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~~FE-30290-20~~

PREIGNITION VOLATILE YIELD AS RELATED TO COAL
CHARACTERISTICS

Quarterly Report for Jan. 1981 - Mar. 1981

AVCO EVERETT RESEARCH LABORATORY, INC.
a Subsidiary of Avco Corporation
2385 Revere Beach Parkway
Everett, Massachusetts 02149

April 1981

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prepared for

U.S. DEPARTMENT OF ENERGY
Contract No. DE-AC22-80PC30290

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1.0 CONTRACT OBJECTIVE

The objectives of this work is to determine the total release of volatile material from a variety of coals under high heating rates and high temperature and to study the effects of enhanced volatile matter release on the design of pulverized coal combustion systems.

2.0 SUMMARY OF PROGRESS

Task 1 - Selection and Characterization of Coals

Four coals were approved for investigation. Samples of three of these have been received from their respective mining companies and are currently being characterized and tested.

Task 2 - High Heating Rate, High Temperature Testing

Shakedown runs with the new reactor were completed and the results showed that the new design did improve the operability of the experimental set-up. Testing of the coals approved for this study is underway. Volatile yields of the North Dakota Zap, Montana Lignite and Illinois No. 6 were measured at two temperatures and were shown to range from 40 to 85%.

Task 3 - Correlation of Test Data and Coal Characteristics

Work on this task has begun; relating the test data with the coal characteristics developed from the chemical and physical examination of the coals. Initial correlation shows that the measured range of carbon conversions of between 40 and 85% is a function of temperature, rank and carbon content.

Task 4 - Computer Projections on Combustor Design

The AERL coal combustion model has been modified to allow staged mixing of the secondary air with the primary mixture of coal, air and recirculated gases. This modification will allow exploration of the effect of preignition volatile yields on flame stability.

3.0 TECHNICAL STATUS

Task 1 - Selection and Characterization of Coals

Four of the eight coals previously suggested (see last Quarterly Report) were approved for the investigation. These were the four lowest rank coals of those suggested. The approved coals and their general analysis are listed in the following table.

Samples of all except the Texas Lignite have been received and are undergoing chemical and physical characterization. The Texas Lignite has been ordered and delivery is expected in April.

TABLE I
COALS RECOMMENDED FOR INITIAL INVESTIGATION

Coal Seam/Location (Rank)	PROXIMATE			ULTIMATE					
	M	V.M.	F.C.	A	C	H	O	N	S
Ill. No. 6/Ill. (High Vol. Bit.)	8.9	38.0	41.7	11.4	62.4	5.4	16.3	1.2	3.3
Rosebud/Mont. (Subbit.)	13.1	29.8	48.9	8.2	62.7	5.5	22.3	0.9	0.4
Darco/Texas (Lignite)	33.6	25.9	29.7	7.8	44.1	6.6	46.1	0.9	0.9
Zap/N. Dakota (Lignite)	35.2	26.4	31.2	7.2	41.8	6.7	43.0	0.6	0.7

Task 2 - High Heating Rate, High Temperature Testing

During the second quarter of this project, the work done on Task II involved (i) comparing the data obtained from the new reactor with the reactor used previously in the study of high temperature pulverized coal pyrolysis at AERL, (ii) finalizing the conditions at which runs are to be made with the twelve selected coals and (iii) conducting devolatilization runs with three of the twelve coals at two different temperatures.

The present reactor has been described in detail in the first quarterly report. For comparison between the new and old reactors, high heating rate and high temperature runs were carried out with Illinois #6 coal at the same conditions where data have been obtained using the previous reactor. The Illinois #6 coal used was separated into fine and coarse fractions with the fine/coarse limit set at a nominal 10 μ . Figure 1 shows the comparison of the mass yield of volatiles obtained from the two reactors. This figure shows that at low temperature there is no substantial difference in the results from these two reactors. The improved design of the new reactor manifests itself in the higher temperature runs where the lower volume of the gases makes the results more sensitive to the improved design which allows more complete suspension of the

Fig. 1 Comparison of Data from Old Reactor and New Reactor

coal particles in the reactive gases. Figure 1 also shows that a higher yield of volatiles was obtained using the fine fraction. However, the two size fractions also differ in chemical composition with the fine fraction having a higher percentage of ash.

For the twelve selected coals, the devolatilization runs will be carried out with N_2/O_2 ratios of 4 and 9 which corresponds to peak temperatures of 2400K and 1600K, respectively. For the majority of the runs, a 70% through 200 mesh size coal will be used. The mass loading of DAF coal to steam will be kept at 0.4 for all the runs. The devolatilization will be carried out at peak pressures of 10-15 atm. This condition is a compromise between having sufficient samples (gas and char) for accurate analysis and the desire to limit the pressure at which coal devolatilizes.

At this stage, tests on three of the twelve coals have been carried out at the stated conditions. The three coals are Zap, Rosebud and Illinois #6. For these coals, the results (see Fig. 2) show a higher volatile yield is obtained at the higher temperature, and the yields appear to decrease with rank, i.e. Zap and Illinois #6 give the highest and lowest yields, respectively.

Task 3 - Correlation of Test Data and Coal Characteristics

This task involves the correlation of the volatile yields measured in Task 2 with each of the coal characteristics measured in Task 1. Figure 3 shows an example of such a correlation plot; in this case, the percentage of C in the coal converted to gaseous species is plotted against the percent carbon (DAF basis) of the coal and this gives an indication of the variation of volatile yield with coal rank. This task is still in the preliminary stage and as new results are obtained, the plots will be updated.

Task IV - Computer Projections on Combustor Design

The coal combustion code has been modified so tests accommodate staged combustion as it is projected to occur in a swirl burner.

A. Modifications

The code prior to modifications allowed only 2 streams to mix and burn. However, in a swirl burner, three streams are involved, viz: a) Primary air stream loaded with coal particles, b) Hot recirculation zone gas stream (R Z gas), and c) swirling secondary air stream. The streams a and b mix first over a time

Fig. 2 Percent of Total Carbon in Coal Converted to Gaseous species. Δ = Zap; O = Rosebud; $\square$ = Illinois #6.

Fig. 3 Variation of Carbon Conversion with Temperature and % Carbon in Coal.

interval of t_{mix} (see Fig. 4) and partially burn.. After a time delay, t_{delay} , the stream c mixes gradually with partially burned products over a time interval, t_3 . In order to handle this situation, the code has been modified to allow three streams mixing, but the third stream is allowed to mix only after a specified time delay.

B. Results

The results for a specific case are shown in Fig. 5. The parameters used in the calculation are listed below.

Coal: Illinois #6

Primary Air	=	20% of total air
Equivalence Ratio	=	0.9
R Z Gas Fraction	=	46.9%
S. Air	=	39.0%
Solid Loading (overall)	=	4.4%
P. Air Fraction	=	9.7%
R Z Temperature	=	1600K
Volatile Yield	=	54%
t_{mix}	=	5 ms
t_{delay}	=	20 ms
t_3	=	30 ms
S. Air Temperature	=	500K

When the primary stream first mixes with hot R Z gas, the gas temperature in the vicinity of the particles rise rapidly and oxygen concentration falls off. Coal particles heat up rapidly and very fine particles pyrolyze. Within 20 ms, there is about 16% fuel gasified (Fig. 6). Since primary air is 20% of the total air, and since total air itself is in excess by 10%, the overall stoichiometry at $t = 20$ ms is lean. The primary air fraction must be reduced still further to achieve faster rise in gas temperature.

When secondary air at 500K is introduced, oxygen concentration increases to supply the necessary oxygen for completing the combustion, but the gas temperature drops down since the amount of enthalpy drop due to mixing of secondary air is more than the amount of heat gained due to combustion. When the oxygen concentration is sufficiently high, the heat liberation overtakes the

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Fig. 4 Schematic of the Modification to Coal Combustion Code.

Fig. 5 Effect of Staged Mixing on Gas Temperature.

Fig. 6 Released Fuel Fraction vs time.

enthalpy drop and the gas temperature rises again at about 100 ms (Fig. 5). The fraction of primary air, the point of introduction of secondary air (i.e. t_{delay}) and the rate of mixing of the secondary air (t_3) must be such that the combustion must have progressed enough within the available residence time to attain an R Z temperature at least equal to the assumed R Z temperature for the calculation.

C. Summary

With the present modification, we will be able to project:

1. The optimum primary air fraction as a function of volatile yield (this will then allow the development of a relationship between burner thruput and burner diameter).
2. The optimum point of secondary air injection as a function of volatile yield to achieve flame stability.