MASTER

**VOLATILE PRODUCTION DURING PREIGNITION
COAL HEATING**

**Quarterly Progress Report
For the Period
September 1980 – December 1980**

February 1980

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

**AVCO EVERETT RESEARCH LABORATORY, INC.
a Subsidiary of Avco Corporation
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PC30291-1

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COAL HISTORY

Quarterly Progress Report
For the Period
September 1980 - December 1980

AVCO EVERETT RESEARCH LABORATORY, INC.,
a subsidiary of Avco Corporation
2385 Revere Beach Parkway

prepared for

U. S. DEPARTMENT OF ENERGY
Pittsburgh Energy Technology Center
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AVCO EVERETT

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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 coal with respect to heating rate, find 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 of the flow system is complete, and is being fabricated at this time. The integration of the experimental set-up with the laser test facility is being finalized, although some fabrication is still to be carried out. Some optical issues remain outstanding but a baseline design has been established.

Task 2

Not initiated at this time.

Task 3

Not initiated at this time.

U.S. DEPARTMENT OF ENERGY
MILESTONE SCHEDULE AND STATUS REPORT

1. Contract Identification Volatile Production During Preignition Coal Heating		2. Reporting Period through		3. Contract Number DE-AC22-80PC30291									
4. Contractor (name, address) Avco Everett Research Laboratory, Inc. 2385 Revere Beach Parkway Everett, MA 02149				5. Contract Start Date 15 September 1980									
				6. Contract Completion Date 15 May 1982									
7. Identification Number	8. Reporting Category (e.g., contract line item or work breakdown structure element)	9. Fiscal Years and Months										10. Percent Complete	
		<div style="display: flex; justify-content: space-around;"> FY 81 FY 82 </div> <div style="display: flex; justify-content: space-around; font-family: monospace;"> ONDJFMAMJJASONDJFMAM </div>										a) Planned	b) Actual
Task 1	Design, Fabrication,												
	Assembly & Checkout	<div style="width: 40%; border: 1px solid black; position: relative;"><div style="position: absolute; right: 0; top: -5px;">Δ</div></div>											
Task 2	Data Collection	<div style="width: 40%; border: 1px solid black; position: relative;"><div style="position: absolute; right: 0; top: -5px;">Δ</div></div>											
Task 3	Data Analysis and												
	Correlation	<div style="width: 40%; border: 1px solid black; position: relative;"><div style="position: absolute; right: 0; top: -5px;">Δ</div></div>											
	Final Report	<div style="width: 20%; border: 1px solid black; position: relative;"><div style="position: absolute; right: 0; top: -5px;">Δ</div></div>											
11. Remarks Detail by Task													
12. Signature of Contractor's Project Manager and Date <i>P. V. Lunny for P. 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 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 evolution of the pyrolysis process can be 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 present laser facility consists of a 15 KW CO₂ laser slaved to three test cells (Figure 3.2). These test cells are

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Figure 3-1 Schematic of Experimental Configuration

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Figure 3-2 Schematic of Laser and Test Cells

normally used for laser metalworking development and are operated on a time-sharing basis. The test cells are supplied with laser power via a beam channel above the cells. By suitable changes in optical configuration, the beam can be selectively directed to a given work station. The laser pyrolysis experiment is to be installed in the end cell, as shown in Figure 3.2. During laser operation, the test cell is off limits to personnel, for reasons of safety. Operation of laser, flow system and diagnostics will be performed from a remote station outside of the cell. The gas supply, diagnostics cables will be passed through an access panel into the cell. The gas supply system will be fed by a bottle bank, which is to be placed in an adjoining area. The laser is operated from remote terminals, typically located outside of the cell door.

The experimental test equipment inside of the cell will consist of the laser mirror assemblies, the flow nozzles and all of the necessary diagnostics. The nozzle assembly and mirror assemblies are to be fixed. The diagnostics are to be mounted on a traversing mechanism. The traversing mechanisms will be either an existing mill bed or a simpler one degree of freedom system. Both are motorized and have remote control capability. The reason for both systems being considered is for integration with the requirements of other programs using the laser. This allows for flexibility in the face of present unforeseen scheduling problems. For this program, the traversing gear is being upgraded for position measurement capability and the diagnostic modules will be compatible with both devices.

3.3 TEST SECTION AND FLOW SYSTEM SCALING

The test flow delivery assembly, shown in Figure 3.3, uses a core flow of carrier gas plus pulverized coal, surrounded by a velocity matched shield flow of inter gas. The constraints upon flow system parameters are imposed by various experimental requirements. Firstly, the required residence time (τ_{reg}) of the coal particles in the laser beam defines the flow velocity of the carrier gas. This is related to the heating rate, as

$$\tau_{\text{reg}} \approx \frac{\Delta T}{\dot{T}_p} \quad (1)$$

where ΔT is the required temperature rise of the particles, and $\dot{T}_p$ is the heating rate. The second system requirement is that the whole test region lies within the potential core of the coal/carrier jet. This precludes dilution of reaction products by the shield gas. From Figure 3-2 the depth of the test region (ℓ) is given by

$$s \approx \ell + L/4 \quad (2)$$

where L is the length of the test region (and hence the laser irradiation zone) and s is the nozzle assembly dimension. This is derived on the basis of a typical turbulent jet core being approximately $4s$ in length. For flow rates to be minimized, the nozzle is taken to be square.

J8221

Figure 3-3 Flow Nozzle Assembly

The flow velocity through the test region is given by

$$u = L/\tau_{\text{reg}} \quad (3)$$

and hence the mass flow rate of carrier gas through the nozzle is given by

$$\dot{m}_c = \frac{\rho_g L \dot{T}_p}{\Delta T} (\ell + L/4)^2 \quad (4)$$

Now, the achievable power of the laser is given by

$$\dot{H} = \bar{\Phi} L \ell$$

where $\bar{\Phi}$ is the mean flux density in the test region. Thus

$$\dot{m}_c = \frac{\rho_g L \dot{T}_p}{\Delta T} \left[\frac{\dot{H}}{\bar{\Phi} \ell} \right]^2 \quad (5)$$

Now $\bar{\Phi}$ is related to heating rate as given by

$$\frac{dT_p}{dt} = \frac{3}{\rho_s c_p a} \left\{ \frac{\bar{\Phi} \epsilon}{2} - \sigma \epsilon T_p^4 - \frac{k(T_p - T_g)}{a} \right\} \quad (6)$$

Assuming that we have approximately constant heating rate (i.e., $T_p = \text{constant}$) and the particles do not change size during heating, and the background gas temperature remains constant.

$$\bar{\Phi} \approx \frac{1}{\Delta T} \left\{ \frac{2}{3} \frac{\rho_s c_p a}{\epsilon} \dot{T}_p \Delta T + \frac{2}{5} \sigma (T_o + \Delta T_p)^5 + \frac{k}{a \epsilon} \Delta T_p^2 \right\} \quad (7)$$

Thus it can be seen that, for a given final particle temperature,

$$\bar{\Phi} \approx A \dot{T}_p + B$$

where A and B are constants. Using Eqs. (5) and (7) the required flow rates can be calculated for given required heating rates and realistic values of laser beam depth. Typical design conditions are shown in Table 3-1. For gas sampling purposes, ℓ should not be less than 1.0 cm. For efficient use of the carrier gas, the nozzle depth should be as small as is feasible. In addition to the carrier gas, a shield gas flow is required. To minimize residence time errors, the flow velocity of the shield flow is matched to that of the carrier gas. This defines the shield gas flow requirements, for a given geometry. The width of the shield flow nozzle is more arbitrary than for the coal/carrier nozzle.

However, a reasonable value of 2.0 cm gap between inner and outer walls has been chosen. As can be seen the carrier flow requirements are small, being of order 10 scfm. However, the shield gas flow rates are much greater than the carrier flow rates, and dominate the design of the flow system. The nominal design condition of a carrier gas nozzle dimension of 3.0 cm appears adequate for most of the range of conditions considered. At the low heating rate conditions, this test section is sufficiently large that no significant loss of experimental resolution is lost by using a smaller test section than the analysis would indicate.

3.4 EXPERIMENTAL FABRICATION

The flow nozzle assembly, as illustrated in Figure 3-3 is being fabricated at this time. The nozzle blocks are being made from plexiglass; this will allow flow visualization experiments to

Table 3-1

NOMINAL DESIGN CONDITIONS FOR FLOW SYSTEM

Heating Rate $\dot{T}_p$ (K/s)	Minimum Required Nozzle Dimension s (cm)	Beam Dimensions		Mean Flux Density $\bar{\Phi}$ (W/cm ²) *	Flow Rates	
		L (cm)	l (cm)		Carrier	Shield (SCFM)
10^4	4.0	12.0	4.0	207	3.5	12.2
5×10^4	3.2	8.8	3.0	378	7.9	36.9
10^5	3.11	8.5	2.0	592	14.5	69.1
5×10^5	2.09	4.34	1.0	2302	16.7	134.3
10^6	1.56	2.25	1.0	4439	9.7	118.4

*Double Pass System. Nominal 10 KW Laser Power

be carried out in order to assess the uniformity of the coal/carrier gas stream. The gas handling system has been partially fabricated and will shortly be integrated with the laser facility.

The coal feeding system is undergoing fabrication at this time, and will be tested in the near future. The chosen system is a consequence of the low flow rates required by the experimental size constraints. At flow rates of order 10 gm/min of pulverized coal existing screw and rotary feeder approaches become difficult to operate for steady flow delivery. The use of an aspirated fluidized bed will enable far more accurate and repeatable coal flows to be established. A schematic of the coal feeder is given in Figure 3-4.

3.5 WORK FORECAST

Most of the design decisions have been made and fabrication of the flow facility is underway. Integration of the diagnostics and flow system into the test cell has to be carried out prior to experimental testing. Component and subsystem testing and integration will be carried out in the next three months.

The laser mirror design issue is being closely examined at this time. The cost effectiveness and experimental utility of given mirror system is being evaluated by our optical engineering staff.

At this time, the scheduled starting date for experimental testing is in accord with previous plans. The test plan requires use of the laser for one week out of three, starting in June 1981.

J 8222

Figure 3-4 Coal Feed Assembly