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TECHNICAL REPORT

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INTEGRATED METHODS FOR PRODUCTION OF CLEAN CHAR
AND ITS COMBUSTION PROPERTIES

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ABSTRACT

The overall objective of this two-year program is to produce clean char using an integrated process scheme which combines physical coal cleaning, mild gasification and char oxydesulfurization. Low sulfur chars which could be used in utility boilers to meet 1995 emission standards of 2.5 lbs SO₂/MMBtu are produced from Illinois coals having emissions of >5 lbs SO₂/MMBtu.

Mild gasification and low temperature oxidation studies for sulfur removal are conducted with selected coals from the Illinois Basin Coal (IBC) Sample Program in a batch fixed-bed reactor at the ISGS. Pound quantities of chars for combustion testing are prepared in a continuous rotary kiln reactor under optimized conditions of mild gasification and oxydesulfurization. Burning characteristics and ash deposition behaviors of desulfurized chars are determined to ensure that a useable fuel is produced. These tests are done at the University of North Dakota Energy and Environmental Research Center (UNDEERC) in a drop tube furnace (DTF), and at the U.S. EPA in a 14 kW pilot-scale combustor. In some tests, methane is examined as an auxiliary fuel, and high-surface-area hydrated lime developed at ISGS is used to further reduce SO₂ emissions. Complete analyses of the fuels are obtained to aid char desulfurization studies and help explain combustion and SO₂ emission characteristics of the char. This project is a cooperative effort between the ISGS, UNDEERC and the U.S. EPA and is cost-shared with the U.S. EPA and the U.S. DOE through UNDEERC.

During the reporting period, an engineering student was hired and trained in proper laboratory procedures. Six coals were obtained from the IBC Sample Program. Distinct size fractions of each coal are currently being prepared, and preliminary tests have been done. The data are currently being analyzed.

This project is funded by the U. S. Department of Energy (METC) and by the Illinois Department of Energy and Natural Resources as part of their cost-shared program.

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EXECUTIVE SUMMARY

Much of the coal mined in Illinois is high-sulfur, high volatile bituminous coal. Many existing utilities burning high-sulfur Illinois coals must consider alternatives to meet 1995 and 2001 emissions guidelines of 2.5 and 1.2 lbs SO_2 /MMBtu. The use of a low cost, low sulfur char could be an attractive alternative to coal-switching or coal-blending which decrease utilization of Illinois coal. In addition, the low sulfur char could be used by utilities which can not add scrubbers due to cost or space limitations. The low sulfur char can be used directly as a compliance fuel, co fired with methane, or blended with Illinois coal to reduce emission levels of the coal.

The goal of this two-year project is to produce clean char using an integrated process scheme which combines physical coal cleaning, mild gasification and char oxydesulfurization. Low-sulfur chars which could be utilized in utility boilers to meet 1995 emission standards of 2.5 lbs SO_2 /MMBtu are produced from Illinois coals having emissions of >5 lbs SO_2 /MMBtu. This work is a cooperative effort between ISGS, UNDEERC and U.S. EPA and is cost-shared with the U.S. EPA and the U.S. DOE through UNDEERC.

The project has six tasks. In the first task, screening studies are conducted to select candidate coals for clean char production. Chars from six coals are produced under mild gasification conditions in a batch 3-inch i.d. fixed-bed reactor, previously used to produce premium liquids from Illinois coal. In the second task, chars are subjected to low temperature oxidation to remove additional sulfur. Optimized conditions for maximum sulfur removal are determined for coals selected from screening studies.

In the third task, low sulfur chars are prepared for combustion testing and ash deposition studies. Fifty pounds of low sulfur chars are prepared on a continuous basis in a rotary tube kiln (RTK) under conditions determined from batch studies. Coal-char blends having 25 and 35 percent volatile matter (VM) are prepared from the chars.

In the fourth task, combustion behaviors of the desulfurized chars are determined in a 14 kW pilot-scale combustor at U.S. EPA. Baseline combustion and SO_2 emission data are obtained at U.S. EPA for the fuels. The char is also co-fired with methane to determine the benefit of an auxiliary fuel. Additional combustion tests at U.S. EPA are conducted for each sample with injection of high-surface-area hydrated lime developed at the ISGS to further reduce SO_2 emissions.

In the fifth task, ash deposition behaviors are obtained for selected fuels in a drop tube furnace (DTF) at UNDEERC under one condition. Deposits are produced on a cooled boiler steel substrate. Sticking coefficients and deposit strengths are determined for these deposits. The deposits will be examined by scanning electron microscopy-point count analysis (SEMPC). The SEMPC technique was developed at UNDEERC to

quantify inorganic phases in ash or deposits.

In the sixth task, physical (porosity, pore surface area and particle size distribution) and chemical (proximate and ultimate analyses, ash chemistry and ash fusion chemistry) properties of the fuels are obtained to aid desulfurization studies and to help explain combustion and ash slagging and fouling properties.

During the reporting period, an engineering student was hired and trained in proper laboratory procedures. Six coals were obtained from the IBC Sample Program. Distinct size fractions of each coal are currently being prepared, and preliminary tests have been done. The data are currently being analyzed.

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.

OBJECTIVES

The objectives of this research are to produce a clean char and determine combustion and emission characteristics of the char and coal-char blends.

The specific goals of the contract are:

- A. Determine oxydesulfurization potential of various Illinois coals.
- B. Modify an existing rotary tube kiln (RTK) for continuous char production and low temperature oxidation tests.
- C. Prepare pound quantities of clean char in the RTK.
- D. Prepare coal-char blends with 25% and 35% VM.
- E. Obtain physical and chemical properties of the fuels.
- F. Determine combustion properties and SO_2 emissions of coal, char, and coal-char blends under conditions representative of coal-fired boilers.
- G. Determine ash deposition behaviors of selected fuels under conditions representative of coal-fired boilers.

INTRODUCTION AND BACKGROUND

In the past several years, the CRSC and U.S. DOE have funded research programs which have focused on producing premium liquids by mild gasification of coal. The principle product (about 60-70 percent by weight) of mild gasification processes is a partially devolatilized coal (herein referred to as char) that must be effectively utilized to help the overall economics of the process. The loss of VM indicates loss of hydrocarbon materials from the coal that are desirable for ignition, carbon burn-out and flame stability. In addition, the char produced from processing high-sulfur Illinois coals still contains a high residual sulfur content which exceeds the 1995 and 2001 emissions limits of 2.5 and 1.2 lbs SO_2 /MMBtu.

To meet 1995 emissions guidelines, utilities burning high-sulfur Illinois coal are considering coal-switching or blending Illinois coal with low-sulfur western coal. Either scenario would ultimately decrease utilization of Illinois coal. Another alternative is using post-combustion scrubbers to remove SO_2 from stack gases. However, scrubbers are too costly for older plants and are not suitable for utilities with limited space for installing a unit. In addition, not all utilities can build and operate scrubbers by 1995 even if they desire to do so. Therefore, alternatives must be developed to be used until 2001.

Investigators at the ISGS have previously studied gas phase desulfurization by hydrogen treatment (Stephenson et al., 1987). Although a low sulfur char can be achieved by hydrogen treatment, the process would produce a char that would be difficult to burn because of reduced VM and reactivity due to the relatively high processing temperature. Recent research conducted by the investigators at the ISGS and others suggest that a high-sulfur Illinois coal (many emitting >5 lbs SO_2 /MMBtu) may produce a clean char with 18 percent VM and emissions of <2.5 lbs SO_2 /MMBtu by selecting appropriate conditions during mild gasification followed by a low temperature oxidation step. However, neither optimized conditions for sulfur removal, nor combustion characteristics of the clean char have been researched extensively. Combustion characteristic data obtained at the ISGS under several CRSC-funded programs indicate that the char derived under mild gasification conditions, when mixed with coal to make a 25 percent VM blend, can be burned with an acceptable combustion efficiency in pulverized coal (PC) boilers (DeBarr et al., 1991).

A low sulfur char can be burned at a compliance level in a boiler designed to burn low volatile fuels, or in conventional PC boilers with or without an auxiliary fuel such as methane or by blending with high-sulfur Illinois coal or low-sulfur Western coal. A low sulfur char could also be an ideal feed stock for production of oxidized char or carbon molecular sieves. Methods for producing these two valuable products from Illinois coal are currently being studied at the ISGS (Kruse et al., 1991; Lizzio et al., 1991).

RESULTS AND DISCUSSION

The first objective for this years' work is to perform screening tests to evaluate the effectiveness of the proposed methods on desulfurization of various coals. Six coals have been obtained from the IBC sample program, including IBC-101, 102, 104, 105, 106 and 109. Appropriate size fraction of the coals are currently being prepared for use in screening tests. An undergraduate engineering student has been hired and trained to aid in sample preparation and data collection.

SUMMARY AND CONCLUSIONS

During the reporting period, an undergraduate engineering student has been hired and trained to aid in sample preparation and data collection. Appropriate size fractions of coals selected from the IBC sample program are currently being prepared.

During the next quarter, research efforts will focus on screening tests to select candidate coals for further investigation.

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