	2.82	0.12	0.41	0.07
200.	4	1539	25	2.82	0.06	0.43	0.08
210.	3	1625	76	2.84	0.08	0.37	0.09
220.	1	1573	0	2.83	0.00	0.42	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	1	1598	0	2.65	0.00	0.26	0.00

NUMBER OF PARTICLES = 223
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1508, 106 - 125 micron:
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	0	0	0	0.00	0.00	0.00	0.00
100.	1	1802	0	2.60	0.00	0.36	0.00
110.	4	1840	67	2.51	0.07	0.75	0.17
120.	10	1777	54	2.49	0.06	0.65	0.26
130.	26	1779	51	2.49	0.05	0.70	0.16
140.	41	1782	78	2.47	0.06	0.66	0.19
150.	45	1741	113	2.46	0.09	0.74	0.22
160.	43	1766	104	2.46	0.06	0.69	0.17
170.	30	1756	98	2.41	0.19	0.64	0.19
180.	15	1764	101	2.45	0.08	0.65	0.16
190.	12	1792	58	2.50	0.04	0.59	0.14
200.	12	1775	27	2.47	0.06	0.59	0.10
210.	4	1795	33	2.47	0.08	0.60	0.14
220.	1	1724	0	2.50	0.00	0.37	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	2	1791	14	2.41	0.04	0.52	0.14

NUMBER OF PARTICLES = 246
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1508, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.1 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	0	0	0	0.00	0.00	0.00	0.00
100.	0	0	0	0.00	0.00	0.00	0.00
110.	2	1721	101	2.71	0.00	0.65	0.07
120.	13	1736	67	2.68	0.06	0.67	0.21
130.	23	1797	75	2.68	0.04	0.68	0.18
140.	34	1748	80	2.68	0.06	0.67	0.22
150.	47	1732	87	2.67	0.08	0.64	0.18
160.	40	1748	83	2.68	0.05	0.60	0.16
170.	27	1769	92	2.70	0.07	0.60	0.16
180.	29	1751	81	2.66	0.06	0.56	0.16
190.	13	1760	79	2.66	0.08	0.59	0.11
200.	9	1753	87	2.67	0.03	0.55	0.13
210.	0	0	0	0.00	0.00	0.00	0.00
220.	1	1694	0	2.60	0.00	0.59	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 238
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1508, 106 - 125 micron
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	0	0	0	0.00	0.00	0.00	0.00
100.	2	1855	146	2.85	0.02	0.52	0.09
110.	1	1603	0	2.89	0.00	0.52	0.00
120.	14	1690	103	2.88	0.06	0.67	0.16
130.	23	1696	95	2.90	0.04	0.72	0.22
140.	38	1733	92	2.92	0.07	0.68	0.16
150.	65	1695	83	2.92	0.09	0.64	0.19
160.	35	1717	87	2.91	0.09	0.57	0.16
170.	25	1726	98	2.90	0.12	0.68	0.19
180.	18	1733	66	2.93	0.06	0.57	0.11
190.	9	1687	105	2.80	0.28	0.67	0.20
200.	3	1755	51	2.76	0.04	0.75	0.15
210.	1	1705	0	2.77	0.00	0.46	0.00
220.	0	0	0	0.00	0.00	0.00	0.00
230.	2	1831	7	3.02	0.08	0.48	0.09
240.	1	1637	0	2.93	0.00	0.39	0.00

NUMBER OF PARTICLES = 237
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**KINETIC ANALYSIS
AND COMBUSTION PARAMETERS**

Data and Analysis Compilation
for PSOC-1508, Pocahontas #3 Coal

Measured and Predicted Carbon Conversions in the CCL
 for PSOC-1508D

Summary of Combustion Parameters for PSOC-1508D		
Char oxidation rate parameters $q = A \exp(-E/RT_p) P^n$	A E n	114 gm-C / cm ² -s-atm ⁿ 30 kcal / mole 0.5 *
Product ratio parameters $CO/CO_2 = A_c \exp(-E_c/RT_p)$	A_c E_c	3 x 10⁸ * 60 * kcal / mole
Burning mode parameter $\rho/\rho_o = (m/m_o)^\alpha$ $d/d_o = (m/m_o)^{(1-\alpha)/3}$	α	0.3
Char structural parameters $\omega = d_o/d_c$ (linear swelling factor) $\rho_{c,o} = mc/V_c$ at $z = 6.5$ cm (initial char particle carbon density)	ω ρ_{c,o}	1.21 0.63 gm / cm ³
<p>As an example, this parameter set yields a combustion rate, q, of 0.00195 gm/sq.cm-s for a 100 μm particle in a gas with T_g = 1600 K containing 6 mole-% oxygen</p> <p>These product ratio parameters yield 3 mole-% carbon dioxide at 1900 K and 15 mole-% carbon dioxide at 1700 K</p> <p>* These particular parameters should be regarded as empirical parameters useful for the prediction of burning rates. They do not necessarily have fundamental significance and/or are not unique for this data set.</p>		

**CALCULATIONS OF THE COAL CHAR REACTIVITY INDEX, τ_{50} ,
FOR VARIOUS ENVIRONMENTS
PRESENT IN PULVERIZED-COAL COMBUSTION SYSTEMS**

Data and Analysis Compilation
for PSOC-1508, Pocahontas #3 Coal

Compilation of Data and Kinetic Analyses for
Lower Kittanning Bituminous Coal
(Pennsylvania, lvb)

PSOC-1516D

TABLE OF CONTENTS

- **Sample history, geologic information and chemical analysis of bulk, raw coal**
- **Chemical analysis of size-fractionated raw coal and partially reacted chars**
- **Measurements of total surface area evolution**
- **Time resolved measurements of the partitioning of elemental coal constituents between the gas and solid phases**
- **Mode of particle burning**
- **Statistical analyses of elemental composition measurements and derived quantities**
- **Optical measurements of single-particle temperature distributions**
- **Optical measurements of single-particle sizes, temperatures, and velocities**
- **Kinetic analysis and combustion parameters**
- **Calculations of the coal char reactivity index, τ_{50} , for various environments present in pulverized-coal combustion systems**

**SAMPLE HISTORY, GEOLOGIC INFORMATION AND
CHEMICAL ANALYSIS OF BULK, RAW COAL**

Data and Analysis Compilation
for PSOC-1516, Lower Kittanning Coal

* PENN STATE COAL DATA BASE *

PSOC-1516
2/18/92
PAGE 1

SAMPLE INFORMATION

PSU NUMBER
SEAM NAME
ALTERNATE SEAM NAME
APPARENT RANK

PSOC-1516
LOWER KITTANNING
PENNSYLVANIA B
LOW VOL

SAMPLE LOCATION

COUNTRY
STATE

USA
PENNSYLVANIA

SAMPLE HISTORY

SAMPLING DATE & AGENCY
SAMPLE RESERVE
SAMPLE TYPE
ADDITIONAL INFORMATION

5/29/86, PSU
924 LB.
CHANNEL-WHOLE SEAM

COUNTY
TOWNSHIP
CITY
COAL PROVINCE
REGION
MAP REFERENCE
LATITUDE
LONGITUDE
QUADRANGLE

SOMERSET
SHADE
STOYSTOWN
EASTERN
APPALACHIAN

40 D 4 M 58 S
8 D 53 M 0 S
STOYSTOWN (7.5')

MINE INFORMATION

MINE NAME
RESERVES
ANNUAL PRODUCTION

JOB 5 JOHNSON BOTTOM

50 THOUSAND TONS

LIFE EXPECTANCY
MINING METHOD

STRIP

SEAM INFORMATION

AGE OF SEAM
GROUP
FORMATION
SEAM THICKNESS

PENNSVL.
ALLEGHENY
KITANNING
6 FT. 1 IN.

ANALYSIS LOG

<u>ANALYSIS</u>	<u>PERFORMED BY</u>	<u>DATE</u>
A.R. MOIST		9/25/86
EQ. MOIST		9/25/86
PROXIMATE		9/25/86
ULTIMATE		9/25/86
SULFUR FORMS		9/25/86
FSI		9/9/86
PLASTOMETER		8/20/86
DIRECT MM		
GRAY-KING		

* PENN STATE COAL DATA BASE *

PSOC-1516
2/18/92
PAGE 2

SAMPLE INFORMATION

SAMPLE LOCATION

PSU NUMBER	PSOC-1516	COUNTRY	USA
SEAM NAME	LOWER KITTANNING	STATE	PENNSYLVANIA
ALTERNATE SEAM NAME	PENNSYLVANIA 8		
APPARENT RANK	LOW VOL		

CHEMICAL DATA

PROXIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF(PARR)
% MOISTURE	1.97			
% ASH	10.11	10.31		
% VOLATILE	17.38	17.73	19.77	18.55
% FIXED CARBON	70.54	71.96	80.23	81.45

% EQUILIBRIUM MOISTURE = 4.81
MM-FREE = 5.43

ULTIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF (PARR)
% ASH	10.11	10.31		(11.90 % MM)
% CARBON	78.10	79.67	88.83	90.44
% HYDROGEN	(*)4.12	4.20	4.68	4.77
% NITROGEN	1.44	1.47	1.64	1.67
% TOTAL SULFUR	1.37	1.40	1.56	
% OXYGEN(DIFF)	(*)2.89	2.95	3.29	3.13

(*)-EXCLUDES MOISTURE

ELEMENTAL ANALYSIS	DRY	DMMF(MOD.P)	DMMF (DIR.)
		(12.00%MM)	(%MM)
% CARBON	79.65	90.51	
% HYDROGEN	4.08	4.63	
% NITROGEN	1.47	1.67	
% ORGANIC SULFUR	0.78	0.89	
% OXYGEN (DIFF)	2.02	2.30	
% MINERAL MATTER	12.00		
(INCL. 1.14% FES2)			

SULFUR FORMS	% PYRITIC	% SULFATIC	% ORGANIC	% TOTAL
DRY	0.61	0.01	0.78	1.40
DAF	0.68	0.01	0.87	1.56

DRY & CHLORINE = 0.13 DRY % CO2 = 0.09
MOTT-SPOONER DIFFERENCE = 102.

CALORIFIC VALUE	DRY	AS REC'D MOIST.	EQUIL. MOIST.
(GROSS. BTU/LB)			
MM-CONTINING	14025.	13749.	13350.
MM-FREE (PARR)	15841.	15488.	14981.
MM-FREE (MOD. P)	15900.	15545.	15037.
NET CV. DMMF BTU/LB	15458.		

ATOM RATIOS (DMMF)	PARR	MOD.PARR	DIRECT
ATOMIC H/C	0.6332	0.6150	
ATOMIC O/C	0.0260	0.0191	

* PENN STATE COAL DATA BASE *

PSOC-1516
2/18/92
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SAMPLE INFORMATION

SAMPLE LOCATION

PSU NUMBER	PSOC-1516	COUNTRY	USA
SEAM NAME	LOWER KITTANNING	STATE	PENNSYLVANIA
ALTERNATE SEAM NAME	PENNSYLVANIA B		
APPARENT RANK	LOW VOL		

RANK CALCULATIONS

APPARENT RANK (AS REC'D MOIST.)	LOW VOL	INTERNATIONAL RANK:	
ASTM RANK (EQUIL. MOIST.)	LOW VOL	AS REC'D MOIST.	
		EQUIL. MOIST.	
REFLECTANCE RANK CATEGORY		REPORTED RANK:	LOW VOL

PETROGRAPHIC DATA

MACERAL COMPOSITION (WHITE LIGHT ANALYSIS)

	VITRINITE	PSEUDO-VITRINITE	FUSINITE	SEMI-FUSINITE	MACRINITE	MICRINITE	TINITE	INITE	RESINITE	ALGINITE	CUTINITE	
DMMF VOL. %	90.0	0.0	3.0	2.0	0.9	4.0	0.0	0.0	0.1	0.0	0.0	
DRY VOL. %	84.5	0.0	2.8	1.9	0.8	3.8	0.0	0.0	0.1	0.0	0.0	6.1 % MM
DRY WT. %	78.7	0.0	3.0	1.8	0.8	3.7	0.0	0.0	0.1	0.0	0.0	11.9 % MM

NO REFLECTANCE DATA THIS SAMPLE

CAKING AND MECHANICAL PROPERTIES

GIESELER COAL PLASTOMETER:

INIT. SOFTENING TEMP	442
TEMP. MAX. FLUIDITY	486
SOLIDIFICATION TEMP.	511
FLUID TEMP. RANGE	69
MAXIMUM FLUIDITY	53

GRAY-KING COKE TYPE

HARDGROVE GRINDABILITY	
FREE SWELLING INDEX	8.5
VICKERS HARDNESS NUMBER	

WASHABILITY DATA AVAILABLE? NO

* PENN STATE COAL DATA BASE *

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2/18/92
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SAMPLE INFORMATION

SAMPLE LOCATION

PSU NUMBER
SEAM NAME
ALTERNATE SEAM NAME
APPARENT RANK

PSOC-1516
LOWER KITTANNING
SYODAK
SUBBIT C

COUNTRY
STATE

USA
PENNSYLVANIA

MAJOR ELEMENT ANALYSIS

% HTA = 11.32

OXIDE % OF HTA	SI02	AL203	TI02	FE203	MG0	CA0	NA20	K20	P205	S03
	42.7	39.0	1.86	10.7	0.57	1.71	0.43	1.61	0.94	0.40

TRACE ELEMENT ANALYSIS

% HTA = 11.32

559

	PPM HTA	PPM TOTAL COAL		PPM HTA	PPM TOTAL COAL		PPM HTA	PPM TOTAL COAL	<u>VOLATILES</u>	PPM TOTAL COAL
AG			GE			SN			AS	
B			LA			SR	2030.		BR	
BA	630.		LI			TH			CD	
BE	8.0		MN	23.		U			CL	1300.
BI			MO			V	370.		F	
CE			NB			Y			HG	
CO			NI	95.		YB			SB	
CR	260.		PB			ZN	370.		SE	
CU	670.		RB	70.		ZR	260.			
GA			SC							

* PENN STATE COAL DATA BASE *

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2/18/92
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SAMPLE INFORMATION

SAMPLE LOCATION

PSU NUMBER
SEAM NAME
ALTERNATE SEAM NAME
APPARENT RANK

PSOC-1516
LOWER KITTANNING
PENNSYLVANIA B
LOW VOL

COUNTRY
STATE

USA
PENNSYLVANIA

ASH FUSION TEMPERATURES (ALL TEMPERATURES IN DEGREES F)

REDUCING

OXIDIZING

INITIAL DEFORMATION

2700.+

2700.+

SOFTENING

2700.+

2700.+

HEMISPHERICAL

2700.+

2700.+

FLUID

2700.+

2700.+

**CHEMICAL ANALYSES OF SIZE-FRACTIONATED RAW COAL
AND PARTIALLY REACTED CHARS**

Data and Analysis Compilation
for PSOC-1516, Lower Kittanning Coal

**Organic Elemental Analysis and Percent Ash of Lower Kittanning Coal
and its Partially Reacted Chars**

Initial particle size range: 75 - 106 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	70.47	3.90	3.32	1.25	1.14	20.4
6.4	69.21	0.53	0.54	1.06	1.13	26.2
12.7	72.28	0.35	0.39	1.09	0.75	26.9
19.1	68.75	0.25	0.08	0.88	0.60	29.0
25.4	67.95	0.50	0.73	1.07	0.76	28.9
25.4	68.06	0.60	3.74	1.07	0.66	29.0

12 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	70.47	3.9	3.32	1.25	1.14	20.4
6.4	61.81	1.27	0.65	1.04	0.99	32.6
12.7	61.68	0.36	0.03	0.9	0.62	36.8
19.1	57.57	0.22	0	0.82	0.53	37.9
25.4	53.956	0.25	0.32	0.77	0.52	41.8

* Data taken in February 1990

**Organic Elemental Analysis and Percent Ash of Lower Kittanning Coal
and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	60.28	3.42	5.35	1.03	2.76	29.0
6.4	62.94	1.41	2.36	1.00	0.70	33.6
12.7	60.39	0.59	0.72	0.90	0.58	35.3
19.1	61.50	0.53	0.96	0.91	0.60	37.2
25.4	59.35	0.51	0.66	0.90	0.31	37.6

12 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	60.28	3.42	5.35	1.03	2.76	29.0
6.4	59.79	1.91	3.89	1.02	1.46	33.6
12.7	59.91	0.70	1.94	0.90	0.69	37.2
19.1	56.53	0.50	1.06	0.80	0.42	42.4
25.4	53.92	0.89	1.75	0.76	0.35	43.3

* Data taken in March 1990

**Ash Content of Lower Kittanning Coal and its
Partially Reacted Chars**

Initial particle size range: 75 - 106 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	9.12	7.61	0.381	2.21	0.266	0.103	0.365	0.069
6.4	11.6	9.38	0.489	2.07	0.144	0.135	0.474	0.100
12.7	13.1	10.5	0.564	1.26	0.686	0.391	0.453	0.148
19.1	14.2	11.4	0.602	0.874	0.481	0.281	0.576	0.121
25.4	13.9	11.1	0.580	1.35	0.216	0.193	0.564	0.162
25.4	14.0	11.3	0.597	1.47	0.614	0.220	0.557	0.102

12 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	9.12	7.61	0.381	2.21	0.266	0.103	0.365	0.069
6.4	15.0	12.3	0.703	2.02	1.37	0.549	0.711	0.117
12.7	17.7	14.6	0.828	2.10	0.551	0.383	0.832	0.155
19.1	18.6	15.0	0.856	1.45	2.91	1.36	0.894	0.182
25.4	20.4	16.4	0.929	1.42	0.292	0.247	1.01	0.176

* Data taken in February 1990

**Ash Content of Lower Kittanning Coal and its
Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	13.6	10.4	0.506	3.03	0.085	0.144	0.415	0.038
6.4	14.4	12.2	0.617	1.64	0.134	0.185	0.481	0.059
12.7	15.4	13.0	0.666	1.40	0.132	0.199	0.484	0.049
19.1	17.3	13.7	0.661	1.83	0.165	0.206	0.508	0.080
25.4	17.3	14.5	0.723	0.949	0.153	0.226	0.557	0.099

12 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	13.6	10.4	0.506	3.03	0.085	0.144	0.415	0.038
6.4	13.7	12.3	0.596	2.86	0.204	0.189	0.364	0.082
12.7	15.6	14.8	0.716	1.96	0.157	0.212	0.383	0.068
19.1	17.9	16.6	0.788	2.19	0.211	0.249	0.376	0.083
25.4	17.2	16.1	0.739	2.32	0.323	0.242	0.382	0.06

* Data taken in March 1990

**MEASUREMENTS OF
TOTAL SURFACE AREA EVOLUTION**

Data and Analysis Compilation
for PSOC-1516, Lower-Kittanning Coal

Surface area evolution for PSOC-1516, Lower Kittanning Coal
Combustion in 6 mole-% oxygen

Surface area evolution for PSOC-1516, Lower Kittanning Coal
Combustion in 12 mole-% oxygen

**TIME RESOLVED MEASUREMENTS OF THE
PARTITIONING OF ELEMENTAL COAL CONSTITUENTS
BETWEEN THE GAS AND SOLID PHASES**

Data and Analysis Compilation
for PSOC-1516, Lower Kittanning Coal

MODE OF PARTICLE BURNING

Data and Analysis Compilation
for PSOC-1516, Lower Kittanning Coal

**Fractional Mass Remaining and Apparent Density
of Lower Kittanning Coal and its Partially Reacted Chars**

Initial particle size range: 75 - 106 μm

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.75	0.70	0.64	0.65
Fractional burnoff, daf	0.0	0.31	0.36	0.43	0.42
Apparent density, g/cc	1.26	0.59	0.66	0.64	0.58

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.62	0.54	0.51	0.47
Fractional burnoff, daf	0.0	0.48	0.58	0.64	0.66
Apparent density, g/cc	1.26	0.62	0.68	0.64	0.61

**Fractional Mass Remaining and Apparent Density
of Lower Kittanning Coal and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.87	0.81	0.77	0.74
Fractional burnoff, daf	0.0	0.18	0.27	0.32	0.36
Apparent density, g/cc	1.45	0.63	0.69	0.71	0.70

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.84	0.68	0.55	0.57
Fractional burnoff, daf	0.0	0.16	0.32	0.45	0.43
Apparent density, g/cc	1.45	0.60	0.68	0.69	0.64

**STATISTICAL ANALYSES
OF ELEMENTAL COMPOSITION MEASUREMENTS
AND DERIVED QUANTITIES**

- **Raw Coal Composition**
- **Overall Combustion Conversion vs. Residence Time**
- **Elemental Partitioning between Gas and Solid Phases**

Data and Analysis Compilation
for PSOC-1516, Lower Kittanning Coal

Average Initial Mass Percents and Statistics						
Lower Kittaning Bituminous Iv 75-106 μm				PSOC-1516d 12 % O ₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	9.120	0.228	2	0.025	2.048	10.263
Al ₂ O ₃	7.610	0.190	2	0.025	1.709	8.563
TiO ₂	0.381	0.010	2	0.025	0.086	0.429
Fe ₂ O ₃	2.210	0.055	2	0.025	0.496	2.487
CaO	0.266	0.007	2	0.025	0.060	0.299
Na ₂ O	0.069	0.002	2	0.025	0.015	0.078
K ₂ O	0.365	0.009	2	0.025	0.082	0.411
MgO	0.103	0.003	2	0.025	0.023	0.116
Σ Oxides	20.124					
C	70.823	1.771	3	0.025	4.399	10.146
H	3.937	0.098	3	0.025	0.245	0.564
O	2.777	0.941	3	0.339	2.338	5.393
N	1.307	0.098	3	0.075	0.244	0.562
S	1.437	0.514	3	0.358	1.277	2.944
Ash-s	21.270	1.697	3	0.080	4.217	9.726
Ash-l	20.400	0.510	2	0.025	4.582	22.956

Residual Total Mass (m/m ₀) as a Function of Residence Time						
Lower Kittaning Bituminous Iv 75-106 μm				PSOC-1516d 12 % O ₂		
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.73	0.61	0.62	0.54	0.59	0.63
72	0.65	0.52	0.52	0.46	0.54	0.55
95	0.58	0.49	0.51	0.45	0.53	0.54
117	0.55	0.45	0.46	0.41	0.50	0.49

Residual Total Mass (m/m0) with Statistics						
Lower Kittaning Bituminous Iv 75-106 μm				PSOC-1516d 12 % O ₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	9	1.00	0.000	0.000
47	0.62	0.077	4	0.52	0.122	0.224
72	0.54	0.080	4	0.42	0.127	0.233
95	0.51	0.056	4	0.39	0.089	0.164
117	0.47	0.058	4	0.34	0.092	0.169

Residual Elemental Mass as a Function of Residence Time						
Lower Kittaning Bituminous Iv 75-106 μm				PSOC-1516d 12 % O ₂		
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.03	1.15	1.01	0.57	3.21	1.06
72	1.04	1.17	1.03	0.51	1.11	1.20
95	1.03	1.14	1.00	0.33	5.53	1.33
117	1.04	1.14	1.01	0.30	0.51	1.19
	K ₂ O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.22	0.54	0.20	0.15	0.50	0.43
72	1.22	0.47	0.05	0.01	0.37	0.23
95	1.24	0.41	0.03	0.00	0.32	0.19
117	1.29	0.36	0.03	0.05	0.27	0.17

Elemental Mass Release (Normalized) and Statistics						
Lower Kittanning Bituminous Iv 75-106 μm				PSOC-1516d 12 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.026	0.145	4	0.142	0.334	0.771
72	-0.041	0.172	4	0.165	0.388	0.894
95	-0.031	0.136	3	0.132	0.316	0.728
117	-0.045	0.147	4	0.141	0.337	0.778
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.008	0.143	4	0.142	0.329	0.758
72	-0.029	0.170	4	0.165	0.383	0.884
95	0.003	0.131	3	0.132	0.305	0.703
117	-0.007	0.142	4	0.141	0.325	0.750
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.151	0.163	4	0.142	0.375	0.865
72	-0.166	0.192	4	0.165	0.434	1.001
95	-0.136	0.149	3	0.132	0.348	0.802
117	-0.139	0.161	4	0.141	0.368	0.849
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.430	0.081	4	0.142	0.186	0.429
72	0.490	0.084	4	0.165	0.190	0.438
95	0.668	0.044	3	0.132	0.102	0.234
117	0.700	0.043	4	0.143	0.099	0.228

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Kittaning Bituminous Iv 75-106 μm				PSOC-1516d 12 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-2.213	0.455	4	0.142	1.047	2.416
72	-0.111	0.183	4	0.165	0.414	0.954
95	-4.532	0.728	3	0.132	1.692	3.904
117	0.487	0.264	2	0.516	2.311	11.576
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.058	0.150	4	0.142	0.345	0.795
72	-0.205	0.199	4	0.165	0.449	1.035
95	-0.334	0.175	3	0.132	0.408	0.941
117	-0.191	0.171	3	0.143	0.393	0.906
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.215	0.172	4	0.142	0.396	0.914
72	-0.223	0.202	4	0.165	0.455	1.050
95	-0.239	0.163	3	0.132	0.379	0.874
117	-0.292	0.182	4	0.141	0.415	0.958
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-2.326	0.471	4	0.142	1.084	2.500
72	-0.995	0.329	4	0.165	0.743	1.713
95	-5.677	0.878	3	0.132	2.043	4.711
117	-0.120	0.343	2	0.306	2.854	14.299

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Kittanning Bituminous Iv 75-106 μm				PSOC-1516d 12 % O2		
C						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.455	0.077	4	0.142	0.171	0.396
72	0.533	0.077	4	0.165	0.170	0.392
95	0.589	0.054	4	0.132	0.121	0.279
117	0.644	0.051	4	0.144	0.114	0.263
H						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.799	0.029	4	0.142	0.063	0.146
72	0.951	0.008	4	0.165	0.018	0.041
95	0.972	0.004	4	0.132	0.008	0.019
117	0.971	0.004	4	0.141	0.009	0.021
O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.343	3	0.343	0.851	1.963
47	0.854	0.053	3	0.364	0.130	0.299
72	0.994	0.002	3	0.374	0.005	0.012
95	1.000	0.000	#NUM!	#NUM!	#NUM!	#NUM!
117	0.947	0.007	4	0.134	0.016	0.036
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.090	3	0.090	0.224	0.517
47	0.503	0.076	4	0.152	0.170	0.393
72	0.631	0.064	4	0.174	0.143	0.331
95	0.683	0.045	4	0.143	0.103	0.237
117	0.727	0.043	4	0.156	0.096	0.222

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Kittanning Bituminous Iv 75-106 μm				PSOC-1516d 12 % O2		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.361	3	0.361	0.897	2.069
47	0.570	0.164	3	0.381	0.401	0.924
72	0.769	0.090	3	0.391	0.219	0.506
95	0.813	0.070	3	0.378	0.173	0.398
117	0.833	0.066	3	0.392	0.160	0.370
Ash-I						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.003	0.141	4	0.142	0.325	0.749
72	0.032	0.160	4	0.165	0.360	0.831
95	0.061	0.124	3	0.132	0.287	0.663
117	0.043	0.135	4	0.141	0.309	0.712
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.094	3	0.094	0.234	0.540
47	-0.060	0.164	4	0.155	0.370	0.854
72	0.007	0.175	4	0.176	0.391	0.901
95	0.053	0.138	4	0.145	0.313	0.723
117	0.067	0.143	4	0.153	0.321	0.741
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.090	3	0.090	0.224	0.517
47	0.503	0.076	4	0.152	0.170	0.393
72	0.631	0.064	4	0.174	0.143	0.331
95	0.683	0.045	4	0.143	0.103	0.237
117	0.727	0.043	4	0.156	0.096	0.222

Average Initial Mass Percents and Statistics						
Lower Kittaning Bituminous Iv 75-106 μm				PSOC-1516d 6 % O ₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	9.120	0.228	2	0.025	2.048	10.263
Al ₂ O ₃	7.610	0.190	2	0.025	1.709	8.563
TiO ₂	0.381	0.010	2	0.025	0.086	0.429
Fe ₂ O ₃	2.210	0.055	2	0.025	0.496	2.487
CaO	0.266	0.007	2	0.025	0.060	0.299
Na ₂ O	0.069	0.002	2	0.025	0.015	0.078
K ₂ O	0.365	0.009	2	0.025	0.082	0.411
MgO	0.103	0.003	2	0.025	0.023	0.116
Σ Oxides	20.124					
C	70.823	1.771	3	0.025	4.399	10.146
H	3.937	0.098	3	0.025	0.245	0.564
O	2.777	0.941	3	0.339	2.338	5.393
N	1.307	0.098	3	0.075	0.244	0.562
S	1.437	0.514	3	0.358	1.277	2.944
Ash-s	21.270	1.697	3	0.080	4.217	9.726
Ash-l	20.400	0.510	2	0.025	4.582	22.956

Residual Total Mass (m/m ₀) as a Function of Residence Time						
Lower Kittaning Bituminous Iv 75-106 μm				PSOC-1516d 6 % O ₂		
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.59	0.79	0.81	0.78	0.77	0.78
72	0.65	0.70	0.72	0.68	0.76	0.76
95	0.61	0.64	0.67	0.63	0.67	0.70
117	0.57	0.65	0.68	0.65	0.71	0.70

Residual Total Mass (m/m0) with Statistics						
Lower Kittaning Bituminous Iv 75-106 μm				PSOC-1516d 6 % O₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	9	1.00	0.000	0.000
47	0.74	0.101	4	0.68	0.160	0.294
72	0.69	0.032	4	0.63	0.051	0.094
95	0.64	0.026	7	0.56	0.024	0.036
117	0.64	0.045	8	0.57	0.038	0.056

Residual Elemental Mass as a Function of Residence Time						
Lower Kittaning Bituminous Iv 75-106 μm				PSOC-1516d 6 % O₂		
	SiO₂	TiO₂	Al₂O₃	Fe₂O₃	CaO	Na₂O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.94	0.95	0.92	0.70	0.40	1.08
72	0.99	1.02	0.95	0.39	1.77	1.47
95	0.99	1.01	0.95	0.25	1.15	1.11
117	0.98	0.99	0.94	0.41	1.00	1.22
	K₂O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.96	0.73	0.10	0.14	0.60	0.58
72	0.85	0.70	0.06	0.10	0.57	0.36
95	1.00	0.62	0.04	0.02	0.43	0.27
117	0.98	0.61	0.09	0.51	0.52	0.32

Elemental Mass Release (Normalized) and Statistics						
Lower Kittanning Bituminous Iv 75-106 μm				PSOC-1516d 6 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.056	0.144	4	0.153	0.329	0.758
72	0.014	0.084	3	0.085	0.657	3.294
95	0.008	0.081	3	0.082	0.193	0.446
117	0.023	0.098	5	0.100	0.140	0.257
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.085	0.140	4	0.153	0.318	0.734
72	0.053	0.080	3	0.085	0.632	3.164
95	0.046	0.078	3	0.082	0.186	0.429
117	0.060	0.094	5	0.100	0.135	0.247
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.047	0.146	4	0.153	0.331	0.765
72	-0.016	0.086	3	0.085	0.678	3.394
95	-0.006	0.082	3	0.082	0.196	0.452
117	0.013	0.099	5	0.100	0.142	0.260
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.305	0.106	4	0.153	0.242	0.558
72	0.609	0.033	3	0.085	0.261	1.307
95	0.748	0.021	3	0.082	0.049	0.113
117	0.592	0.037	6	0.092	0.044	0.073

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Kittaning Bituminous Iv 75-106 μm				PSOC-1516d 6 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.598	0.061	4	0.153	0.140	0.323
72	-0.770	0.150	3	0.085	1.180	5.913
95	-0.151	0.094	3	0.082	0.224	0.517
117	0.003	0.104	5	0.104	0.151	0.278
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.076	0.164	4	0.153	0.374	0.863
72	-0.472	0.125	3	0.085	0.982	4.918
95	-0.112	0.091	3	0.082	0.217	0.500
117	-0.222	0.119	5	0.098	0.147	0.243
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.036	0.147	4	0.153	0.335	0.774
72	0.148	0.072	3	0.085	0.568	2.846
95	-0.004	0.082	3	0.082	0.196	0.452
117	0.019	0.099	5	0.101	0.141	0.259
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.027	0.149	4	0.153	0.339	0.781
72	-1.606	0.221	3	0.085	1.737	8.704
95	-0.735	0.141	3	0.082	0.338	0.780
117	-0.281	0.141	4	0.110	0.212	0.389

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Kittanning Bituminous Iv 75-106 μm				PSOC-1516d 6 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.274	0.111	4	0.153	0.245	0.565
72	0.300	0.059	3	0.085	0.141	0.324
95	0.382	0.050	4	0.082	0.109	0.250
117	0.387	0.061	5	0.100	0.073	0.121
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.900	0.015	4	0.153	0.034	0.078
72	0.939	0.005	3	0.085	0.012	0.028
95	0.960	0.003	4	0.082	0.007	0.016
117	0.911	0.008	6	0.089	0.008	0.013
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.343	3	0.343	0.851	1.963
47	0.856	0.053	3	0.368	0.129	0.298
72	0.904	0.033	3	0.346	0.083	0.190
95	0.982	0.006	3	0.345	0.016	0.036
117	0.486	0.045	6	0.087	0.046	0.072
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.090	3	0.090	0.224	0.517
47	0.398	0.098	4	0.163	0.219	0.506
72	0.427	0.058	3	0.102	0.140	0.322
95	0.571	0.042	4	0.099	0.095	0.220
117	0.477	0.056	5	0.106	0.068	0.112

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Kittaning Bituminous Iv 75-106 μm				PSOC-1516d 6 % O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.361	3	0.361	0.897	2.069
47	0.416	0.225	3	0.386	0.548	1.265
72	0.642	0.130	3	0.364	0.323	0.746
95	0.734	0.097	3	0.363	0.238	0.549
117	0.684	0.099	3	0.314	0.237	0.546
Ash-I						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.047	0.146	4	0.153	0.332	0.765
72	0.095	0.077	3	0.085	0.604	3.024
95	0.095	0.074	3	0.082	0.177	0.407
117	0.093	0.091	5	0.100	0.129	0.237
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.094	3	0.094	0.234	0.540
47	0.030	0.160	4	0.165	0.359	0.829
72	0.095	0.095	3	0.105	0.229	0.528
95	0.053	0.097	4	0.103	0.219	0.506
117	0.096	0.109	5	0.120	0.160	0.293
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.090	3	0.090	0.224	0.517
47	0.398	0.098	4	0.163	0.219	0.506
72	0.427	0.058	3	0.102	0.140	0.322
95	0.571	0.042	4	0.099	0.095	0.220
117	0.477	0.056	5	0.106	0.068	0.112

Average Initial Mass Percents and Statistics						
Lower Kittaning Bituminous Iv 106-125 μm				PSOC-1516d 12 % O ₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	13.600	0.340	2	0.025	3.055	15.304
Al ₂ O ₃	10.350	0.259	2	0.025	2.325	11.647
TiO ₂	0.506	0.021	2	0.042	0.191	0.955
Fe ₂ O ₃	3.025	0.163	2	0.054	1.461	7.320
CaO	0.085	0.002	2	0.025	0.019	0.096
Na ₂ O	0.076	#DIV/0!	1	#DIV/0!	#DIV/0!	#DIV/0!
K ₂ O	0.415	0.177	2	0.428	1.595	7.989
MgO	0.144	0.004	2	0.025	0.032	0.161
Σ Oxides	28.200					
C	60.790	1.520	3	0.025	3.776	8.708
H	3.473	0.087	3	0.025	0.216	0.498
O	4.643	1.482	3	0.319	3.682	8.494
N	1.060	0.089	3	0.084	0.221	0.509
S	2.410	0.308	3	0.128	0.765	1.765
Ash-s	29.070	0.727	3	0.025	1.805	4.164
Ash-l	29.050	0.726	2	0.025	6.525	32.690

Residual Total Mass (m/m ₀) as a Function of Residence Time						
Lower Kittaning Bituminous Iv 106-125 μm				PSOC-1516d 12 % O ₂		
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.75	0.99	0.84	0.85	0.87	0.86
72	0.65	0.87	0.70	0.71	0.81	0.78
95	0.60	0.76	0.62	0.64	0.68	0.69
117	0.59	0.79	0.64	0.68	0.67	0.67

Residual Total Mass (m/m0) with Statistics						
Lower Kittaning Bituminous Iv 106-125 μm				PSOC-1516d 12 % O₂		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	9	1.00	0.000	0.000
47	0.86	0.100	5	0.81	0.124	0.205
72	0.73	0.095	6	0.66	0.100	0.157
95	0.66	0.070	6	0.53	0.074	0.115
117	0.68	0.085	5	0.54	0.105	0.175

Residual Elemental Mass as a Function of Residence Time						
Lower Kittaning Bituminous Iv 106-125 μm				PSOC-1516d 12 % O₂		
	SiO₂	TiO₂	Al₂O₃	Fe₂O₃	CaO	Na₂O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.87	1.01	1.02	0.81	2.06	0.93
72	0.84	1.04	1.05	0.47	1.35	0.66
95	0.87	1.02	1.05	0.48	1.63	0.72
117	0.86	0.99	1.05	0.52	2.57	0.53
	K₂O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.75	0.84	0.47	0.72	0.83	0.52
72	0.68	0.72	0.15	0.31	0.62	0.21
95	0.60	0.61	0.09	0.15	0.50	0.11
117	0.62	0.60	0.17	0.26	0.49	0.10

Elemental Mass Release (Normalized) and Statistics						
Lower Kittanning Bituminous Iv 106-125 μm				PSOC-1516d 12 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.135	0.117	4	0.136	0.183	0.335
72	0.159	0.124	5	0.148	0.153	0.254
95	0.135	0.111	5	0.128	0.161	0.296
117	0.144	0.124	4	0.145	0.191	0.351
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.021	0.139	4	0.136	0.216	0.396
72	-0.048	0.155	5	0.148	0.191	0.317
95	-0.054	0.135	5	0.128	0.196	0.360
117	-0.053	0.152	4	0.145	0.235	0.431
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.012	0.137	4	0.136	0.214	0.392
72	-0.037	0.154	5	0.148	0.189	0.313
95	-0.024	0.131	5	0.128	0.191	0.350
117	0.011	0.144	4	0.145	0.222	0.407
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.073	2	0.073	0.660	3.305
47	0.188	0.111	4	0.137	0.174	0.320
72	0.525	0.071	5	0.149	0.088	0.146
95	0.524	0.062	5	0.130	0.090	0.166
117	0.481	0.075	4	0.144	0.115	0.212

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Kittanning Bituminous Iv 106-125 μm				PSOC-1516d 12 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-1.061	0.280	4	0.136	0.435	0.799
72	-0.354	0.200	5	0.148	0.247	0.409
95	-0.632	0.209	5	0.128	0.304	0.558
117	-1.573	0.357	4	0.139	0.539	0.990
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	0.073	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	0.344	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	0.282	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	0.465	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.431	2	0.431	3.873	19.404
47	0.246	0.337	2	0.446	2.883	14.441
72	0.323	0.305	2	0.450	2.537	12.709
95	0.404	0.265	2	0.444	2.252	11.285
117	0.376	0.276	2	0.443	2.344	11.745
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.131	0.154	4	0.136	0.239	0.438
72	-0.083	0.160	5	0.148	0.197	0.327
95	-0.140	0.146	5	0.128	0.212	0.390
117	-0.142	0.165	4	0.144	0.254	0.467

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Kittaning Bituminous Iv 106-125 μm				PSOC-1516d 12 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.155	0.115	4	0.136	0.173	0.317
72	0.278	0.107	5	0.148	0.129	0.214
95	0.389	0.078	5	0.128	0.096	0.160
117	0.399	0.087	4	0.145	0.130	0.240
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.528	0.064	4	0.136	0.097	0.177
72	0.852	0.022	5	0.148	0.026	0.044
95	0.905	0.012	5	0.128	0.015	0.025
117	0.826	0.024	5	0.138	0.035	0.065
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.323	3	0.323	0.803	1.851
47	0.281	0.247	3	0.343	0.591	1.364
72	0.694	0.107	3	0.348	0.248	0.573
95	0.850	0.051	3	0.340	0.121	0.279
117	0.745	0.060	4	0.236	0.137	0.316
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.098	3	0.098	0.243	0.559
47	0.174	0.125	4	0.152	0.195	0.358
72	0.378	0.101	5	0.163	0.145	0.267
95	0.504	0.072	5	0.145	0.106	0.195
117	0.514	0.078	4	0.161	0.121	0.223

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Kittanning Bituminous Iv 106-125 μm				PSOC-1516d 12 % O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.137	3	0.137	0.341	0.787
47	0.480	0.093	4	0.180	0.205	0.474
72	0.790	0.040	4	0.189	0.060	0.110
95	0.885	0.020	4	0.174	0.031	0.057
117	0.902	0.020	4	0.204	0.045	0.103
Ash-I						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.007	0.135	4	0.136	0.210	0.385
72	0.061	0.139	5	0.148	0.171	0.284
95	0.041	0.123	5	0.128	0.179	0.328
117	-0.009	0.145	4	0.144	0.223	0.409
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.016	0.134	4	0.136	0.201	0.370
72	0.092	0.134	5	0.148	0.162	0.268
95	0.035	0.124	5	0.128	0.152	0.252
117	-0.009	0.145	5	0.144	0.217	0.398
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.098	3	0.098	0.243	0.559
47	0.174	0.125	4	0.152	0.195	0.358
72	0.378	0.101	5	0.163	0.145	0.267
95	0.504	0.072	5	0.145	0.106	0.195
117	0.514	0.078	4	0.161	0.121	0.223

Average Initial Mass Percents and Statistics						
Lower Kittaning Bituminous Iv 106-125 μm				PSOC-1516d 6 % O₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	13.600	0.340	2	0.025	3.055	15.304
Al ₂ O ₃	10.350	0.259	2	0.025	2.325	11.647
TiO ₂	0.506	0.021	2	0.042	0.191	0.955
Fe ₂ O ₃	3.025	0.163	2	0.054	1.461	7.320
CaO	0.085	0.002	2	0.025	0.019	0.096
Na ₂ O	0.038	0.054	2	1.414	0.483	2.419
K ₂ O	0.415	0.177	2	0.428	1.595	7.989
MgO	0.144	0.004	2	0.025	0.032	0.161
Σ Oxides	28.162					
C	60.790	1.520	2	0.025	13.654	68.406
H	3.460	0.087	2	0.025	0.777	3.894
O	4.145	1.704	2	0.411	15.311	76.705
N	1.095	0.092	2	0.084	0.826	4.138
S	2.525	0.332	2	0.132	2.986	14.959
Ash-s	29.305	0.733	2	0.025	6.582	32.977
Ash-l	29.000	#DIV/0!	1	#DIV/0!	#DIV/0!	#DIV/0!

Residual Total Mass (m/m₀) as a Function of Residence Time						
Lower Kittaning Bituminous Iv 106-125 μm				PSOC-1516d 6 % O₂		
	mass bal.	SiO₂	Al₂O₃	TiO₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.69	0.94	0.85	0.82	0.88	0.86
72	0.63	0.88	0.80	0.76	0.80	0.82
95	0.53	0.79	0.76	0.77	0.76	0.79
117	0.56	0.79	0.71	0.70	0.75	0.77

Residual Total Mass (m/m0) with Statistics						
Lower Kittaning Bituminous lv 106-125 μm				PSOC-1516d 6 % O₂		
	Mean (mf)	σ	n	Mean (daf)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	1.00	0.000	9	1.00	0.000	0.000
47	0.83	0.105	5	0.78	0.130	0.216
72	0.77	0.104	5	0.69	0.129	0.214
95	0.71	0.120	8	0.62	0.101	0.149
117	0.69	0.096	5	0.60	0.119	0.197

Residual Elemental Mass as a Function of Residence Time						
Lower Kittaning Bituminous lv 106-125 μm				PSOC-1516d 6 % O₂		
	SiO₂	TiO₂	Al₂O₃	Fe₂O₃	CaO	Na₂O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.87	1.01	0.97	0.45	1.30	1.28
72	0.87	1.01	0.96	0.36	1.19	0.99
95	0.90	0.93	0.94	0.43	1.38	1.49
117	0.88	0.98	0.97	0.22	1.24	1.80
	K₂O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.96	0.85	0.34	0.47	0.75	0.23
72	0.90	0.76	0.13	0.13	0.63	0.18
95	0.87	0.72	0.11	0.16	0.59	0.17
117	0.93	0.67	0.10	0.11	0.57	0.08

Elemental Mass Release (Normalized) and Statistics						
Lower Kittanning Bituminous Iv 106-125 μm				PSOC-1516d 6 % O2		
SiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.126	0.127	4	0.145	0.195	0.359
72	0.130	0.133	4	0.153	0.203	0.372
95	0.098	0.166	7	0.184	0.152	0.230
117	0.123	0.137	4	0.156	0.208	0.382
Al2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.027	0.142	4	0.145	0.217	0.399
72	0.036	0.147	4	0.153	0.225	0.412
95	0.061	0.173	7	0.184	0.158	0.240
117	0.034	0.150	4	0.155	0.227	0.417
TiO2						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.007	0.146	4	0.145	0.225	0.413
72	-0.011	0.154	4	0.153	0.235	0.432
95	0.074	0.170	7	0.184	0.156	0.236
117	0.015	0.152	4	0.155	0.231	0.423
Fe2O3						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.073	2	0.073	0.660	3.305
47	0.552	0.066	4	0.147	0.101	0.186
72	0.645	0.055	4	0.154	0.084	0.154
95	0.571	0.079	7	0.185	0.073	0.111
117	0.784	0.039	4	0.181	0.086	0.199

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Kittanning Bituminous Iv 106-125 μm				PSOC-1516d 6 % O2		
CaO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.302	0.189	4	0.145	0.291	0.534
72	-0.192	0.182	4	0.153	0.278	0.510
95	-0.377	0.253	7	0.184	0.232	0.352
117	-0.241	0.195	4	0.157	0.298	0.547
Na2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	1.415	2	1.415	12.714	63.696
47	-0.282	1.822	2	1.421	16.268	81.502
72	0.010	1.408	2	1.422	12.561	62.930
95	-0.494	2.129	2	1.425	18.731	93.840
117	-0.796	2.069	2	1.152	18.389	92.129
K2O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.431	2	0.431	3.873	19.404
47	0.042	0.431	2	0.449	3.656	18.317
72	0.103	0.405	2	0.452	3.417	17.120
95	0.131	0.402	3	0.463	3.053	15.296
117	0.074	0.386	2	0.417	3.214	16.101
MgO						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	-0.065	0.155	4	0.145	0.238	0.437
72	-0.065	0.163	4	0.153	0.248	0.455
95	-0.018	0.187	7	0.184	0.172	0.260
117	-0.085	0.168	4	0.155	0.254	0.466

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Kittanning Bituminous Iv 106-125 μm				PSOC-1516d 6 % O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.145	0.124	4	0.145	0.191	0.351
72	0.237	0.117	4	0.153	0.178	0.326
95	0.282	0.132	7	0.184	0.121	0.183
117	0.327	0.105	4	0.157	0.161	0.295
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.664	0.049	4	0.145	0.075	0.138
72	0.869	0.020	4	0.153	0.031	0.056
95	0.891	0.020	7	0.184	0.018	0.028
117	0.898	0.016	4	0.157	0.024	0.045
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.414	2	0.414	3.721	18.642
47	0.530	0.204	2	0.433	1.722	8.628
72	0.867	0.058	2	0.436	0.488	2.445
95	0.836	0.074	3	0.448	0.552	2.767
117	0.890	0.068	2	0.616	0.585	2.933
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.098	2	0.098	0.878	4.398
47	0.246	0.121	4	0.160	0.264	0.609
72	0.369	0.105	4	0.167	0.228	0.525
95	0.410	0.115	7	0.196	0.116	0.182
117	0.434	0.097	4	0.170	0.208	0.479

Elemental Mass Release (Normalized) and Statistics (con't)						
Lower Kittaning Bituminous Iv 106-125 μm				PSOC-1516d 6 % O2		
S						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.141	2	0.141	1.265	6.337
47	0.771	0.043	3	0.190	0.102	0.236
72	0.824	0.034	3	0.195	0.080	0.184
95	0.831	0.037	6	0.220	0.044	0.073
117	0.915	0.025	3	0.295	0.194	0.971
Ash-l						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
47	0.043	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
72	0.065	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
95	0.101	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
117	0.106	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Ash-s						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.059	0.137	4	0.145	0.210	0.386
72	0.036	0.147	4	0.153	0.225	0.412
95	0.068	0.171	7	0.184	0.157	0.238
117	0.076	0.144	4	0.156	0.219	0.401
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.098	2	0.098	0.878	4.398
47	0.246	0.121	4	0.160	0.264	0.609
72	0.369	0.105	4	0.167	0.228	0.525
95	0.410	0.115	7	0.196	0.116	0.182
117	0.434	0.097	4	0.170	0.208	0.479

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE TEMPERATURE DISTRIBUTIONS**

Data and Analysis Compilation
for PSOC-1516, Lower Kittanning Coal

6 mole-% Oxygen
Environment

12 mole-% Oxygen
Environment

LOWER KITTANNING COAL CHAR

COAL TYPE: Lower Kittanning, psoc1516, 10kgc133. 7-13-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	1	1355.9	0.0	2.16	0.00	0.700	0.000
1400.0	4	1406.4	12.2	2.17	0.08	0.971	0.267
1450.0	6	1459.3	3.8	2.25	0.12	0.759	0.176
1500.0	6	1511.2	8.5	2.34	0.09	0.769	0.199
1550.0	9	1545.6	12.4	2.42	0.03	0.850	0.318
1600.0	15	1600.6	16.1	2.43	0.07	0.959	0.286
1650.0	197	1652.2	12.0	2.52	0.04	0.815	0.243
1700.0	45	1692.9	14.1	2.54	0.05	0.863	0.324
1750.0	7	1746.7	12.5	2.54	0.05	0.782	0.286
1800.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1850.0	1	1826.0	0.0	2.50	0.00	0.498	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 291
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Lower Kittanning, psoc1516, 15kgc133. 7-13-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	2	1511.7	15.7	2.48	0.06	0.829	0.116
1550.0	18	1560.5	10.2	2.64	0.09	0.739	0.277
1600.0	180	1602.6	11.7	2.67	0.06	0.738	0.225
1650.0	46	1646.3	13.4	2.68	0.07	0.739	0.231
1700.0	32	1693.6	11.8	2.66	0.19	0.817	0.276
1750.0	10	1740.5	9.9	2.72	0.04	0.631	0.193
1800.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 288
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Lower Kittanning, psoc1516, 20kgc133. 7-13-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	40	1513.3	8.7	2.82	0.09	0.768	0.268
1550.0	158	1544.7	11.8	2.82	0.12	0.769	0.221
1600.0	33	1594.2	14.0	2.84	0.09	0.719	0.167
1650.0	27	1650.0	16.4	2.84	0.10	0.766	0.177
1700.0	21	1696.8	14.4	2.86	0.06	0.742	0.234
1750.0	9	1747.0	14.0	2.88	0.05	0.778	0.175
1800.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 288
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Lower Kittanning, psoc1516, 10kgc142. 7-12-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1652.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	2	1463.3	3.4	2.22	0.08	0.511	0.047
1500.0	3	1498.1	14.4	2.13	0.16	0.887	0.136
1550.0	4	1552.7	16.5	2.33	0.03	0.605	0.163
1600.0	3	1593.7	9.8	2.33	0.01	0.739	0.120
1650.0	7	1660.8	6.2	2.52	0.08	0.479	0.241
1700.0	69	1710.7	10.4	2.48	0.05	0.779	0.267
1750.0	91	1746.3	12.8	2.47	0.06	0.819	0.217
1800.0	38	1801.8	13.8	2.46	0.17	0.848	0.249
1850.0	24	1846.0	15.2	2.50	0.09	0.721	0.259
1900.0	17	1897.5	14.6	2.47	0.12	0.782	0.299
1950.0	2	1947.3	11.2	2.33	0.15	0.664	0.223
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	1	2043.8	0.0	2.02	0.00	0.882	0.000
2100.0	1	2103.4	0.0	1.94	0.00	0.918	0.000
2150.0	1	2162.7	0.0	2.18	0.00	9.167	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 263
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Lower Kittanning, psoc 1516, 15kgc142. 7-13-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	2	1557.1	1.4	2.56	0.06	0.572	0.184
1600.0	23	1615.2	8.3	2.64	0.23	0.557	0.232
1650.0	122	1651.8	12.4	2.63	0.05	0.702	0.189
1700.0	41	1696.4	14.1	2.62	0.08	0.803	0.294
1750.0	22	1751.9	15.0	2.69	0.03	0.797	0.210
1800.0	27	1800.4	13.3	2.68	0.04	0.837	0.197
1850.0	22	1845.7	13.3	2.70	0.04	0.793	0.224
1900.0	8	1893.6	15.0	2.65	0.11	0.761	0.284
1950.0	4	1947.1	7.9	2.41	0.17	0.635	0.243
2000.0	2	1982.7	9.7	2.50	0.10	1.102	0.130
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	1	2178.1	0.0	2.38	0.00	1.480	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 274
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Lower Kittanning, psoc1516, 20kgc142. 7-13-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	11	1505.6	11.7	2.81	0.13	0.651	0.300
1550.0	52	1555.6	13.3	2.85	0.06	0.685	0.233
1600.0	109	1597.8	13.4	2.80	0.13	0.716	0.174
1650.0	25	1641.5	13.6	2.79	0.08	0.802	0.318
1700.0	25	1703.9	13.4	2.87	0.06	0.874	0.159
1750.0	25	1750.2	15.8	2.81	0.23	0.807	0.210
1800.0	15	1800.1	13.8	2.87	0.04	0.867	0.175
1850.0	8	1844.3	14.9	2.85	0.04	0.795	0.147
1900.0	4	1896.3	11.9	2.80	0.14	0.714	0.088
1950.0	2	1945.8	9.7	2.64	0.01	0.562	0.033
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 276
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC1516
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	1	1685	0	2.63	0.00	0.36	0.00
90.	4	1702	39	2.53	0.08	1.15	0.74
100.	2	1551	130	2.47	0.23	0.78	0.20
110.	6	1616	83	2.46	0.16	1.00	0.36
120.	12	1671	47	2.52	0.07	1.12	0.44
130.	18	1661	30	2.53	0.05	0.98	0.22
140.	33	1646	51	2.52	0.05	0.95	0.23
150.	52	1644	44	2.50	0.08	0.86	0.19
160.	39	1660	45	2.52	0.04	0.77	0.17
170.	42	1654	30	2.52	0.06	0.74	0.18
180.	28	1648	43	2.51	0.06	0.76	0.19
190.	18	1643	35	2.51	0.06	0.77	0.29
200.	6	1592	81	2.44	0.14	0.79	0.12
210.	11	1626	88	2.46	0.11	0.64	0.17
220.	5	1507	112	2.31	0.20	0.72	0.26
230.	6	1611	90	2.45	0.10	0.70	0.17
240.	4	1615	57	2.48	0.10	0.57	0.15

NUMBER OF PARTICLES = 287
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC1516
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.10 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	1	1656	0	2.77	0.00	0.47	0.00
100.	4	1668	51	2.79	0.03	0.39	0.40
110.	7	1620	35	2.71	0.07	0.85	0.36
120.	12	1642	46	2.70	0.05	0.89	0.27
130.	35	1637	48	2.68	0.09	0.94	0.29
140.	41	1624	43	2.69	0.05	0.80	0.19
150.	44	1626	33	2.68	0.04	0.78	0.17
160.	45	1620	46	2.67	0.07	0.72	0.17
170.	31	1607	45	2.67	0.06	0.69	0.16
180.	27	1605	23	2.66	0.05	0.69	0.17
190.	14	1605	41	2.65	0.06	0.63	0.08
200.	4	1595	9	2.67	0.02	0.54	0.04
210.	5	1601	16	2.60	0.06	0.62	0.12
220.	5	1608	12	2.64	0.03	0.51	0.07
230.	3	1598	8	2.64	0.08	0.51	0.19
240.	2	1619	33	2.63	0.16	0.33	0.09

NUMBER OF PARTICLES = 280
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE SIZES, TEMPERATURES, AND VELOCITIES**

Data and Analysis Compilation
for PSOC-1516, Lower Kittanning Coal

COAL TYPE: PSOC1516
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	0	0	0	0.00	0.00	0.00	0.00
100.	1	1711	0	2.96	0.00	0.31	0.00
110.	3	1619	100	2.89	0.05	0.82	0.23
120.	17	1584	67	2.87	0.07	0.82	0.29
130.	21	1570	65	2.85	0.07	0.88	0.33
140.	46	1583	61	2.84	0.08	0.84	0.21
150.	52	1577	60	2.86	0.05	0.77	0.17
160.	46	1573	66	2.84	0.06	0.76	0.15
170.	42	1571	58	2.82	0.20	0.68	0.16
180.	24	1571	57	2.82	0.10	0.69	0.19
190.	11	1556	44	2.79	0.07	0.77	0.24
200.	14	1538	27	2.74	0.09	0.72	0.16
210.	5	1550	36	2.79	0.12	0.56	0.08
220.	0	0	0	0.00	0.00	0.00	0.00
230.	1	1562	0	2.77	0.00	0.41	0.00
240.	2	1547	18	2.61	0.23	0.77	0.16

NUMBER OF PARTICLES = 285
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC1516
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	1	1653	0	2.57	0.00	0.64	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	1	1853	0	2.60	0.00	0.14	0.00
100.	4	1792	180	2.44	0.29	0.39	0.32
110.	2	1678	22	2.49	0.12	0.77	0.92
120.	7	1829	114	2.41	0.17	0.98	0.35
130.	12	1791	58	2.49	0.11	0.88	0.24
140.	24	1751	79	2.46	0.09	0.96	0.24
150.	35	1743	66	2.47	0.05	0.82	0.18
160.	45	1763	72	2.47	0.09	0.82	0.25
170.	42	1753	79	2.46	0.10	0.78	0.20
180.	37	1774	64	2.48	0.04	0.76	0.20
190.	17	1707	97	2.42	0.11	0.74	0.28
200.	13	1749	47	2.48	0.06	0.69	0.14
210.	10	1727	74	2.35	0.30	0.70	0.23
220.	4	1808	44	2.48	0.08	0.67	0.27
230.	4	1778	69	2.49	0.02	0.51	0.08
240.	1	1465	0	2.16	0.00	0.54	0.00

NUMBER OF PARTICLES = 259
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1516
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.10 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	1	2178	0	2.38	0.00	1.48	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	0	0	0	0.00	0.00	0.00	0.00
100.	3	1685	100	2.74	0.02	0.39	0.23
110.	5	1638	45	2.75	0.03	0.45	0.17
120.	5	1792	127	2.71	0.08	0.72	0.30
130.	12	1788	120	2.57	0.31	0.83	0.32
140.	30	1712	81	2.66	0.05	0.84	0.21
150.	46	1702	85	2.64	0.07	0.80	0.23
160.	39	1714	73	2.66	0.05	0.83	0.19
170.	42	1696	78	2.65	0.05	0.71	0.17
180.	35	1709	84	2.64	0.06	0.68	0.22
190.	20	1705	86	2.63	0.05	0.68	0.14
200.	13	1673	47	2.63	0.05	0.62	0.18
210.	7	1692	50	2.60	0.10	0.85	0.27
220.	5	1695	32	2.60	0.13	0.73	0.23
230.	2	1675	36	2.64	0.01	0.64	0.04
240.	1	1753	0	2.68	0.00	0.49	0.00

NUMBER OF PARTICLES = 266
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1516
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	2	1518	32	2.95	0.02	0.25	0.01
100.	2	1554	17	2.98	0.03	0.25	0.25
110.	1	1527	0	2.86	0.00	0.56	0.00
120.	5	1650	151	2.85	0.11	0.79	0.46
130.	11	1651	124	2.74	0.34	0.81	0.22
140.	31	1655	98	2.85	0.06	0.89	0.16
150.	37	1641	103	2.83	0.07	0.78	0.17
160.	52	1635	90	2.83	0.07	0.78	0.18
170.	42	1651	88	2.84	0.05	0.75	0.17
180.	37	1623	84	2.82	0.09	0.72	0.16
190.	20	1647	74	2.84	0.08	0.70	0.28
200.	19	1657	84	2.75	0.26	0.68	0.21
210.	5	1614	10	2.77	0.12	0.71	0.24
220.	4	1601	3	2.75	0.07	0.57	0.16
230.	1	1632	0	2.80	0.00	0.53	0.00
240.	3	1570	16	2.78	0.05	0.63	0.06

NUMBER OF PARTICLES = 272
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**KINETIC ANALYSIS
AND COMBUSTION PARAMETERS**

Data and Analysis Compilation
for PSOC-1516, Lower Kittanning Coal

Summary of Combustion Parameters for PSOC-1516D			
Char oxidation rate parameters $q = A \exp(-E/RT_p) P^n$	A	10.5	gm-C / cm ² -s-atm ⁿ
	E	20.5	kcal / mole
	n	0.5 *	
Product ratio parameters $CO/CO_2 = A_c \exp(-E_c/RT_p)$	A _c	no carbon dioxide production	
	E _c		
Burning mode parameter $\rho/\rho_o = (m/m_o)^\alpha$ $d/d_o = (m/m_o)^{(1-\alpha)/3}$			
	α	0.0	
Char structural parameters $\omega = d_o / d_c$ (linear swelling factor) $\rho_{c,o} = m_c/V_c$ at $z = 6.5$ cm (Initial char particle carbon density)	ω	1.27	
	$\rho_{c,o}$	0.48	gm / cm ³
As an example, this parameter set yields a combustion rate, q , of 0.0031 gm/sq.cm-s for a 100 μ m particle in a gas with $T_g = 1600$ K containing 6 mole-% oxygen * This particular parameter should be regarded as empirical parameters useful for the prediction of burning rates. It does not necessarily have fundamental significance and /or is not necessarily unique for this data set.

Measured Carbon Conversions in the CCL
for PSOC-1516D

**CALCULATIONS OF THE COAL CHAR REACTIVITY INDEX, τ_{50} ,
FOR VARIOUS ENVIRONMENTS
PRESENT IN PULVERIZED-COAL COMBUSTION SYSTEMS**

Data and Analysis Compilation
for PSOC-1516, Lower Kittanning Coal

Compilation of Data and Kinetic Analyses for

Smith-Roland Sub-bituminous Coal
(Wyoming, SubC)

PSOC-1520D

TABLE OF CONTENTS

- **Sample history, geologic information and chemical analysis of bulk, raw coal**
- **Chemical analysis of size-fractionated raw coal and partially reacted chars**
- **Time resolved measurements of the partitioning of elemental coal constituents between the gas and solid phases**
- **Mode of particle burning**
- **Statistical analyses of elemental composition measurements and derived quantities**
- **Optical measurements of single-particle temperature distributions**
- **Optical measurements of single-particle sizes, temperatures, and velocities**
- **Kinetic analysis and combustion parameters**
- **Calculations of the coal char reactivity index, τ_{50} , for various environments present in pulverized-coal combustion systems**

**SAMPLE HISTORY, GEOLOGIC INFORMATION AND
CHEMICAL ANALYSIS OF BULK, RAW COAL**

Data and Analysis Compilation
for PSOC-1520, Smith-Roland Coal

* PENN STATE COAL DATA BASE *

PSOC-1520
5/30/92
PAGE 1

SAMPLE INFORMATION

PSU NUMBER
SEAM NAME
ALTERNATE SEAM NAME
APPARENT RANK

PSOC-1520
SMITH-ROLAND
SYODAK
SUBBIT C

SAMPLE LOCATION

COUNTRY
STATE

USA
WYOMING

COUNTY
TOWNSHIP
CITY

CAMPBELL

COAL PROVINCE
REGION
MAP REFERENCE
LATITUDE
LONGITUDE
QUADRANGLE

GILLETTE
NORTHERN GREAT PLAINS
FORT UNION

44D 17 M 5 S
105 D 23M 25S
GILLETTE EAST (7.5')

SAMPLE HISTORY

SAMPLING DATE & AGENCY
SAMPLE RESERVE
SAMPLE TYPE
ADDITIONAL INFORMATION

7/18/86, PSU
998 LB.
RUN OF MINE

MINE INFORMATION

MINE NAME
RESERVES
ANNUAL PRODUCTION

WYODAK

LIFE EXPECTANCY
MINING METHOD

30 YEARS
STRIP

SEAM INFORMATION

AGE OF SEAM
GROUP
FORMATION
SEAM THICKNESS

PALEO.

FORT UNION

ANALYSIS LOG

<u>ANALYSIS</u>	<u>PERFORMED BY</u>	<u>DATE</u>
A.R. MOIST		9/25/86
EQ. MOIST		9/25/86
PROXIMATE		9/25/86
ULTIMATE		9/25/86
SULFUR FORMS		9/25/86
FSI		9/9/86
PLASTOMETER		
DIRECT MM		
GRAY-KING		

* PENN STATE COAL DATA BASE *

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5/30/92
PAGE 2

SAMPLE INFORMATION

PSU NUMBER
SEAM NAME
ALTERNATE SEAM NAME
APPARENT RANK

PSOC-1520
SMITH-ROLAND
SYODAK
SUBBIT C

SAMPLE LOCATION

COUNTRY
STATE

USA
WYOMING

CHEMICAL DATA

PROXIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF(PARR)
% MOISTURE	26.69			
% ASH	9.08	12.38		
% VOLATILE	40.13	54.74	62.47	61.96
% FIXED CARBON	24.10	32.88	37.53	38.04

% EQUILIBRIUM MOISTURE = 26.26
MM-FREE = 29.29

ULTIMATE ANALYSIS	AS REC'D	DRY	DAF	DMMF (PARR)
% ASH	9.08	12.38		(14.04 % MM)
% CARBON	47.39	64.65	73.78	75.21
% HYDROGEN	(*)1.78	2.43	2.77	2.83
% NITROGEN	0.71	0.97	1.11	1.13
% TOTAL SULFUR	0.89	1.21	1.38	
% OXYGEN(DIFF)	(*)13.46	18.36	20.95	20.84

(*)-EXCLUDES MOISTURE

ELEMENTAL ANALYSIS	DRY	DMMF(MOD.P)	DMMF (DIR.)
		(14.03%MM)	(%MM)
% CARBON	64.59	75.13	
% HYDROGEN	2.27	2.64	
% NITROGEN	0.97	1.13	
% ORGANIC SULFUR	1.15	1.34	
% MINERAL MATTER	14.03	19.76	
(INCL. 0.09% FES2)			

SULFUR FORMS	% PYRITIC	% SULFATIC	% ORGANIC	% TOTAL
DRY	0.05	0.01	1.15	1.21
DAF	0.06	0.01	1.31	1.38

DRY & CHLORINE = 0.03 DRY % CO2 = 0.21
MOTT-SPOONER DIFFERENCE = 1789.

CALORIFIC VALUE	DRY	AS REC'D MOIST.	EQUIL. MOIST.
(GROSS. BTU/LB)			
MM-CONTINING	11291.	8277.	8326.
MM-FREE (PARR)	13064.	9177.	9237.
MM-FREE (MOD. P)	13130.	9224.	9284.
NET CV. DMMF BTU/LB	12868.		

ATOM RATIOS (DMMF)	PARR	MOD.PARR	DIRECT
ATOMIC H/C	0.4515	0.4221	
ATOMIC O/C	0.2080	0.1975	

* PENN STATE COAL DATA BASE *

PSOC-1520
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SAMPLE INFORMATION

PSU NUMBER
SEAM NAME
ALTERNATE SEAM NAME
APPARENT RANK

PSOC-1520
SMITH-ROLAND
SYODAK
SUBBIT C

SAMPLE LOCATION

COUNTRY
STATE

USA
WYOMING

RANK CALCULATIONS

APPARENT RANK (AS REC'D MOIST.)

SUBBIT C

INTERNATIONAL RANK:

ASTM RANK (EQUIL. MOIST.)

SUBBIT C

AS REC'D MOIST.
EQUIL. MOIST.

REFLECTANCE RANK CATEGORY

REPORTED RANK:

PETROGRAPHIC DATA

NO PETROGRAPHIC DATA THIS SAMPLE

CAKING AND MECHANICAL PROPERTIES

GIESELER COAL PLASTOMETER:

GRAY-KING COKE TYPE

INIT. SOFTENING TEMP

HARDGROVE GRINDABILITY

TEMP. MAX. FLUIDITY

FREE SWELLING INDEX

0.0

SOLIDIFICATION TEMP.

VICKERS HARDNESS NUMBER

FLUID TEMP. RANGE

MAXIMUM FLUIDITY

WASHABILITY DATA AVAILABLE? NO

* PENN STATE COAL DATA BASE *

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SAMPLE INFORMATION

PSU NUMBER
SEAM NAME
ALTERNATE SEAM NAME
APPARENT RANK

PSOC-1520
SMITH-ROLAND
SYODAK
SUBBIT C

SAMPLE LOCATION

COUNTRY
STATE

USA
WYOMING

MAJOR ELEMENT ANALYSIS

% HTA = 11.32

	SI02	AL203	TI02	FE203	MG0	CA0	NA20	K20	P205	S03
OXIDE % OF HTA	33.7	18.0	0.98	8.61	3.47	15.5	0.96	0.59	0.54	17.4
	SI	AL	TI	FE	MG	CA	NA	K	P	S
ELEMENT % OF TOTAL DRY COAL	1.8	1.1	0.07	0.68	0.24	1.3	0.08	0.06	0.03	1.2

% HTA = 11.32

TRACE ELEMENT ANALYSIS

627

	PPM HTA	PPM TOTAL COAL		PPM HTA	PPM TOTAL COAL		PPM HTA	PPM TOTAL COAL	<u>VOLATILES</u>	PPM TOTAL COAL
AG			GE			SN			AS	
B			LA			SR	2110.	239.	BR	
BA	3060.	346.	LI			TH			CD	
BE	5.0	0.6	MN	250.	28.	U			CL	300.
BI			MO			V	240.	27.	F	
CE			NB			Y			HG	
CO			NI	130.	15.	YB			SB	
CR	110.	12.	PB			AN	180.	20.	SE	
CU	150.	17.	RB	35.	4.	ZR	190.	22.		

* PENN STATE COAL DATA BASE *

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GA

SC

SAMPLE INFORMATION

SAMPLE LOCATION

PSU NUMBER

PSOC-1520

COUNTRY

USA

SEAM NAME

SMITH-ROLAND

STATE

WYOMING

ALTERNATE SEAM NAME

SYODAK

APPARENT RANK

SUBBIT C

ASH FUSION TEMPERATURES (ALL TEMPERATURES IN DEGREES F)

REDUCING

OXIDIZING

INITIAL DEFORMATION

2180.

2290.

SOFTENING

2220.

2340.

HEMISPHERICAL

2255.

2395.

FLUID

2320.

2460.

**CHEMICAL ANALYSES OF SIZE-FRACTIONATED RAW COAL
AND PARTIALLY REACTED CHARS**

Data and Analysis Compilation
for PSOC-1520, Smith-Roland Coal

**Organic Elemental Analysis and Percent Ash of Smith Roland Coal
and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	61.55	4.84	23.78	0.91	1.63	9.32
6.4	72.46	1.75	8.20	1.16	0.63	20.6
6.4	71.33	1.73	11.54	1.15	1.04	18.6
12.7	67.49	2.32	14.34	1.00	1.32	20.5
19.1	61.84	0.64	7.68	0.75	2.99	35.8
25.4	51.73	1.06	10.59	0.83	2.70	42.2
25.4	44.09	0.60	7.40	0.72	2.92	48.5

12 mole-% Oxygen Environment*

Hgt (cm)	%-C	%-H	%-O	%-N	%-S	%-Ash
0.0	62.81	4.9	24.52	0.93	1.58	10.3
6.4	73.51	0.76	7.40	0.91	1.72	24.1
12.7	60.78	0.36	6.65	0.61	2.36	37.2
19.1	32.22	0.33	4.51	0.46	2.57	63.0
25.4	--	--	--	--	--	--

* Data taken in August 1989

**Ash Content of Smith Roland Coal and its
Partially Reacted Chars**

Initial particle size range: 106 - 125 μ m

6 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	2.12	1.38	0.080	1.68	1.70	0.385	0.027	0.124
6.4	5.46	3.59	0.199	2.76	3.05	0.701	0.080	0.155
6.4	5.04	3.15	0.185	1.86	3.22	0.742	0.077	0.16
12.7	5.36	3.37	0.191	2.46	3.23	0.761	0.074	0.142
19.1	10.08	6.32	0.362	2.69	6.31	1.46	0.129	0.247
25.4	13.9	8.14	0.444	2.80	6.65	1.59	0.196	0.395
25.4	16.3	9.20	0.506	3.09	7.65	1.97	0.202	0.457

12 mole-% Oxygen Environment*

Hgt (cm)	% SiO ₂	% Al ₂ O ₃	% TiO ₂	% Fe ₂ O ₃	% CaO	% MgO	% K ₂ O	% Na ₂ O
0.0	1.89	1.18	0.078	1.08	1.86	0.43	0.017	0.145
6.4	6.48	3.96	0.238	1.57	4.51	1.13	0.075	0.211
12.7	10.2	6.42	0.410	2.26	7.64	1.77	0.119	0.528
19.1	25.5	13.5	0.732	4.21	7.99	2.10	0.353	0.530
25.4	--	--	--	--	--	--	--	--

* Data taken in August 1989

**TIME RESOLVED MEASUREMENTS OF THE
PARTITIONING OF ELEMENTAL COAL CONSTITUENTS
BETWEEN THE GAS AND SOLID PHASES**

Data and Analysis Compilation
for PSOC-1520, Smith-Roland Coal

MODE OF PARTICLE BURNING

Data and Analysis Compilation
for PSOC-1520, Smith-Roland Coal

**Fractional Mass Remaining and Apparent Density
of Smith Roland Coal and its Partially Reacted Chars**

Initial particle size range: 106 - 125 μm

6 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.42	0.40	0.21	0.14
Fractional burnoff, daf	0.0	0.62	0.64	0.85	0.91
Apparent density, g/cc	1.12	0.72	0.76	0.59	0.56

12 mole-% Oxygen Environment

Sampling height, cm	0.0	6.4	12.7	19.1	25.4
Approximate residence time, ms	0	47	72	95	117
Fractional mass remaining, m/m_0	1.0	0.33	0.18	0.08	--
Fractional burnoff, daf	0.0	0.72	0.87	0.97	--
Apparent density, g/cc	1.12	0.67	0.51	0.69	--

**STATISTICAL ANALYSES
OF ELEMENTAL COMPOSITION MEASUREMENTS
AND DERIVED QUANTITIES**

- **Raw Coal Composition**
- **Overall Combustion Conversion vs. Residence Time**
- **Elemental Partitioning between Gas and Solid Phases**

Data and Analysis Compilation
for PSOC-1520, Smith-Roland Coal

Average Initial Mass Percents and Statistics						
Smith Roland subbituminous 106-125 μm				PSOC-1520d 6% O ₂ GC 133		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95\%$	$\delta \pm 99\%$
SiO ₂	2.005	0.163	2	0.081	1.461	7.320
Al ₂ O ₃	1.280	0.141	2	0.110	1.271	6.366
TiO ₂	0.079	0.002	2	0.025	0.018	0.089
Fe ₂ O ₃	1.380	0.424	2	0.307	3.812	19.097
CaO	1.780	0.113	2	0.064	1.016	5.092
Na ₂ O	0.135	0.015	2	0.110	0.133	0.668
K ₂ O	0.022	0.007	2	0.321	0.064	0.318
MgO	0.408	0.032	2	0.078	0.286	1.432
C	63.057	1.644	3	0.026	4.084	9.420
H	4.780	0.159	3	0.033	0.394	0.910
O	21.757	4.162	3	0.191	10.339	23.848
N	0.913	0.023	3	0.025	0.057	0.131
S	1.520	0.149	3	0.098	0.371	0.856
Ash-s	10.095	0.658	2	0.065	5.908	29.600
Ash-l	10.330	1.025	3	0.099	2.547	5.875

Residual Total Mass (m/m ₀) as a Function of Residence Time						
Smith Roland subbituminous 106-125 μm				PSOC-1520d 6% O ₂ GC 133		
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.52	0.38	0.38	0.41	0.53	0.53
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Residual Total Mass (m/m0) with Statistics						
Smith Roland subbituminous 106-125 μm				PSOC-1520d 6% O2 GC 133		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	6	1.00	0.000	0.000
47	0.39	0.018	6	0.35	0.019	0.029
0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!

Residual Elemental Mass as a Function of Residence Time						
Smith Roland subbituminous 106-125 μm				PSOC-1520d 6% O2 GC 133		
	SiO2	TiO2	Al2O3	Fe2O3	CaO	Na2O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.02	0.95	1.03	0.65	0.69	0.46
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

	K2O	MgO	Ash-l	Ash-s	S	N
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.40	0.69	0.74	0.74	0.21	0.49
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics						
Smith Roland subbituminous 106-125 μm				PSOC-1520d 6% O2 GC 133		
SiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.095	2	0.095	0.856	4.289
47	-0.024	0.108	3	0.105	0.830	4.157
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Al2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.121	2	0.121	1.090	5.459
47	-0.030	0.133	2	0.129	1.073	5.377
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
TiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.050	0.080	3	0.084	0.193	0.445
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Smith Roland subbituminous 106-125 μm				PSOC-1520d 6% O2 GC 133		
Fe2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.311	2	0.311	2.798	14.020
47	0.345	0.206	2	0.315	1.814	9.088
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
CaO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.081	2	0.081	0.727	3.640
47	0.311	0.064	3	0.093	0.472	2.364
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Na2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.121	2	0.121	1.089	5.455
47	0.542	0.059	2	0.129	0.477	2.390
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Smith Roland subbituminous 106-125 μm				PSOC-1520d 6% O2 GC 133		
K2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.325	2	0.325	2.922	14.641
47	-0.395	0.458	2	0.328	4.041	20.246
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
MgO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.093	2	0.093	0.833	4.174
47	0.308	0.071	3	0.103	0.545	2.733
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
C						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.554	0.037	4	0.084	0.082	0.189
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Smith Roland subbituminous 106-125 μm				PSOC-1520d 6% O2 GC 133		
H						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.858	0.012	4	0.084	0.026	0.060
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
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0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.198	3	0.198	0.491	1.133
47	0.823	0.036	3	0.203	0.087	0.201
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \text{ +/- } 95 \%$	$\delta \text{ +/- } 99 \%$
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.505	0.042	4	0.084	0.091	0.209
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
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0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Smith Roland subbituminous 106-125 μm				PSOC-1520d 6% O2 GC 133		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.110	3	0.110	0.274	0.632
47	0.785	0.026	3	0.119	0.059	0.137
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.082	2	0.082	0.738	3.696
47	0.258	0.070	3	0.094	0.516	2.586
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Ash-l						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.111	3	0.111	0.276	0.637
47	0.258	0.089	3	0.120	0.207	0.477
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Average Initial Mass Percents and Statistics						
Smith Roland subbituminous 106-125 μm				PSOC-1520d 12% O ₂		
	Mean (mf)	σ	n	σ/μ	$\delta \pm 95 \%$	$\delta \pm 99 \%$
SiO ₂	2.005	0.163	2	0.081	1.461	7.320
Al ₂ O ₃	1.280	0.141	2	0.110	1.271	6.366
TiO ₂	0.079	0.002	2	0.025	0.018	0.089
Fe ₂ O ₃	1.380	0.424	2	0.307	3.812	19.097
CaO	1.780	0.113	2	0.064	1.016	5.092
Na ₂ O	0.135	0.015	2	0.110	0.133	0.668
K ₂ O	0.022	0.007	2	0.321	0.064	0.318
MgO	0.408	0.032	2	0.078	0.286	1.432
Σ Oxides	7.088					
C	63.057	1.644	3	0.026	4.084	9.420
H	4.780	0.159	3	0.033	0.394	0.910
O	21.757	4.162	3	0.191	10.339	23.848
N	0.913	0.023	3	0.025	0.057	0.131
S	1.520	0.149	3	0.098	0.371	0.856
Ash-s	10.095	0.658	2	0.065	5.908	29.600
Ash-l	10.330	1.025	3	0.099	2.547	5.875

Residual Total Mass (m/m ₀) as a Function of Residence Time						
Smith Roland subbituminous 106-125 μm				PSOC-1520d 12% O ₂		
	mass bal.	SiO ₂	Al ₂ O ₃	TiO ₂	Ash-s	Ash-l
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	0.35	0.31	0.32	0.33	0.44	0.43
72	0.15	0.20	0.20	0.19	0.27	0.28
95	0.05	0.08	0.09	0.11	0.16	0.16
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Residual Total Mass (m/m0) with Statistics						
Smith Roland subbitumous 106-125 μm				PSOC-1520d 12% O2		
	Mean (mf)	σ	n	Mean (daf)	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	1.00	0.000	8	1.00	0.000	0.000
47	0.33	0.019	4	0.28	0.030	0.055
72	0.18	0.025	4	0.13	0.039	0.072
95	0.08	0.025	4	0.03	0.040	0.074
117	#DIV/0!	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!

Residual Elemental Mass as a Function of Residence Time						
Smith Roland subbitumous 106-125 μm				PSOC-1520d 12% O2		
	SiO2	TiO2	Al2O3	Fe2O3	CaO	Na2O
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.07	0.99	1.02	0.38	0.84	0.52
72	0.94	0.95	0.92	0.30	0.79	0.72
95	1.05	0.77	0.87	0.25	0.37	0.33
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	K2O	C	H	O	N	S
t (ms)						
0	1.00	1.00	1.00	1.00	1.00	1.00
47	1.12	0.38	0.05	0.11	0.33	0.37
72	0.99	0.18	0.01	0.06	0.12	0.29
95	1.33	0.04	0.01	0.02	0.04	0.14
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Smith Roland subbitumous 106-125 μm				PSOC-1520d 12% O2		
CaO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.081	2	0.081	0.727	3.640
47	0.165	0.083	3	0.099	0.643	3.220
72	0.211	0.124	3	0.157	0.286	0.661
95	0.629	0.117	4	0.316	0.256	0.591
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Na2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.121	2	0.121	1.089	5.455
47	0.483	0.069	2	0.134	0.572	2.868
72	0.278	0.131	3	0.181	0.319	0.737
95	0.674	0.107	4	0.328	0.238	0.550
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
K2O						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.325	2	0.325	2.922	14.641
47	-0.124	0.371	2	0.330	3.286	16.461
72	0.005	0.350	2	0.352	2.939	14.723
95	-0.327	0.592	3	0.446	4.387	21.981
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
MgO						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.093	2	0.093	0.833	4.174
47	0.086	0.099	3	0.109	0.791	3.965
72	0.201	0.131	3	0.163	0.307	0.707
95	0.574	0.136	4	0.319	0.299	0.689
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics						
Smith Roland subbitumous 106-125 μm				PSOC-1520d 12% O2		
SiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.095	2	0.095	0.856	4.289
47	-0.065	0.118	3	0.111	0.945	4.734
72	0.064	0.154	3	0.165	0.364	0.839
95	-0.052	0.336	4	0.320	0.740	1.706
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Al2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.121	2	0.121	1.090	5.459
47	-0.020	0.137	2	0.134	1.130	5.659
72	0.078	0.167	3	0.181	0.408	0.942
95	0.128	0.286	4	0.328	0.638	1.472
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
TiO2						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.071	2	0.071	0.635	3.183
47	0.007	0.090	3	0.091	0.686	3.435
72	0.046	0.145	4	0.152	0.331	0.763
95	0.234	0.240	4	0.313	0.523	1.206
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Fe2O3						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.311	2	0.311	2.798	14.020
47	0.625	0.119	2	0.317	1.050	5.261
72	0.699	0.102	2	0.339	0.853	4.276
95	0.748	0.110	3	0.436	0.810	4.056
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Smith Roland subbitumous 106-125 μm				PSOC-1520d 12% O2		
C						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.616	0.035	3	0.091	0.081	0.188
72	0.823	0.027	4	0.152	0.060	0.138
95	0.958	0.013	4	0.313	0.029	0.066
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
H						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.948	0.005	3	0.091	0.011	0.025
72	0.986	0.002	4	0.152	0.005	0.011
95	0.994	0.002	4	0.313	0.004	0.009
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
O						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.198	3	0.198	0.491	1.133
47	0.888	0.023	3	0.206	0.057	0.131
72	0.944	0.013	3	0.239	0.032	0.073
95	0.983	0.006	4	0.363	0.014	0.032
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
N						
	Mean (μ)	σ	n	σ/(1-μ)	δ +/- 95 %	δ +/- 99 %
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.673	0.030	3	0.091	0.069	0.160
72	0.877	0.019	4	0.152	0.041	0.095
95	0.958	0.013	4	0.313	0.028	0.065
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Elemental Mass Release (Normalized) and Statistics (con't)						
Smith Roland subbitumous 106-125 μm				PSOC-1520d 12% O2		
S						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.110	3	0.110	0.274	0.632
47	0.627	0.046	3	0.124	0.111	0.256
72	0.714	0.050	4	0.174	0.113	0.260
95	0.860	0.045	4	0.324	0.099	0.228
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Ash-l						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.111	3	0.111	0.276	0.637
47	0.231	0.096	3	0.125	0.231	0.532
72	0.338	0.116	4	0.175	0.262	0.605
95	0.496	0.164	4	0.325	0.358	0.825
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Ash-s						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.082	2	0.082	0.738	3.696
47	0.243	0.076	3	0.100	0.590	2.955
72	0.327	0.106	3	0.158	0.246	0.566
95	0.488	0.162	4	0.316	0.354	0.816
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
N						
	Mean (μ)	σ	n	$\sigma/(1-\mu)$	$\delta \pm 95 \%$	$\delta \pm 99 \%$
t (ms)						
0	0.000	0.071	3	0.071	0.176	0.405
47	0.673	0.030	3	0.091	0.069	0.160
72	0.877	0.019	4	0.152	0.041	0.095
95	0.958	0.013	4	0.313	0.028	0.065
117	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE TEMPERATURE DISTRIBUTIONS**

Data and Analysis Compilation
for PSOC-1520, Smith-Roland Coal

SMITH ROLAND COAL CHAR

COAL TYPE: Smith Roland, psoc1520, 10kgc133. 7-09-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1437.9	0.0	2.25	0.00	0.946	0.000
1500.0	2	1485.2	13.4	2.33	0.01	0.877	0.043
1550.0	1	1530.2	0.0	2.38	0.00	1.003	0.000
1600.0	2	1584.4	7.3	2.40	0.06	0.456	0.026
1650.0	5	1651.4	10.6	2.49	0.06	0.698	0.285
1700.0	71	1713.0	11.4	2.56	0.03	0.660	0.194
1750.0	159	1739.6	9.7	2.58	0.03	0.574	0.154
1800.0	3	1783.3	7.6	2.57	0.05	0.414	0.089
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 244
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Smith Roland, psoc1520, 15kgc133. 7-09-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	1	1534.7	0.0	2.55	0.00	0.456	0.000
1600.0	1	1606.3	0.0	2.68	0.00	0.539	0.000
1650.0	4	1665.8	1.9	2.77	0.02	0.717	0.124
1700.0	114	1712.8	10.9	2.77	0.03	0.527	0.148
1750.0	146	1741.2	12.8	2.78	0.11	0.428	0.116
1800.0	8	1779.8	4.4	2.81	0.04	0.294	0.051
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 274
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Smith Roland, psoc1520, 20kgc133. 7-09-90
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1550.0	6	1558.0	14.1	2.89	0.05	0.302	0.148
1600.0	6	1603.8	17.4	2.93	0.03	0.329	0.093
1650.0	17	1657.6	11.6	2.95	0.07	0.530	0.196
1700.0	117	1707.3	12.0	2.97	0.04	0.465	0.134
1750.0	136	1748.0	13.8	3.00	0.05	0.319	0.125
1800.0	8	1789.0	7.4	3.01	0.07	0.169	0.085
1850.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1900.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1950.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 290
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Smith Roland, psoc1520, 10kgc142. 7-09-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1652.0 K
 SAMPLING HEIGHT: 12.70 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	1	1510.3	0.0	2.38	0.00	0.732	0.000
1550.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1600.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1650.0	1	1674.0	0.0	2.57	0.00	0.427	0.000
1700.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1750.0	4	1754.7	0.5	2.55	0.00	0.707	0.006
1800.0	3	1819.6	1.2	2.05	0.59	0.707	0.392
1850.0	9	1850.9	15.6	2.56	0.02	0.669	0.261
1900.0	100	1907.5	12.4	2.56	0.13	0.681	0.190
1950.0	102	1942.9	13.3	2.60	0.03	0.505	0.180
2000.0	16	1988.0	11.0	2.61	0.03	0.475	0.366
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 236
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Smith Roland, psoc1520, 15kgc142. 7-09-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.05 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1500.0	5	1498.8	11.3	2.60	0.09	1.340	0.546
1550.0	6	1547.0	14.4	2.67	0.06	0.741	0.128
1600.0	5	1611.8	13.8	2.72	0.04	0.434	0.174
1650.0	10	1652.8	9.9	2.76	0.03	0.765	0.602
1700.0	14	1694.9	15.3	2.74	0.04	0.853	0.689
1750.0	32	1751.7	13.3	2.76	0.05	1.026	0.809
1800.0	67	1805.0	12.2	2.77	0.14	0.887	1.235
1850.0	68	1847.8	12.9	2.78	0.17	0.508	0.312
1900.0	11	1882.0	6.6	2.79	0.03	0.531	1.110
1950.0	1	1929.2	0.0	2.68	0.00	0.169	0.000
2000.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2050.0	1	2029.6	0.0	2.71	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 220
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: Smith Roland, psoc1520, 20kgc142. 7-09-90
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

TEMP (K)	NUM	TEMP (K)	rms (T) (K)	VEL (m/s)	rms (V) (m/s)	EMISS	rms (E)
1300.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1350.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1400.0	0	0.0	0.0	0.00	0.00	0.000	0.000
1450.0	1	1443.3	0.0	2.96	0.00	0.062	0.000
1500.0	5	1504.3	6.1	2.79	0.02	0.552	0.150
1550.0	12	1557.4	12.8	2.94	0.07	0.163	0.136
1600.0	16	1599.9	16.0	2.92	0.10	0.152	0.170
1650.0	18	1649.6	13.5	2.92	0.08	0.152	0.124
1700.0	21	1692.4	12.3	2.84	0.27	0.145	0.176
1750.0	5	1749.5	15.7	3.00	0.04	0.202	0.103
1800.0	9	1800.6	13.9	2.75	0.34	0.626	0.391
1850.0	17	1850.0	14.5	2.62	0.57	0.650	0.497
1900.0	17	1901.9	10.9	2.98	0.06	0.408	0.149
1950.0	25	1950.5	11.4	2.99	0.09	0.159	0.091
2000.0	5	1989.1	13.9	2.57	0.68	0.287	0.288
2050.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2100.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2150.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2200.0	0	0.0	0.0	0.00	0.00	0.000	0.000
2250.0	0	0.0	0.0	0.00	0.00	0.000	0.000

NUMBER OF PARTICLES = 151
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**OPTICAL MEASUREMENTS OF
SINGLE-PARTICLE SIZES, TEMPERATURES, AND VELOCITIES**

Data and Analysis Compilation
for PSOC-1520, Smith-Roland Coal

COAL TYPE: PSOC-1520
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1642.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	1	1742	0	2.57	0.00	1.01	0.00
100.	9	1740	22	2.58	0.02	0.79	0.36
110.	12	1731	29	2.58	0.03	0.83	0.16
120.	48	1727	26	2.58	0.04	0.66	0.15
130.	66	1725	48	2.56	0.05	0.63	0.17
140.	63	1724	36	2.57	0.04	0.56	0.11
150.	31	1720	34	2.55	0.06	0.48	0.08
160.	7	1724	12	2.55	0.05	0.49	0.07
170.	5	1682	94	2.54	0.10	0.49	0.20
180.	2	1732	1	2.55	0.00	0.33	0.05
190.	0	0	0	0.00	0.00	0.00	0.00
200.	0	0	0	0.00	0.00	0.00	0.00
210.	0	0	0	0.00	0.00	0.00	0.00
220.	0	0	0	0.00	0.00	0.00	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 244
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1520
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1593.0 K
 SAMPLING HEIGHT: 19.10 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	0	0	0	0.00	0.00	0.00	0.00
70.	0	0	0	0.00	0.00	0.00	0.00
80.	0	0	0	0.00	0.00	0.00	0.00
90.	3	1744	38	2.78	0.01	0.55	0.21
100.	15	1729	28	2.79	0.03	0.58	0.21
110.	34	1741	20	2.79	0.02	0.51	0.17
120.	48	1734	28	2.78	0.03	0.50	0.15
130.	76	1723	30	2.78	0.04	0.49	0.12
140.	51	1725	16	2.77	0.03	0.43	0.11
150.	33	1720	16	2.78	0.02	0.41	0.09
160.	11	1714	8	2.78	0.03	0.37	0.08
170.	1	1756	0	2.71	0.00	0.34	0.00
180.	2	1719	33	2.14	0.93	0.36	0.20
190.	0	0	0	0.00	0.00	0.00	0.00
200.	0	0	0	0.00	0.00	0.00	0.00
210.	0	0	0	0.00	0.00	0.00	0.00
220.	0	0	0	0.00	0.00	0.00	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 274
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1520
 OXYGEN CONTENT OF GAS: 6.0 mole-%
 GAS TEMPERATURE: 1536.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	1	1768	0	3.03	0.00	0.48	0.00
70.	5	1724	46	2.97	0.03	0.61	0.36
80.	6	1721	69	2.97	0.07	0.48	0.25
90.	22	1736	33	2.97	0.05	0.36	0.14
100.	47	1736	34	2.99	0.05	0.38	0.15
110.	61	1734	39	2.99	0.05	0.32	0.12
120.	67	1714	41	2.99	0.05	0.41	0.16
130.	46	1705	34	2.97	0.04	0.41	0.11
140.	17	1691	42	2.95	0.07	0.41	0.15
150.	12	1698	39	2.97	0.05	0.38	0.11
160.	2	1684	9	2.98	0.07	0.43	0.08
170.	2	1708	108	2.87	0.09	0.39	0.53
180.	1	1717	0	2.96	0.00	0.48	0.00
190.	0	0	0	0.00	0.00	0.00	0.00
200.	0	0	0	0.00	0.00	0.00	0.00
210.	0	0	0	0.00	0.00	0.00	0.00
220.	1	1655	0	2.83	0.00	0.00	0.00
230.	0	0	0	0.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 290
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1520
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1645.0 K
 SAMPLING HEIGHT: 12.70 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	0	0	0	0.00	0.00	0.00	0.00
60.	2	1976	3	2.64	0.01	1.32	0.21
70.	1	1950	0	2.60	0.00	1.55	0.00
80.	5	1979	21	2.59	0.02	0.84	0.03
90.	14	1914	14	2.55	0.04	0.81	0.20
100.	20	1943	22	2.60	0.01	0.56	0.13
110.	38	1941	25	2.60	0.03	0.49	0.15
120.	60	1914	53	2.59	0.04	0.61	0.19
130.	36	1923	24	2.60	0.03	0.60	0.21
140.	34	1895	71	2.58	0.05	0.60	0.16
150.	12	1881	73	2.56	0.04	0.54	0.25
160.	5	1892	12	2.59	0.01	0.59	0.11
170.	1	1941	0	2.60	0.00	0.18	0.00
180.	0	0	0	0.00	0.00	0.00	0.00
190.	0	0	0	0.00	0.00	0.00	0.00
200.	2	1939	38	2.48	0.17	0.29	0.23
210.	0	0	0	0.00	0.00	0.00	0.00
220.	2	1891	40	2.35	0.36	0.10	0.11
230.	1	1977	0	2.50	0.00	0.19	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 233
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1520
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1591.0 K
 SAMPLING HEIGHT: 19.10 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	1	1857	0	2.74	0.00	0.69	0.00
60.	3	1816	23	2.79	0.01	2.16	0.65
70.	6	1845	47	2.77	0.05	1.24	0.57
80.	2	1868	29	2.82	0.06	0.75	0.70
90.	9	1804	71	2.80	0.02	0.77	0.25
100.	16	1808	58	2.77	0.04	0.76	0.28
110.	25	1756	97	2.77	0.06	0.71	0.55
120.	45	1797	68	2.79	0.04	0.68	0.42
130.	44	1771	92	2.74	0.21	0.72	0.54
140.	21	1776	95	2.78	0.04	0.34	0.22
150.	13	1767	104	2.69	0.31	0.81	0.69
160.	11	1773	91	2.77	0.08	0.71	0.84
170.	4	1777	62	2.81	0.09	0.53	0.67
180.	5	1770	85	2.72	0.06	0.31	0.22
190.	4	1649	93	2.67	0.06	1.52	0.35
200.	0	0	0	0.00	0.00	0.00	0.00
210.	0	0	0	0.00	0.00	0.00	0.00
220.	2	1741	61	2.77	0.08	0.13	0.16
230.	0	0	0	0.00	0.00	0.00	0.00
240.	1	1862	0	2.77	0.00	0.10	0.00

NUMBER OF PARTICLES = 212
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

COAL TYPE: PSOC-1520
 OXYGEN CONTENT OF GAS: 12.0 mole-%
 GAS TEMPERATURE: 1532.0 K
 SAMPLING HEIGHT: 25.40 cm

SIZE (micron)	NUM	TEMP	rms (T) (K)	VEL (K)	rms (V) (m/s)	EMISS (m/s)	rms (E)
50.	2	1669	34	2.88	0.07	0.05	0.01
60.	5	1742	153	2.94	0.06	0.14	0.09
70.	0	0	0	0.00	0.00	0.00	0.00
80.	1	1901	0	2.96	0.00	0.47	0.00
90.	9	1707	151	2.93	0.12	0.33	0.35
100.	18	1805	145	2.97	0.06	0.31	0.18
110.	26	1746	155	2.94	0.11	0.24	0.22
120.	25	1739	149	2.92	0.13	0.22	0.19
130.	21	1767	148	2.96	0.09	0.18	0.22
140.	10	1689	147	2.79	0.38	0.19	0.17
150.	9	1747	153	2.45	0.62	0.48	0.28
160.	5	1865	77	2.96	0.08	0.49	0.44
170.	5	1817	43	2.76	0.47	0.25	0.25
180.	3	1696	26	2.93	0.08	0.36	0.33
190.	0	0	0	0.00	0.00	0.00	0.00
200.	3	1878	61	2.91	0.11	0.05	0.00
210.	1	1702	0	1.78	0.00	0.00	0.00
220.	3	1854	148	2.28	0.70	0.00	0.00
230.	1	1902	0	3.00	0.00	0.00	0.00
240.	0	0	0	0.00	0.00	0.00	0.00

NUMBER OF PARTICLES = 147
 PARTICLES SCREENED BASED ON EMISSIVITIES FROM 0.00 TO 10.00

**KINETIC ANALYSIS
AND COMBUSTION PARAMETERS**

Data and Analysis Compilation
for PSOC-1520, Smith-Roland Coal

Summary of Combustion Parameters for PSOC-1520D		
Char oxidation rate parameters $q = A \exp(-E/RT_p) P^n$	A E n	Chars reacted at their diffusion-limit rates (zone 3) in both 6 and 12 mole-% oxygen
Product ratio parameters $CO/CO_2 = A_c \exp(-E_c/RT_p)$	A _c E _c	no carbon dioxide production
Burning mode parameter $\rho/\rho_o = (m/m_o)^\alpha$ $d/d_o = (m/m_o)^{(1-\alpha)/3}$	α	0.3
Char structural parameters $\omega = \bar{d}(z = 6.4 \text{ cm}) / \bar{d}_{\text{coal}}$ (linear swelling factor) $\rho_{c,o} = m_c/V_c \text{ at } z = 6.5 \text{ cm}$ (Initial char particle carbon density)	ω ρ _{c,o}	0.85 0.62 gm / cm ³
As an example, this parameter set yields a combustion rate, q, of 0.0075 gm/sq.cm-sec for a 100 μm particle in a gas with a temperature of 1600 K containing 6 mole-% oxygen

**CALCULATIONS OF THE COAL CHAR REACTIVITY INDEX, τ_{50} ,
FOR VARIOUS ENVIRONMENTS
PRESENT IN PULVERIZED-COAL COMBUSTION SYSTEMS**

Data and Analysis Compilation
for PSOC-1520, Smith-Roland Coal

12. AN EXAMPLE SET OF OPTICAL DATA FOR PSOC-1451D, PITTSBURGH #8 COAL

On the following pages is a complete listing of the raw optical data taken during combustion experiments in the CCL for PSOC-1451D, Pittsburgh #8 coal. The listing comprises six data files, corresponding to three locations in the reactor (12.7, 19.1 and 25.4 cm above the burner surface) in each of two gas environments (containing 6 and 12 mole-% oxygen), for a total of six files. Each file contains measured values of particle diameter (μm), particle temperature (K), particle velocity (cm/sec), and particle emissivity. The single-particle emissivity measurements are strongly dependent of particle shape, and are calculated from the optical signals only to provide a consistency check on the optical calibrations. These emissivity values are not used in any of the analyses. For kinetic analyses, these optical data were reduced by a statistical sorting routing described in section 6. The reduced data appear in tabular form in table 6.1.

COAL TYPE: psocl451
 OXYGEN CONCENTRATION 6.0 mole-%, GAS TEMPERATURE 1642.0 K
 SAMPLING HEIGHT 12.70 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
124.7	1582.2	243.0	0.54
144.2	1707.3	257.0	0.54
101.9	1745.4	257.0	1.01
122.3	1736.0	257.0	0.95
154.3	1683.1	263.0	0.46
100.8	1735.5	260.0	0.66
127.2	1722.8	255.0	0.77
115.1	1702.4	133.0	0.98
95.3	1707.2	260.0	1.22
84.1	1696.4	257.0	0.95
149.7	1690.5	257.0	0.75
138.9	1742.4	257.0	0.59
130.5	1705.1	260.0	0.57
197.4	1685.4	260.0	0.30
129.6	1572.4	238.0	0.76
88.2	1701.4	260.0	1.50
129.6	1713.2	257.0	0.70
146.4	1689.7	252.0	0.79
114.5	1737.5	260.0	0.57
88.5	1713.3	260.0	1.52
156.7	1642.7	257.0	0.78
224.5	1715.9	257.0	0.17
126.4	1721.5	260.0	0.61
137.6	1667.4	257.0	0.63
114.5	1553.7	236.0	0.74
144.2	1691.4	260.0	0.61
130.9	1724.2	260.0	0.77
132.1	1711.8	260.0	0.86
92.8	1680.7	260.0	1.30
133.8	1733.6	260.0	1.00
188.7	1735.3	255.0	0.37
123.5	1722.3	257.0	0.70
99.5	1704.9	257.0	0.65
93.4	1737.6	255.0	0.96
233.3	1659.4	157.0	0.63
94.7	1746.9	257.0	1.25
165.6	1688.2	260.0	0.43
97.5	1701.0	260.0	1.17
145.5	1719.9	255.0	0.77
146.4	1719.0	260.0	0.57
94.4	1729.8	263.0	0.68
86.1	1728.5	263.0	1.40
147.8	1741.7	257.0	0.65
157.2	1685.0	257.0	0.50
90.3	1716.1	260.0	1.34
97.5	1758.4	257.0	0.98
149.7	1697.9	257.0	0.47

COAL TYPE: psocl451

OXYGEN CONCENTRATION 6.0 mole-%, GAS TEMPERATURE 1642.0 K

SAMPLING HEIGHT 12.70 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
238.9	1707.9	260.0	0.23
77.7	1695.8	257.0	2.07
131.3	1712.5	257.0	0.85
110.4	1704.4	255.0	0.99
130.1	1677.9	255.0	1.43
144.2	1777.5	260.0	0.29
146.0	1707.8	260.0	0.50
111.6	1585.7	245.0	0.53
183.1	1591.5	236.0	0.31
135.5	1698.1	257.0	0.66
109.8	1720.2	257.0	0.95
156.3	1689.2	255.0	0.66
119.2	1710.5	257.0	0.76
146.0	1691.3	260.0	0.43
125.2	1564.6	238.0	0.59
96.6	1700.5	257.0	1.14
140.7	1711.3	260.0	0.40
159.7	1719.0	257.0	0.65
107.0	1725.5	260.0	0.73
148.7	1640.1	250.0	0.58
140.7	1717.5	260.0	0.43
90.0	1689.7	260.0	1.29
103.0	1682.3	263.0	1.14
130.9	1693.5	260.0	0.63
75.2	1865.2	260.0	0.94
173.9	1732.6	257.0	0.29
138.5	1685.3	255.0	0.89
145.1	1696.5	260.0	0.53
111.0	1691.2	260.0	1.00
99.2	1680.8	257.0	1.55
81.1	1739.1	257.0	1.11
209.6	1685.9	257.0	0.31
79.0	1715.3	260.0	1.78
111.6	1722.1	257.0	0.76
151.5	1552.3	238.0	0.64
176.6	1676.5	260.0	0.40
114.5	1708.1	257.0	0.63
98.5	1757.8	265.0	0.74
80.7	1702.5	257.0	1.84
118.0	1704.8	260.0	0.75
104.2	1753.5	260.0	0.94
107.0	1733.6	260.0	0.79
132.1	1697.3	255.0	0.77
86.1	1751.4	260.0	1.09
148.7	1720.3	260.0	0.47
228.5	1722.7	263.0	0.35
141.5	1706.6	260.0	0.38
138.0	1691.7	257.0	0.51

COAL TYPE: psocl45l

OXYGEN CONCENTRATION 6.0 mole-%, GAS TEMPERATURE 1642.0 K

SAMPLING HEIGHT 12.70 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
88.5	1716.4	260.0	1.18
180.3	1687.5	255.0	0.55
149.7	1738.8	260.0	0.23
115.7	1670.8	263.0	0.66
109.3	1677.6	260.0	0.98
101.4	1717.5	263.0	0.92
121.1	1761.8	257.0	0.61
126.0	1764.8	257.0	0.57
112.7	1684.4	263.0	0.91
124.1	1712.6	257.0	0.59
179.8	1697.1	255.0	0.49
115.1	1728.4	257.0	0.86
159.7	1772.6	260.0	0.26
99.5	1653.8	255.0	0.46
157.7	1662.2	257.0	0.48
96.9	1713.8	257.0	0.82
95.6	1705.9	255.0	1.28
110.4	1694.9	257.0	0.93
192.7	1772.8	247.0	0.37
119.8	1752.8	257.0	0.66
171.8	1724.4	257.0	0.28
95.6	1675.2	260.0	1.31
146.0	1752.4	255.0	0.52
83.2	1678.3	255.0	2.22
106.4	1714.4	257.0	1.20
145.5	1744.7	257.0	0.62
156.7	1707.5	257.0	0.52
100.3	1731.8	257.0	1.63
123.5	1737.4	257.0	0.66
115.1	1723.9	260.0	1.05

COAL TYPE: psoc1451
 OXYGEN CONCENTRATION 6.0 mole-%, GAS TEMPERATURE 1593.0 K
 SAMPLING HEIGHT 19.10 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
112.2	1707.6	277.0	0.83
168.2	1655.5	271.0	0.47
97.5	1680.7	274.0	1.30
78.6	1604.8	265.0	0.67
130.5	1613.9	274.0	1.00
86.1	1690.8	274.0	1.44
117.5	1737.6	274.0	0.75
159.2	1698.3	271.0	0.54
85.9	1715.3	271.0	1.65
132.9	1595.7	263.0	0.44
146.9	1635.4	274.0	0.61
119.8	1692.9	277.0	0.70
128.0	1666.5	277.0	0.49
103.6	1623.3	277.0	0.76
172.8	1623.6	274.0	0.57
94.4	1684.7	277.0	1.09
131.3	1702.5	277.0	0.47
93.1	1755.5	274.0	0.97
154.8	1635.5	271.0	0.68
130.1	1707.3	265.0	0.80
133.8	1670.0	271.0	0.74
90.3	1660.8	277.0	1.12
107.5	1654.2	271.0	1.08
85.6	1745.9	274.0	1.24
150.6	1652.0	271.0	0.57
173.9	1698.8	271.0	0.35
96.6	1665.3	274.0	1.23
133.4	1712.7	274.0	0.52
118.0	1696.1	277.0	0.63
121.7	1695.5	274.0	0.46
88.8	1654.3	280.0	1.09
99.5	1655.1	277.0	1.16
97.2	1748.1	277.0	0.82
98.5	1702.9	274.0	1.17
115.1	1679.0	277.0	0.57
95.6	1678.6	280.0	0.79
202.8	1673.9	274.0	0.28
137.2	1653.1	274.0	0.58
163.1	1709.4	271.0	0.53
118.0	1654.2	271.0	1.47
93.4	1664.9	274.0	0.84
126.8	1641.5	274.0	0.69
140.2	1648.9	274.0	0.62
98.2	1705.4	274.0	0.58
114.5	1665.9	271.0	1.02
131.7	1664.5	277.0	0.60
122.9	1636.7	271.0	0.76

COAL TYPE: psocl451

OXYGEN CONCENTRATION

6.0 mole-%,

GAS TEMPERATURE 1593.0 K

SAMPLING HEIGHT 19.10 cm,

emin =

0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
98.5	1761.5	277.0	0.89
85.3	1613.2	277.0	0.98
112.2	1667.6	274.0	0.80
105.8	1634.6	274.0	0.88
112.2	1683.5	274.0	0.91
98.2	1783.7	274.0	1.08
240.3	1613.1	268.0	0.36
146.4	1640.5	274.0	0.68
182.5	1721.4	158.0	0.35
119.8	1661.6	274.0	0.85
240.3	1605.9	274.0	0.36
115.1	1654.9	271.0	1.03
104.7	1701.2	274.0	0.77
141.1	1698.7	277.0	0.53
79.8	1757.2	274.0	1.42
97.5	1676.2	274.0	1.28
118.0	1676.6	274.0	0.62
131.3	1631.8	274.0	0.67
162.1	1676.6	271.0	0.27
138.9	1649.7	274.0	0.52
144.2	1695.7	271.0	0.60
108.1	1720.1	277.0	0.80
130.9	1677.0	271.0	0.78
171.8	1649.0	274.0	0.46
104.7	1706.8	277.0	0.88
229.9	1610.1	265.0	0.49
98.5	1652.1	274.0	1.12
150.6	1697.4	274.0	0.60
85.3	1678.4	274.0	1.31
126.0	1660.8	277.0	0.52
115.1	1693.3	277.0	0.65
140.7	1640.7	277.0	0.69
95.0	1668.5	274.0	0.92
164.6	1686.2	271.0	0.42
95.0	1726.9	274.0	0.98
100.3	1609.4	280.0	0.98
126.4	1682.8	277.0	0.44
92.2	1651.3	274.0	1.05
152.9	1685.5	277.0	0.50
128.4	1746.3	274.0	0.35
162.6	1677.7	271.0	0.45
126.4	1696.4	274.0	0.51
134.6	1664.7	274.0	0.71
146.0	1636.5	274.0	0.78
137.2	1661.9	277.0	0.61
119.8	1671.3	162.0	0.79
139.8	1698.7	274.0	0.49
129.2	1689.6	271.0	0.56
92.5	1775.1	265.0	1.01

COAL TYPE: psocl451
 OXYGEN CONCENTRATION 6.0 mole-%, GAS TEMPERATURE 1593.0 K
 SAMPLING HEIGHT 19.10 cm, $e_{min} = 0.00$ $e_{max} = 10.00$

size (micron)	temp (K)	vel (m/s)	emiss
141.5	1472.1	243.0	0.26
101.4	1661.2	274.0	0.93
155.3	1652.7	271.0	0.71
130.5	1659.5	274.0	0.62
122.3	1686.1	274.0	0.69
169.7	1674.9	274.0	0.44
101.9	1685.4	274.0	1.02
188.1	1671.1	271.0	0.35
145.1	1684.2	268.0	0.96
93.4	1628.1	274.0	0.93
100.8	1705.4	274.0	0.81
97.2	1683.2	274.0	0.96
148.3	1669.9	274.0	0.49
130.9	1654.4	274.0	0.62
166.6	1692.0	274.0	0.33
137.6	1682.2	268.0	0.64
158.7	1619.6	274.0	0.56
152.0	1659.7	271.0	0.47
92.5	1688.7	274.0	0.90
138.0	1718.9	277.0	0.39
91.6	1660.8	274.0	1.09
92.8	1658.4	277.0	1.08
99.2	1688.9	274.0	0.72
123.5	1678.9	274.0	0.73
93.7	1653.9	277.0	0.93
88.2	1632.5	274.0	0.89
146.0	1688.1	274.0	0.41
132.1	1531.7	257.0	0.75
103.6	1673.9	277.0	1.17
142.4	1556.4	250.0	0.51
133.8	1696.4	274.0	0.41
162.1	1661.5	257.0	0.68
76.9	1772.3	274.0	1.65
152.9	1650.4	277.0	0.51
125.2	1635.4	274.0	0.84
174.4	1662.7	274.0	0.50
133.8	1661.0	274.0	0.57
98.2	1665.2	277.0	0.96
80.7	1696.6	271.0	2.57
154.3	1653.9	274.0	0.62
138.9	1656.5	274.0	0.77
126.8	1637.1	277.0	0.74
92.8	1674.4	274.0	1.27
147.4	1634.2	277.0	0.39
94.4	1700.2	274.0	0.94
128.8	1671.3	274.0	0.51
98.5	1657.9	274.0	1.48
74.4	1719.5	277.0	1.57

COAL TYPE: psoc1451
 OXYGEN CONCENTRATION 6.0 mole-%, GAS TEMPERATURE 1593.0 K
 SAMPLING HEIGHT 19.10 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
221.2	1593.0	274.0	0.82
111.6	1642.2	271.0	0.60
97.9	1678.7	274.0	0.93
103.6	1682.5	277.0	0.86
139.8	1692.8	271.0	0.51
89.7	1694.3	274.0	0.89
98.8	1680.9	274.0	1.29
232.6	1505.8	280.0	0.29
100.3	1639.5	271.0	1.08
97.2	1652.9	274.0	1.54
132.1	1680.7	274.0	0.52
97.5	1646.6	274.0	0.98
136.3	1706.5	274.0	0.41
128.8	1667.4	274.0	0.54
185.3	1645.1	122.0	0.45
136.3	1767.5	277.0	0.24

COAL TYPE: psoc1451
 OXYGEN CONCENTRATION 6.0 mole-%, GAS TEMPERATURE 1536.0 K
 SAMPLING HEIGHT 25.40 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
77.3	1626.8	293.0	1.42
133.8	1663.9	300.0	0.60
105.8	1628.5	293.0	0.84
100.3	1627.8	296.0	1.16
162.1	1586.3	286.0	0.59
138.0	1577.8	289.0	0.61
188.1	1552.4	289.0	0.38
194.5	1570.4	293.0	0.43
94.0	1683.6	293.0	1.30
137.6	1566.6	293.0	0.63
83.2	1643.5	293.0	1.14
120.5	1578.4	289.0	0.78
130.5	1592.5	289.0	0.68
101.9	1591.4	293.0	0.87
107.5	1618.2	293.0	1.14
106.4	1597.3	293.0	0.93
98.5	1597.5	293.0	1.12
104.7	1650.5	293.0	0.61
99.2	1602.2	293.0	1.21
138.5	1617.5	289.0	0.57
105.8	1604.9	300.0	0.75
173.9	1588.0	171.0	0.58
153.4	1674.0	296.0	0.33
119.8	1614.0	289.0	0.98
101.4	1633.6	293.0	1.26
122.3	1641.0	289.0	0.78
189.9	1578.2	286.0	0.56
134.2	1494.6	274.0	0.76
108.1	1633.8	293.0	0.85
103.6	1682.9	293.0	0.99
129.6	1603.5	286.0	0.92
137.6	1583.0	289.0	0.66
180.3	1604.0	296.0	0.68
99.8	1580.4	300.0	0.91
128.8	1613.7	289.0	0.68
135.1	1635.0	296.0	0.69
213.4	1601.2	289.0	0.28
111.6	1582.7	289.0	0.96
143.3	1583.3	286.0	0.77
88.2	1642.9	296.0	0.85
90.6	1681.8	293.0	1.27
119.8	1609.2	289.0	0.89
124.7	1642.1	293.0	0.63
145.1	1601.1	286.0	0.74
98.2	1632.5	293.0	0.96
85.0	1642.5	293.0	1.59
90.9	1752.4	257.0	0.74
100.3	1556.8	286.0	0.89

COAL TYPE: psoc1451
 OXYGEN CONCENTRATION 6.0 mole-%, GAS TEMPERATURE 1536.0 K
 SAMPLING HEIGHT 25.40 cm, $e_{min} = 0.00$ $e_{max} = 10.00$

size (micron)	temp (K)	vel (m/s)	emiss
94.7	1592.4	289.0	0.95
100.8	1634.2	286.0	1.50
109.8	1726.3	289.0	1.23
128.0	1601.9	293.0	0.58
106.4	1590.3	293.0	1.05
105.8	1598.3	293.0	0.73
220.5	1554.6	296.0	0.54
83.7	1664.8	289.0	1.39
128.8	1600.5	296.0	0.78
142.9	1649.0	289.0	0.49
107.0	1674.6	293.0	0.80
106.4	1586.4	293.0	0.94
184.8	1631.5	286.0	0.36
105.8	1615.7	289.0	1.41
141.1	1615.8	289.0	0.66
108.1	1650.1	289.0	0.81
89.7	1577.8	293.0	1.30
114.5	1589.5	289.0	1.09
82.0	1634.8	289.0	1.23
153.9	1638.8	293.0	0.51
204.7	1485.0	296.0	0.73
207.7	1560.4	296.0	0.54
188.1	1495.8	293.0	0.92
150.6	1609.7	293.0	0.55
108.1	1629.5	289.0	1.01
115.7	1586.3	289.0	0.65
93.7	1593.7	293.0	1.52
86.1	1629.5	293.0	1.07
123.5	1659.1	293.0	0.49
80.2	1662.6	293.0	1.30
121.1	1659.1	289.0	0.92
161.1	1623.6	293.0	0.33
91.2	1649.5	289.0	1.17
89.7	1607.3	289.0	1.27
155.8	1613.5	289.0	0.61
95.9	1668.3	293.0	0.80
151.1	1598.1	289.0	0.63
113.9	1646.9	289.0	0.67
89.1	1568.0	293.0	1.48
91.2	1597.9	289.0	0.93
151.1	1621.3	289.0	0.56
130.1	1598.5	283.0	0.60
211.5	1494.3	293.0	0.88
130.5	1614.1	289.0	0.85
83.7	1630.5	289.0	1.41
164.6	1597.5	293.0	0.44
133.4	1589.3	286.0	0.96

COAL TYPE: psoc1451
 OXYGEN CONCENTRATION 6.0 mole-%, GAS TEMPERATURE 1536.0 K
 SAMPLING HEIGHT 25.40 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
176.6	1526.4	263.0	0.25
99.2	1594.5	293.0	1.02
148.3	1605.3	289.0	0.72
182.0	1523.6	271.0	0.26
91.9	1671.0	296.0	0.97
125.6	1650.0	283.0	1.43
111.6	1657.4	293.0	0.81
85.9	1628.7	289.0	1.32
147.8	1594.7	289.0	0.63
106.4	1608.3	293.0	0.84
160.6	1645.6	289.0	0.43
130.5	1603.4	289.0	0.82
110.4	1617.9	289.0	0.70
141.1	1601.5	289.0	0.67
98.2	1636.4	293.0	1.27
105.3	1600.4	289.0	1.04
146.9	1598.7	289.0	0.53
157.2	1629.2	289.0	0.51

COAL TYPE: psoc1451
 OXYGEN CONCENTRATION 12.0 mole-%, GAS TEMPERATURE 1645.0 K
 SAMPLING HEIGHT 12.70 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
183.7	1901.0	255.0	0.37
139.8	1872.3	255.0	0.48
146.4	1882.3	257.0	0.59
93.4	1941.9	257.0	0.79
218.5	1886.3	260.0	0.23
185.9	1798.5	260.0	1.07
117.5	1917.0	255.0	0.63
165.6	1858.7	257.0	0.47
219.8	1933.4	260.0	0.14
86.1	1829.5	255.0	0.99
131.3	1899.0	260.0	0.56
141.1	1907.7	255.0	0.70
96.3	1891.4	257.0	0.86
154.3	1925.4	252.0	0.46
124.1	1865.5	257.0	0.96
79.8	1890.1	255.0	1.66
135.5	1891.6	260.0	0.54
220.5	1892.1	260.0	0.21
82.0	1793.3	257.0	1.36
97.5	1871.4	255.0	1.79
163.1	1836.8	257.0	0.50
195.1	1904.3	157.0	0.60
99.8	1887.4	257.0	1.12
144.2	1817.4	260.0	0.59
95.6	1871.6	255.0	0.78
120.5	1915.4	257.0	0.86
167.7	1846.3	255.0	0.71
87.3	1846.8	260.0	0.92
100.8	1884.3	257.0	0.92
111.0	1829.7	257.0	0.90
139.3	1875.6	255.0	0.71
89.7	1915.8	260.0	0.80
100.8	1919.5	257.0	0.59
125.2	1861.4	257.0	0.72
95.3	1874.8	255.0	1.42
157.7	1914.3	265.0	0.41
162.6	1912.3	260.0	0.48
151.5	1822.5	257.0	0.65
125.6	1884.0	257.0	0.94
135.1	1914.4	257.0	0.46
85.9	1910.8	257.0	1.85
131.7	1865.8	257.0	0.79
143.3	1837.5	255.0	0.69
95.3	1931.3	260.0	1.11
95.6	1892.1	263.0	0.93
113.3	1918.6	263.0	0.58
86.4	1857.5	257.0	1.88
147.4	1857.4	260.0	0.53

COAL TYPE: psoc1451

OXYGEN CONCENTRATION 12.0 mole-%, GAS TEMPERATURE 1645.0 K

SAMPLING HEIGHT 12.70 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
149.7	1855.7	255.0	0.96
85.6	1871.3	257.0	1.72
172.8	1828.0	252.0	0.62
154.3	1863.0	263.0	0.73
59.8	1891.5	260.0	1.67
101.4	1886.7	255.0	1.24
144.6	1548.4	232.0	0.62
173.4	1947.1	260.0	0.29
131.7	1868.6	260.0	0.63
90.0	1899.0	257.0	1.60
115.1	1911.6	257.0	0.74
164.6	1914.4	257.0	0.51
228.5	1814.9	252.0	0.40
97.5	1885.7	260.0	0.91
101.9	1892.5	265.0	0.85
145.5	1848.5	257.0	0.32
125.2	1822.2	257.0	0.83
98.8	1825.6	257.0	1.13
141.5	1910.8	263.0	0.25
139.8	1766.1	247.0	0.58
115.7	1850.8	260.0	0.93
105.8	1879.2	263.0	1.05
224.5	1850.5	257.0	0.22
172.8	1834.1	255.0	0.38
88.2	1959.6	260.0	0.81
152.5	1842.7	260.0	0.74
98.8	1889.6	257.0	1.25
108.7	1836.1	260.0	0.95
143.3	1843.7	260.0	0.46
122.3	1924.6	260.0	0.83
133.4	1823.1	257.0	0.60
169.7	1821.7	257.0	0.58
108.1	1826.4	257.0	0.69
173.9	1842.9	257.0	0.52
127.6	1908.2	260.0	0.66
56.9	1889.3	260.0	2.26
96.9	1860.7	260.0	1.01
161.6	1844.7	257.0	0.72
138.9	1820.9	260.0	0.73
128.0	1833.4	260.0	1.06
180.9	1935.4	245.0	0.58
126.0	1833.4	255.0	0.66
150.6	1881.5	257.0	0.58
105.3	1870.4	255.0	0.95
152.0	1830.4	252.0	0.57
83.2	1825.2	252.0	1.15
151.5	1787.2	252.0	0.78
104.2	1833.7	257.0	0.68

COAL TYPE: psocl451

OXYGEN CONCENTRATION 12.0 mole-%, GAS TEMPERATURE 1645.0 K

SAMPLING HEIGHT 12.70 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
96.3	1828.7	257.0	0.98
119.2	1879.4	260.0	0.84
139.3	1841.7	255.0	0.80
122.3	1887.7	260.0	0.52
135.9	1913.9	257.0	0.59
197.4	1836.3	260.0	0.40
217.2	1846.0	257.0	0.25
143.7	1839.5	257.0	0.62
79.0	1822.9	255.0	1.83
169.7	1849.8	260.0	0.43
115.1	1844.1	255.0	0.50
134.6	1863.2	255.0	0.66
142.9	1610.9	236.0	1.05
137.6	1828.1	260.0	0.91
127.6	1897.7	263.0	0.71
157.7	1888.2	257.0	0.24
151.5	1923.2	260.0	0.36
111.0	1847.2	257.0	0.53
152.0	1882.3	257.0	0.45
101.4	1898.3	257.0	0.97
121.7	1824.3	260.0	0.73
109.3	1862.9	257.0	1.31
120.5	1854.5	260.0	0.67
151.1	1914.8	257.0	0.38
123.5	1861.8	257.0	0.69
168.2	1831.1	257.0	0.73
126.0	1857.9	257.0	1.02
146.0	1897.6	257.0	0.72
88.8	1918.8	257.0	1.06
143.3	1903.2	257.0	0.46
131.3	1868.7	257.0	0.78
77.7	1949.5	257.0	1.96
82.4	1870.1	260.0	1.84
91.9	1837.1	255.0	1.20
113.9	1879.4	255.0	1.36
183.7	1906.0	257.0	0.39
108.1	1867.9	255.0	0.96
115.7	1903.4	255.0	0.87
100.3	1830.9	252.0	0.83
159.2	1844.3	260.0	0.87
116.3	1503.8	232.0	1.17
109.8	1848.6	260.0	0.69
115.1	1988.4	260.0	0.77
156.3	1833.6	257.0	0.54
98.2	1835.7	255.0	1.51
132.1	1862.8	255.0	0.80
113.3	1855.7	257.0	0.69
108.7	1835.7	257.0	0.91

COAL TYPE: psoc1451

OXYGEN CONCENTRATION 12.0 mole-%, GAS TEMPERATURE 1645.0 K

SAMPLING HEIGHT 12.70 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
107.5	1911.2	257.0	0.75
131.7	1886.1	255.0	0.70
172.3	1866.8	263.0	0.38
132.9	1865.8	257.0	1.04
173.4	1832.9	250.0	0.45
109.3	1830.0	257.0	0.48
91.2	1852.6	255.0	0.89
154.3	1800.3	263.0	0.76
128.4	1893.7	257.0	0.65
127.6	1897.7	260.0	0.58
74.4	1912.6	252.0	3.15
138.0	1836.5	257.0	0.61
102.5	1899.1	260.0	1.37
196.2	1866.5	255.0	0.35
114.5	1866.0	260.0	0.88
120.5	1882.4	255.0	1.08
136.8	1866.5	250.0	0.87
130.5	1563.5	234.0	0.94
143.3	1904.8	255.0	0.64
108.7	1854.8	257.0	1.25
103.6	1868.1	260.0	1.30
109.3	1894.0	260.0	0.57

COAL TYPE: psoc1451

OXYGEN CONCENTRATION 12.0 mole-%, GAS TEMPERATURE 1591.0 K
SAMPLING HEIGHT 19.10 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
162.6	1555.1	250.0	0.44
111.0	1870.9	277.0	0.67
185.9	1821.4	277.0	0.47
103.6	1895.2	274.0	1.04
88.2	1846.4	274.0	0.96
98.5	1825.9	277.0	1.06
143.7	1793.6	274.0	0.61
104.7	1834.7	274.0	1.09
148.3	1828.9	274.0	0.63
89.1	1706.6	277.0	1.19
104.7	1885.1	277.0	0.91
152.0	1831.1	280.0	0.60
118.0	1772.5	271.0	0.86
106.4	1797.0	277.0	0.87
139.8	1864.8	274.0	0.71
137.6	1828.7	280.0	0.79
136.3	1735.8	274.0	0.56
150.6	1896.9	277.0	0.52
161.1	1793.5	271.0	0.53
132.1	1866.1	268.0	0.67
90.0	1820.3	277.0	0.75
104.7	1861.5	277.0	0.93
136.3	1882.8	277.0	0.59
114.5	1876.9	274.0	0.98
99.5	1813.2	277.0	1.48
119.8	1897.7	271.0	0.89
104.2	1774.8	274.0	0.94
95.6	1807.1	271.0	0.89
149.2	1869.9	274.0	0.55
135.5	1850.2	277.0	0.64
98.2	1769.7	277.0	1.04
125.6	1762.6	271.0	0.68
101.4	1831.1	274.0	0.75
132.9	1860.6	277.0	0.72
119.8	1860.5	280.0	0.79
106.4	1882.9	274.0	0.60
91.2	1894.9	280.0	1.19
93.7	1854.0	274.0	1.16
168.7	1869.9	274.0	0.52
83.7	1755.7	271.0	1.35
65.8	1844.9	274.0	2.01
159.7	1869.2	277.0	0.50
119.2	1868.4	277.0	0.83
107.5	1601.3	257.0	0.51
120.5	1846.7	274.0	0.79
158.2	1823.4	265.0	0.59
103.6	1874.3	283.0	0.63

COAL TYPE: psocl451

OXYGEN CONCENTRATION 12.0 mole-%, GAS TEMPERATURE 1591.0 K

SAMPLING HEIGHT 19.10 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
102.5	1821.0	271.0	1.01
85.9	1868.4	277.0	1.08
112.7	1762.3	271.0	0.55
97.2	1881.8	274.0	0.96
112.2	1821.1	274.0	0.77
88.8	1887.4	274.0	1.05
153.9	1797.7	274.0	0.49
79.0	1766.9	277.0	1.33
113.3	1705.2	277.0	0.57
88.5	1834.6	268.0	1.02
141.5	1592.2	260.0	0.31
136.3	1862.0	274.0	0.85
135.5	1729.9	274.0	0.49
128.0	1900.8	274.0	0.34
95.3	1670.5	274.0	1.04
116.9	1843.4	274.0	0.90
122.3	1749.5	271.0	0.60
95.6	1833.4	274.0	1.05
130.9	1828.4	277.0	0.51
118.0	1830.6	277.0	0.95
89.1	1822.9	274.0	0.80
131.3	1669.7	271.0	0.61
116.9	1809.2	274.0	0.66
71.2	1831.9	280.0	2.01
138.9	1841.8	277.0	0.50
116.3	1817.2	263.0	0.73
131.7	1768.0	271.0	1.30
79.4	1820.0	277.0	1.13
146.9	1835.6	274.0	0.50
99.8	1846.8	271.0	1.04
158.7	1783.5	277.0	0.66
88.5	1776.1	274.0	0.83
147.4	1849.5	274.0	0.75
78.1	1837.3	280.0	1.87
168.2	1844.8	143.0	0.55
92.8	1807.1	274.0	1.27
107.0	1773.0	268.0	0.91
105.3	1839.8	274.0	1.07
96.9	1851.1	274.0	0.83
99.5	1886.8	274.0	0.96
96.9	1831.9	274.0	0.88
99.2	1870.9	277.0	0.92
121.7	1874.3	277.0	0.62
113.9	1802.5	274.0	0.79
141.1	1754.4	274.0	0.75
127.6	1864.1	277.0	0.79
90.3	1844.0	271.0	0.98

COAL TYPE: psocl451

OXYGEN CONCENTRATION 12.0 mole-%, GAS TEMPERATURE 1591.0 K

SAMPLING HEIGHT 19.10 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
126.0	1828.1	274.0	0.44
120.5	1812.3	274.0	0.63
148.7	1799.3	274.0	0.68
117.5	1873.7	271.0	0.63
184.2	1823.7	274.0	0.44
132.9	1560.0	250.0	0.47
114.5	1806.9	271.0	0.61
93.4	1857.5	271.0	1.32
153.9	1814.5	271.0	0.77
73.2	1767.8	274.0	0.00
158.7	1897.7	277.0	0.56
96.3	1937.5	274.0	1.38
139.8	1814.7	274.0	0.59
99.2	1875.4	274.0	1.25
129.2	1804.9	268.0	0.86
132.9	1876.9	280.0	0.59
157.2	1753.9	274.0	0.52
105.8	1782.8	271.0	1.14
88.5	1787.4	277.0	1.43
131.3	1809.7	277.0	0.90
79.8	1875.1	277.0	1.15
90.6	1876.0	280.0	0.96
104.7	1706.7	274.0	1.17
127.2	1801.6	277.0	0.87
76.9	1842.5	274.0	1.30
198.6	1814.8	277.0	0.39
99.2	1844.0	277.0	0.90
105.8	1818.9	268.0	0.70
196.2	1814.5	271.0	0.48
231.9	1862.4	271.0	0.50
109.3	1863.0	277.0	0.81
155.3	1875.8	274.0	0.64
107.5	1773.6	268.0	1.06
150.1	1801.2	268.0	0.88
141.5	1860.5	274.0	0.57
114.5	1854.3	277.0	0.89
149.2	1859.8	274.0	0.78
151.1	1860.0	271.0	0.64
99.2	1787.9	277.0	1.09
117.5	1854.9	277.0	0.80
121.1	1875.5	271.0	0.77
134.6	1804.7	274.0	0.43
137.2	1803.0	274.0	0.43
186.4	1837.8	265.0	0.75
134.6	1879.2	274.0	0.65
94.4	1800.1	277.0	0.75

COAL TYPE: psocl451

OXYGEN CONCENTRATION 12.0 mole-%, GAS TEMPERATURE 1591.0 K
SAMPLING HEIGHT 19.10 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
183.7	1886.6	277.0	0.37
112.7	1804.4	271.0	0.66
183.7	1763.2	268.0	0.82
99.5	1860.4	274.0	1.85
107.0	1681.7	271.0	1.10
129.6	1883.4	274.0	0.68
114.5	1863.0	271.0	0.99
146.0	1833.7	277.0	0.56
121.1	1878.5	277.0	0.46
109.3	1883.4	271.0	0.72
84.5	1831.5	274.0	1.66
128.0	1839.5	274.0	0.78
126.4	1817.3	271.0	0.62
164.1	1828.1	271.0	0.64
96.9	1827.6	274.0	1.06
128.0	1807.7	274.0	0.64
95.9	1800.7	271.0	0.85
111.6	1783.5	274.0	1.10
98.8	1832.9	274.0	1.39
132.5	1795.8	274.0	0.55
85.6	1751.3	277.0	1.22
82.8	1869.3	274.0	1.69
116.3	1794.2	274.0	1.00
138.5	1775.8	271.0	0.44
91.6	1869.8	274.0	1.31
125.2	1743.3	277.0	0.59
120.5	1886.2	277.0	0.93

COAL TYPE: psoc1451

OXYGEN CONCENTRATION 12.0 mole-%, GAS TEMPERATURE 1532.0 K
 SAMPLING HEIGHT 25.40 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
77.3	1777.4	289.0	1.36
100.3	1772.3	289.0	1.44
98.2	1617.1	289.0	1.19
57.8	1507.6	286.0	0.92
166.1	1816.0	289.0	0.77
99.5	1614.6	286.0	0.70
94.4	1555.5	286.0	0.93
95.3	1707.6	293.0	1.27
95.6	1632.6	293.0	1.03
65.3	1847.3	293.0	1.56
126.0	1825.0	293.0	0.98
98.8	1786.4	289.0	0.85
128.0	1726.0	289.0	0.66
96.3	1681.9	289.0	1.14
95.6	1769.1	289.0	1.14
107.0	1768.7	289.0	0.87
124.1	1688.3	289.0	0.58
104.7	1811.8	289.0	1.06
170.2	1677.8	289.0	0.56
95.0	1726.9	293.0	0.97
132.9	1826.9	293.0	0.95
96.6	1726.7	289.0	1.13
181.4	1650.2	293.0	0.35
122.3	1655.3	286.0	1.05
88.2	1715.3	293.0	1.06
109.3	1744.3	289.0	0.87
115.7	1760.6	293.0	0.79
117.5	1677.4	286.0	1.01
150.1	1636.1	296.0	0.39
88.2	1570.8	283.0	0.25
107.5	1736.9	289.0	1.00
115.1	1799.7	293.0	0.72
88.8	1628.1	293.0	1.03
81.1	1773.1	293.0	1.60
85.0	1802.7	289.0	1.19
90.3	1745.1	293.0	1.03
109.8	1807.3	289.0	0.92
129.6	1711.1	286.0	0.69
113.3	1564.2	293.0	0.56
92.2	1730.5	289.0	0.93
102.5	1694.7	289.0	1.42
129.2	1716.4	289.0	0.74
148.3	1653.4	293.0	0.57
87.3	1777.6	296.0	1.10
117.5	1774.3	289.0	0.87
126.4	1497.8	271.0	0.51
58.3	1735.0	293.0	2.28

COAL TYPE: psoc1451

OXYGEN CONCENTRATION 12.0 mole-%, GAS TEMPERATURE 1532.0 K
SAMPLING HEIGHT 25.40 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
102.5	1830.9	293.0	0.88
152.9	1693.1	293.0	0.36
107.5	1656.5	289.0	0.95
113.9	1630.1	289.0	0.88
126.0	1530.8	277.0	0.30
106.4	1697.3	293.0	1.08
138.5	1709.9	289.0	0.78
135.5	1585.7	293.0	0.65
102.5	1729.2	289.0	1.17
128.0	1830.9	289.0	0.62
131.7	1824.3	293.0	0.83
108.7	1611.0	286.0	1.01
93.7	1655.0	289.0	1.42
100.8	1627.1	293.0	0.79
106.4	1717.9	289.0	1.29
138.9	1629.4	289.0	0.66
152.0	1751.7	293.0	0.59
134.2	1845.7	293.0	0.57
84.5	1809.4	289.0	1.16
91.9	1783.4	289.0	1.08
119.8	1676.9	293.0	0.75
88.2	1711.9	289.0	1.32
92.5	1721.3	296.0	1.23
85.3	1845.6	300.0	0.95
76.1	1799.3	289.0	1.44
146.9	1690.9	286.0	0.67
208.4	1669.4	289.0	0.51
135.9	1783.3	289.0	0.40
132.5	1782.7	286.0	0.88
117.5	1730.4	286.0	0.76
127.2	1762.4	289.0	0.71
111.6	1574.8	289.0	0.95
122.9	1576.7	293.0	0.67
109.8	1565.9	289.0	1.01
112.2	1726.4	293.0	0.66
89.4	1702.9	296.0	1.28
132.1	1677.3	283.0	0.71
148.7	1617.7	286.0	0.83
100.8	1565.8	293.0	1.07
93.1	1814.7	289.0	1.08
98.8	1768.5	289.0	0.91
111.6	1771.0	293.0	0.92
95.3	1796.7	289.0	1.05
94.4	1774.2	296.0	1.32
78.6	1731.8	289.0	1.97
129.6	1558.9	274.0	0.32
96.9	1655.6	293.0	1.29
128.0	1765.3	286.0	0.77

COAL TYPE: psoc1451

OXYGEN CONCENTRATION 12.0 mole-%, GAS TEMPERATURE 1532.0 K
SAMPLING HEIGHT 25.40 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
75.7	1767.4	293.0	1.39
116.9	1706.4	289.0	0.82
123.5	1532.1	274.0	0.37
107.5	1661.5	293.0	1.27
130.9	1591.4	293.0	0.87
159.7	1701.9	289.0	0.54
100.3	1616.2	296.0	0.84
87.6	1586.0	293.0	1.20
97.9	1593.7	293.0	1.05
127.2	1741.8	286.0	0.89
112.2	1764.4	293.0	0.84
108.1	1769.9	289.0	0.97
133.8	1695.0	289.0	0.96
136.3	1691.1	289.0	0.65
90.6	1648.0	293.0	0.90
97.5	1774.9	293.0	1.97
147.4	1650.9	293.0	0.79
70.4	1771.1	293.0	1.57
90.9	1560.8	289.0	0.92
165.6	1728.2	289.0	0.30
120.5	1764.5	289.0	0.74
104.7	1497.8	268.0	1.23
86.7	1779.4	289.0	1.20
124.1	1795.8	289.0	0.76
200.4	1879.6	293.0	0.41
133.8	1780.0	286.0	0.80
136.8	1613.1	293.0	0.83
131.7	1823.9	289.0	0.54
95.9	1579.3	289.0	1.14
97.9	1816.7	289.0	1.08
75.2	1759.6	293.0	1.38
114.5	1692.4	289.0	0.97
86.7	1589.4	289.0	1.55
81.5	1820.2	289.0	1.33
94.0	1755.0	293.0	1.22
108.7	1810.0	289.0	1.35
164.1	1562.3	286.0	0.69
128.4	1787.2	289.0	0.99
171.8	1829.1	289.0	0.43
78.1	1787.4	289.0	1.51
130.9	1720.7	289.0	0.95
89.1	1736.6	286.0	1.16
135.5	1634.5	296.0	0.64
139.8	1737.9	286.0	0.66
124.7	1746.4	289.0	0.76
177.6	1689.6	293.0	0.30

COAL TYPE: psoc1451

OXYGEN CONCENTRATION 12.0 mole-%, GAS TEMPERATURE 1532.0 K
SAMPLING HEIGHT 25.40 cm, emin = 0.00 emax = 10.00

size (micron)	temp (K)	vel (m/s)	emiss
119.2	1652.9	293.0	0.76
143.7	1488.9	271.0	0.54
118.6	1753.4	289.0	0.96
135.9	1624.0	293.0	0.44
135.5	1671.6	289.0	0.64
87.3	1633.7	293.0	1.56
94.0	1693.9	289.0	1.40
89.1	1818.9	286.0	2.17
155.3	1773.9	289.0	0.47
178.2	1538.7	268.0	0.40
107.5	1819.0	293.0	0.62
138.0	1780.2	289.0	0.57
124.7	1644.8	289.0	0.72
134.6	1787.5	293.0	0.92
87.0	1840.5	293.0	0.76
101.4	1689.7	289.0	1.11
96.9	1609.2	293.0	0.93
90.3	1656.7	293.0	1.26
131.7	1696.0	289.0	0.74
135.5	1782.9	293.0	0.70
94.7	1766.2	289.0	1.28
105.3	1597.2	293.0	0.95
130.5	1680.5	289.0	0.65
118.0	1810.5	289.0	1.09
123.5	1821.4	286.0	1.07
140.6	1786.6	289.0	0.58
213.4	1776.7	293.0	0.37
119.8	1712.9	293.0	0.59
128.8	1739.9	289.0	0.78

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