DOE/TIC--2006853

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DE82 006853

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ATOMIZATION CHARACTERISTICS OF COAL SLURRIES

First Quarterly Report
September 1 - November 30, 1981

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1. INTRODUCTION

In the combustion of liquid fuels, it is known that atomization affects the efficient combustion of the fuel. This has led to the development of a number of types of atomizers and also to studies on the fundamentals of the atomization process (1). With a fuel such as coal in oil, the process of atomization is complicated by the presence of solids in the liquid. While the importance of the process to efficient combustion remains, there has been very little work contributing to its understanding. Only recently has work been started on atomization of coal-oil mixtures (2,3). A slurry fuel of revived and significant interest is coal in water (4). This slurry differs from coal in oil in the obvious sense that the liquid (water) is non-combustible and, therefore, it would seem that its combustion properties would correlate with that of the coal. But, the water has to be evaporated from the coal and this would depend on the drop sizes coming from the atomizer. Also, there are observations that suggest that the "coal-water flame" may appear to be like an oil flame (5). The reasons for this are not clear, but, if true, this has important implications for coal-water mixture as a retrofit fuel for furnaces designed to burn oil. For these reasons, the importance of studying atomization has been recognized (4) and the present work is one attempt towards understanding atomization of coal-water mixtures.

2. PROPOSED WORK

The work is broken down into several tasks which will be accomplished over a period of two years. The tasks include:

1. Selected review of solid-liquid mixture flow properties relevant to atomization and an update of slurry atomization review;
2. Measurement of drop size characteristics of coal-water mixtures as a function of the key atomizer parameters for an air atomizer;
3. Analysis and correlation of the data; and
4. Preparation of a final report summarizing the results of the work.

3. TECHNICAL PROGRESS IN THE QUARTER ENDING NOVEMBER 30, 1981

The work done in this period included:

1. Modification of the atomizer test rig;
2. Measurements using water;
3. Measurements using a low coal concentration coal-water mixture; and
4. A continuing review of slurry atomization literature;

and is described below.

3.1 Experimental System Modification

A test rig had been built to provide a means of spraying coal-oil mixtures. This had no provision for measurements on the spray. This rig forms the basis of the atomizer test rig for coal-water mixtures and Fig. 1 shows it in the present form. The major addition to the rig has been the installation of a Malvern particle sizer. A number of other modifications had to be done to provide for the flexibility needed to test atomizers for coal-water mixtures. One of these was the inclusion of a by-pass system to provide independent control of the fuel (coal-water) flow rate as that provided in the variable speed positive displacement pump was found to be insufficient. Also, the spray exhaust system needed an extension to confine the spray and prevent it from dirtying the particle sizer lenses. It is expected that modifications will continue to be required as the experimental measurements progress.

The Laser transmitter and the receiver of the Malvern particle sizer were removed from their common base. Another base was constructed to fit on the atomizer test rig and to permit unimpeded spraying into the slurry holding tank. The transmitter and receiver were mounted on this base and re-aligned.

It was decided to use a Delavan Air Atomizing Nozzle - AIRO 30615-3 - for the present tests as this was readily available and fitted the constraints of flow rates, etc. of the system.

3.2 Baseline Atomization Measurements Using Water

It is a purpose of the present program to contribute towards the understanding of slurry atomization by building on what is known about liquid atomization. Hence, it was decided to carry out first atomization tests using water. These results would form the baseline and any departures from these

for coal-water mixtures could be attributed to the presence of coal particles. Previous measurements and correlations for liquid atomization suggest that the ratio of the rates of atomizing air flow to fuel flow and atomizing air pressure could be the key parameters determining atomizer performance. The measurements were, therefore, carried out as a function of these parameters and the results are reported below.

Two air pressures were chosen, within the design range for the nozzle, at which to measure drop size as a function of water to air ratios. The Malvern particle sizer was set to fit a Rosin-Rammler distribution to each measured drop size distribution. The Mass Mean Diameters (MMD) are calculated from these distributions and plotted against the ratio of water flow rate to air flow rate in Fig. 2. A typical Rosin-Rammler distribution is given in Fig. 3.

3.3 Atomization Measurements Using a 33% Coal-Water Mixture

A coal-water mixture (CWM) containing 33% coal was tested after the water tests. The coal had been obtained pulverized from the Empire Coke Co. and its properties are given in Table 1. The tests were run at the same atomizing air pressures (20 psig and 30 psig) as for the water. The data is shown similarly plotted in Fig. 4 and a typical Rosin-Rammler distribution is given in Fig. 5.

Table 1. Properties of Coal Used

Ultimate Analysis:		
(% by weight)		
C		78
H		5.1
N		1.6
Ash		8
Higher Heating Value:		
cal/gm (Btu/lb)		7700 (13,900)
Ash Fusion Temperatures:*		
°C (°F)		
Initial Deformation	1270	(2320)
Softening	1370	(2500)
Hemispherical	1430	(2600)
Fluid	1500	(2740)
Size Distribution:		
% by weight smaller than		
37 microns		7.9
74 microns (200 mesh)		69.1
150 microns		99.1
250 microns		99.9

*Test conducted by Fuel Engineering Company of New York.

3.4 Slurry Atomization Literature Review

As part of this program, a review of recent slurry atomization literature will be provided. The work done towards this during the quarter will be summarized here.

As mentioned earlier, there is very little published information on solid-liquid mixture atomization. Masters' Spray Drying Handbook contains no references to slurry atomization. Three references that have bearing on coal-water atomization were found in a search of the literature and are briefly reviewed here.

Reference 6 studied the effect of coal concentration on the breakup of coal-water slurry drops. This was done by dropping large coal-water drops into an air stream, measuring the velocity required for breakup and also observing this breakup pattern. The quantitative conclusions and their significance is not clear at present. The qualitative observation reported was that at large coal concentrations ($\sim 50\%$), the drops broke up at a lower Weber number than at intermediate concentrations and the pattern of breakup suggested that the drop broke without much initial deformation of the surface. The authors take this to mean "that atomization of such (solid-liquid) fuel mixtures should not involve great difficulties."

Reference 7 is primarily a theoretical paper examining the possible modes of breakup of slurry drops and the resulting drop size distribution. These considerations arise because the solid particles have a size distribution that is not affected by the atomization and depending on the distribution of the solid particles in the liquid droplets, the defined mean diameter can be different. They calculate these theoretical mean diameters under different assumptions for low and high solids concentrations.

Reference 8 describes the measurements of drop size distribution in a coal-liquid mixture. The liquid used was benzoic acid as the sizes were measured by freezing the drop after atomization. A pressure atomizer was used. The key results can be summarized as follows. The Rosin-Rammler parameters changed with the coal concentration in the mixture, and the mean drop size increased with solids concentration. The nozzle clogging set a limit to the maximum possible solids concentration.

4. OBSERVATIONS FROM THE ATOMIZATION MEASUREMENTS

Figures 2 and 4 show that the basis chosen for representing the data appears reasonable so far. In Figure 6, the data for water and coal-water are compared on the same basis. Rather surprisingly, over the range of measurements carried out so far, this indicates a smaller measured mass mean diameter (MMD) for the coal-water mixture compared to that for water at the same fuel/air flow ratio. This is in apparent contrast to the data of Reference 3 on coal-oil mixtures and reference 8 on coal-benzoic acid mixtures; but there are significant differences in the experimental conditions and so it is not clear whether the contrast suggests anything yet. In reference 3, the data is compared at the same fluid temperature while in reference 8 a pressure nozzle was used and the data compared at the same fluid pressure.

The representation of the data in Figs. 3 and 5 suggests only that within the accuracy of the measurement method, the drop size distribution is reasonably well represented by the Rosin-Rammler function.

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ATOMIZER TEST RIG

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6