MASTER

**VOLATILE PRODUCTION DURING PREIGNITION
COAL HEATING**

**Quarterly Progress Report
For the Period
April 1981 - June 1981**

July 1981

Work Performed under Contract DE-AC-22-80PC30291

**AVCO EVERETT RESEARCH LABORATORY, INC.
a Subsidiary of Avco Corporation
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1.0 PROGRAM OBJECTIVES AND SCOPE OF WORK

The objective of this program is to define the relationship between volatile matter production from pulverized coal and flame stabilization in a boiler environment. The behavior of pulverized coal under preignition heating conditions will be experimentally determined and subsequently correlated with a detailed kinetic and transport model.

The program is an experimental one, comprising of three tasks.

Task 1

Conduct design, fabrication and checkout of the experimental system to measure pulverized coal pyrolysis under steady flow laser heated conditions.

Task 2

Employ this system to investigate the pyrolysis behavior of a series of coals with respect to heating rate, final particle temperatures and particle size.

Task 3

The data from these experiments will be analyzed and correlated using a comprehensive computer code, which in turn will be used to predict the combustion behavior of the coals in industrial boilers.

2.0 SUMMARY OF PROGRAM TO DATE

Program status and projected performance are shown in Figure

2.1. Individual task summaries follow.

Task 1

Design and fabrication of the experimental apparatus is essentially complete. Mirror design and component assembly has been carried out. The flow system has undergone preliminary flow quality analysis; the coal feed system operates very well and the nozzle flow field appears adequately uniform. The new two-color pyrometer has been built and calibrated; its performance so far has been excellent.

Task 2

Not initiated at this time.

Task 3

Not initiated at this time.

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Task 1	Design, Fabrication,																										
	Assembly & Checkout																										
Task 2	Data Collection																										
Task 3	Data Analysis and																										
	Correlation																										
	Final Report																										
11. Remarks																											
Detail by Task																											
12. Signature of Contractor's Project Manager and Date <i>P.V. Murray for R. Ballantine 10-30-80</i>														13. Signature of Government Technical Representative and Date													

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Figure 2.1 Milestone Schedule and Status Report

3.0 EXPERIMENTAL PROGRAM

3.1 GENERAL APPROACH

The goal of this program is to determine the characteristic pyrolysis behavior of representative coals under laser heating. The use of a CO₂ laser enables a controllable heating rate to be given to the coal particles as they pass through the laser beam. The development of such a laser heating diagnostic should prove to be an extremely valuable tool for generation of a data base necessary for the future design of coal burning facilities.

The experimental configuration is illustrated in Figure 3.1. A dilute coal/gas stream, surrounded by an inert shield flow is passed through a laser beam from an Avco HPL[®] CO₂ laser. Under a prescribed flux density, and thus heating rate, the particles pyrolyse. The gaseous products are sampled and subsequently analyzed (primarily by gas chromatography) for carbon conversion. Particle temperature is to be monitored by a two-color pyrometer and particle velocity by laser Doppler velocimeter, by which means, evolution of the pyrolysis process can be

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Figure 3.1 Schematic of Experimental Configuration

determined. The data can then be correlated with a detailed kinetic and transport model, which will enable the representative kinetic parameters to be determined.

3.2 LASER FACILITY INTEGRATION

The gas extraction system components have been assembled, and a filter assembly has been constructed for particulate removal. At this time we are waiting for building modifications to be carried out prior to final system installation.

The original approach to be taken for diagnostic linear positional control was that of using an existing mill bed in the test cell. This proved to be an unsatisfactory solution as a consequence of space constraints. The present approach is to use a much smaller and compact traverse mechanism, equipped with stepping motor positional control. This gives us much more flexibility in control of the limited space delineated by the laser beam delivery system. This system requires that the two-color pyrometer be spatially fixed and that the traverse be equipped with a periscope for radiation collection from the measurement points. Both the sampling probe and the LDV will be mounted upon the traversing assembly.

3.3 LASER MIRROR SYSTEM

All the components of the laser mirror system have been assembled. The mirror mounting plates and brackets have been made and an initial installation carried out in the laser cell. A test alignment will be carried out during our first working session in the laser test cell.

3.4 TWO-COLOR PYROMETER

The upgraded two-color pyrometer system has been built and is undergoing exhaustive testing. A photograph of the device is shown in Figure 3.2 and a schematic of the entire system is shown in Figure 3.3. The entire detection element of the system is enclosed in an optically shielded box, which is mounted upon an optical table. The entrance slit is shielded by a remotely controlled shutter. The incoming radiation passes through a filter wheel, giving a dynamic range of 10^8 in attenuation. The filter wheel is controlled by a stepping motor and filter position displayed on a light board. The beam, after splitting and focusing, is directed through the narrow band filters onto the photomultiplier faces. The photomultiplier tubes are cooled to -20°C by thermoelectric cooling elements with a convective water flow heat sink. As a consequence, the photomultiplier housing windows have to be heated in order to prevent condensation interfacing with operation of the device. This improves dark current performance by factors greater than two orders of magnitude as compared to ambient. In fact, use of both cooled tubes and the neutral density filter wheel are the means by which the whole technique becomes viable; without either of these devices the dynamic range of the phototube is not wide enough for the system to be workable. For run-to-run reproducibility, the photomultipliers are driven by one power supply using a voltage divider, in order that no gain errors creep into the system.

Figure 3.2 Photograph of Two Color Pyrometer

Figure 3.3 Schematic of Two Color Pyrometer System

With the use of the lock-in amplifiers, referenced to the chopping wheel, the system has successfully been operated at 600 K using a reference blackbody source. With more fine tuning a slightly lower temperature could be accessible. This translates to a lower bound on operation, for the actual coal flow experiment, of ≈ 800 K. Using a blackbody source, a calibration curve has been obtained. As can be seen in Figure 3.4 the signal ratio measured has a slope in precise agreement with the theoretical value ($= h\Delta\nu/k$). The actual value of the ratio is different from the theoretical value as a consequence of the different transmission behavior of the optical component at the two wavelengths (7600°A and 8400°A with 100 A bandwidths).

3.5 FLOW SYSTEM CALIBRATION

The coal feed device has been given initial testing and appears to work very satisfactorily. The weigh scale has been delivered and in consequence we have been able to accurately monitor coal feed rates. However, the dynamic response of the scale digital readout is not fast enough for our requirements. This has necessitated use of the analogue readout capability of the device; unfortunately this does not have the capability to tare out the initial value as does the scale's own digital readout. This has limited our capability to measure very low flow rates as accurately as we would wish. The manufacturer is modifying the scale to our specifications, in order to counteract this problem. Typical calibration results are shown in Figure 3.5. There is some

Figure 3.4 Calibration Curve for Two Color Pyrometer

Figure 3.5 Coal Flow Measurements in Fluidized Bed Feeder

scatter about a linear rate of change in scale reading; this is especially so at early times, when the change is small. This is most likely an artifact of the previously described scale reading problem. However, the flow rates do appear to be reasonably stable and constant. Further calibrations will be carried out when the scale has been modified to check that flow stability is at its required level for the experiment.

Spatial and temporal stability of the nozzle coal flow has also been investigated. Figure 3.6 illustrates the spatial uniformity of the coal particle number density across the jet. This was obtained by utilizing attenuation of a He-Ne laser beam across the jet. The central region of the jet is remarkably uniform, with roughly 10% fluctuations being observed. At the edges of the orifice, the density does drop off. There also appears to be a slight shift in density to the lower side of the nozzle which would appear due to gravitational settling. However, the nozzle flow appears adequately uniform for use in the experimental program.

3.6 MODELING OF LASER HEATING

The computer code continues to be used to assess the consequences of experimental design choices. In particular, it has been used to investigate the potential problems associated with laser power instability. The HPL[®] laser is equipped with a feedback control system to maintain long-term power level stability to a 2% level. However, by virtue of its e-beam sustainer

Figure 3.6 Nozzle Exit Plane Coal Number Density Distribution

configuration it is susceptible to high frequency voltage oscillations getting through its power rectification circuitry. This leads to possible 120-720 Hz laser power instabilities occurring. Although these have not as yet been investigated experimentally, it was felt necessary to investigate the possible influence of such power fluctuations upon pyrolysis behavior. The computer model was adapted to perform the necessary ensemble averaging over the range of harmonic frequencies possible. It was established that the consequences of even large amplitude fluctuations ($\approx 30\%$) would not significantly alter the results of the pyrolysis, insofar as time averaged measurements are concerned.

3.7 WORK FORECAST

The majority of design, fabrication and system checkout work has been completed. In the next quarter the entire system will be placed in the laser test cell and initial experiments will be carried out. At this time, the scheduled starting date for the experimental testing is July 13, as required to interface with other laser users.