MASTER

DOE/PC/30290--T1

~~FE-30290-10~~

PREIGNITION VOLATILE YIELD AS RELATED TO COAL
CHARACTERISTICS

Quarterly Report for Oct. 1980 - Dec. 1980

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

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

January 1980

prepared for

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

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

1.0 CONTRACT OBJECTIVE

The objective 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

A list of eight coals ranging in rank from anthracite to lignite was submitted for approval. These eight coals would comprise the initial set of coals to be investigated. Others would be added as the study proceeds.

Task 2 - High Heating Rate, High Temperature Testing

The test reactor was modified to improve its operability and the precision of test results.

Task 3 - Correlation of Test Data and Coal Characteristics

This task is scheduled to begin in the next quarter.

Task 4 - Computer Projections on Combustor Design

The computer model, previously developed at AERL, for the study of pulverized fuel processing is being modified to investigate the effect of variations in preignition volatile release on the suspension burning of coal in a conventional swirl burner.

3.0 Technical Status

Task 1 - Selection and Characterization of Coals

The published properties of over fifty coals were reviewed for the purpose of selecting candidates for initial study. In the selection process, we first limited our choice to whole coals that are currently being mined with reported reserves of greater than 100 million tons. We then classified these coals, according to rank; anthracite, medium volatile bituminous, high volatile bituminous, subbituminous and lignite. We reduced this list to about twenty coals on the basis of their known availability in small research quantities. We based the final selection on the diversity of petrographic activity, i.e. we attempted to select, where possible, petrographically active and inactive coals within the same rank. The eight coals that we recommended for the initial phase of our study are given in Table I.

TABLE I
COALS RECOMMENDED FOR INITIAL INVESTIGATION

Coal Seam/Location (Rank)	PROXIMATE			ULTIMATE						PETROGRAPHS
	M	V.M.	V.C.	A	C	H	O	N	S	Active/Inert*
#8 Leader/Pa (Anthracite)	1.25	7.01	83.52	8.22	83.7	3.6	2.8	0.5	1.0	-
Upper Eagle/W.Va. (Med. Vol. Bit.)	-	23.9	70.4	5.7	-	-	-	-	0.84	1.8
Middle Eagle/W.Va. (Med. Vol. Bit.)	-	25.7	70.9	3.4	-	-	-	-	1.17	4.3
Lewiston/W.Va. (High Vol. Bit.)	2.0	35.2	56.6	6.2	78.4	5.3	7.9	1.4	0.8	1.6
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	5.7
Rosebud/Mont. (Subbit.)	13.1	29.8	48.9	8.2	62.7	5.5	22.3	0.9	0.4	3.6
Darco/Texas (Lignite)	33.6	25.9	29.7	7.8	44.1	6.6	46.1	0.9	0.9	woody**
Zap/N. Dakota (Lignite)	35.2	26.4	31.2	7.2	41.8	6.7	43.0	0.6	0.7	attrital**

* In calculating the active/inert maceral ratio, the Vitrinite, Exinite, Resinite and part of the Semi-Fusinites were considered to be active macerals and Fusinites, Micronites and the remainder of the Semi-Fusinites were considered inert. The classification of the Semi-Fusinite macerals as reactive or inert depended on the rank of the coal.

** Since all lignites are relatively active, it is considered more relevant to classify them according to their origins, i.e. woody or attrital (resinous).

Task 2 - High Heating Rate, High Temperature Testing

During the first quarter of this project, the work done on Task II was mainly concerned with the setting up and testing of the reactor for the coal devolatilization experiments, and the gas chromatograph for the analysis of the volatiles. A schematic of the reactor is shown in Fig. 1. This reactor is a modification of the reactor used in the previous study of high temperature pulverized coal pyrolysis and gasification at AERL. The two major modifications are the shape of the reactor and the material of construction. The previous reactor was an aluminum cylinder with steel end plates. In the present reactor, the absence of sharp corners will ease the collection of char after the devolatilization run. In addition, the present reactor is an all stainless steel vessel, and this should minimize pitting of the reactor walls and ease cleaning of the reactor. The other features of this reactor are basically the same as the previous reactor. The quartz pressure transducers mounted on the walls of the vessel are capable of measuring the very rapid, high pressure changes encountered in this work. Before each run, pulverized coal is placed on top of the perforated plate and the air in the chamber is evacuated. The reactor is preloaded with an O_2-N_2 mixture and the high pressure reservoir is filled with an H_2-N_2 mixture. Dispersion of the coal occurs when the gas mixture from the high pressure reservoir is impulsively loaded into the reactor with the opening of the fast-acting ball valve for a few milliseconds. Ignition of the gas mixture in the reactor is then initiated with the spark plug. The sequence of events as they occur in the reactor during a test run is illustrated in Fig. 2.

At present the reactor and the gas handling system have been set up and leak-testing of these systems have been completed. The selection of the operating conditions and column for the gas chromatograph has been completed and the gas chromatograph is now ready for sample analysis. The work in progress includes testing and experimenting with the timing electronics to control the impulsive gas leading from the high pressure reservoir so as to obtain the correct gas mixture in the reactor and to synchronize

J8463

Fig. 1 SCHEMATIC OF REACTOR FOR COAL DEVOLATILIZATION EXPERIMENTS

HI432

Figure I-5 Timing Diagram-Sequence of Events in Explosion Driven Batch Process Reactor

the dispersion of coal and the ignition of the gas mixture in the reactor. The last phase in checking out the reactor is to repeat some of the runs carried out with the old reactor used in the previous gasification work at AERL. These runs will begin within the next week. After the completion of the testing of the reactor, the runs with the coal selected for this project will be carried out.

Task 3 - Correlation of Test Data and Coal Characteristics

Work on this task is not scheduled to begin until February.

Task 4 - Computer Projections on Combustor Design

The computer model for the study of pulverized fuel processing is being modified to reflect the effect of variations in preignition volatile yields on the burning of coal in a conventional swirl burner. Two important criteria which define the performance of suspension burning of a solid fuel in a swirl burner are: i) flame stability and ii) combustion efficiency. Both of these parameters depend strongly on the ratio of kinetic or combustion time scales of the fuel to the residence time available in the vicinity of the recirculation zone of the swirl burner. [Annamalai and Stickler]

The kinetic time scale increases significantly with both particle size and moisture content. For a given size and moisture, it is dominated by the slow burning char particles if volatile yield is low. Furthermore, these char particles are subject to radiative extinction in the far field of the recirculation zone, affecting both combustion and pollutant production. On the other hand, if the major mass fraction of the solid fuel is converted by pyrolysis into volatiles, the pyrolysis process, including particle heating, will dominate the reaction time scale, since the combustion time scale of gas phase volatiles is small at boiler combustion conditions.

Another design consideration related to pyrolysis release is that the residual char may be more porous when volatile yield increases; thus, the available reaction surface area for heterogeneous oxidation is increased which again can reduce the kinetic time scale.

Finally, the optimum percentage of primary air relative to coal particle feed is affected by volatile yield. Normally the

primary air flow is chosen such that the primary air is in stoichiometry with the volatile matter content of the finer fraction of the coal feed so that the flame velocity is a maximum, and flame stability is maximized. However, with volatile yield much greater than defined by the proximate analysis test, the primary air fraction may require an increase to optimize performance. Depending on the correlation of high heating rate volatile production with proximate, this may impose rather different proportioning, as fuel is changed, than would be expected. Recently, it was also suggested analytically that increased volatile yield increases the flame velocity of coal: air flames [Yip, et al]. This suggests that the overall kinetic time scales may be reduced with increased yield.

Consequently, enhanced pyrolysis yield at high heating rate may function in three ways in boiler combustion: i) enhanced mixture ignitability, resulting in a heat release closer to the input structure; ii) enhanced combustion rate, allowing easier overall stabilization of the flame; and iii) enhanced fuel burnout both in the vicinity of the recirculation stabilization region and downstream of it.

The existing combustion model, previously developed at AERL, Inc. for general modeling of pulverized fuel processing, is being modified to investigate these effects in a semi-quantitative manner. The flow, mixing and radiative environment of a swirl are simulated, while the combustion history of the fuel is predicted as a function of such fuel-related parameters as size distribution, volatile yield and char reactivity. Primary stream stoichiometry and mixing behavior are also variable. Using this code, the effect of volatile yield on flame stability and fuel utilization will be investigated, with reference both to its variation among coals and the difference between proximate and high heating rate results.

References:

1. Annamalai, K. and Stickler, D.B., "Wood Combustion In A Swirl Burner", Eastern Section of the Combustion Institute, Princeton Univ. Nov. 12-14, 1980.
2. Gary Yip, T.W., Krier, H. and Buckian, R.O., "Modeling The Effects of Volatile Content and Heat Loss on The Flame Propagation of Coal: Dust Air Mixtures", Eastern Section of the Combustion Institute, Princeton Univ., Nov. 12-14, 1980.