Objectives

The objective of this study is to investigate the use of pulse combustion to provide the energy required for the endothermic gasification of black liquor in a fluidized bed. In this process it is critical that the temperature remain in the small window above the gasification temperature but below the smelting temperature of the inorganic salts in the black liquor. Pulse combustors have been shown to have high heat transfer rates between the hot combustion products and the combustor tailpipe. Similarly, fluidized beds have high heat transfer rates within the bed itself, promoting temperature uniformity throughout. By combining a pulse combustor with a fluidized bed as the means of supplying energy to the gasification process we take advantage of the high heat transfer rates associated with each.

Typical analysis of the gasified black liquor shows there is a large percentage of combustible gases in the products of the gasification process (approximately 70%). The potential exists, therefore, for using this fuel mixture to fire the pulse combustor. This makes the entire process more efficient and may be necessary to make it economically feasible.

The overall goals of this study are to determine: (1) which is the limiting heat transfer rate in the process of transferring the heat from the hot combustion products to the pipe, through the pipe, from the tailpipe to the bed and then throughout the bed; i.e., whether increased heat transfer within the pulse combustor will significantly increase the overall heat transfer rate; (2) whether the temperature distribution in the bed can be maintained within the narrow temperature range required by the process without generating hot spots in the bed even if the heat transfer from the pulse combustor is significantly increased; and (3) whether the fuel gas produced during the gasification process can be used to efficiently fire the pulse combustor.
Results and Discussion

Work this quarter has mainly progressed on two fronts, experimental measurements in the fluidized bed facility and continued development of the theoretical heat transfer model described in the last report.

On the experimental side, the acoustic characteristics of the heat pipe have been fully determined by traversing a cooled microphone along the axis of the tube. This was necessary since the heater attached to the upstream end of the pipe has an unknown admittance. A technique was also developed for rapidly finding and maintaining the resonance frequency of the pipe, which varies as the temperature changes.

Early heat transfer tests have been carried out using fluidizing flow rates between zero and 30 cm/sec. The minimum flow through the bed required to cause fluidization was determined to be about 15 cm/s under present conditions. This was determined by monitoring the pressure difference between the bottom and the top of the bed which increases with air flow rate until the bed is fully fluidized.

The flow in the simulated pulse combustor tail pipe enters the facility at just over 800 °K for all test reported here. The flow rate of air in this pipe ranged from about 210 to 410 l/min, which at a density of 0.43 kg/m³ and a viscosity of 8.63x10⁻⁶ m²/sec corresponds to Reynolds numbers of 1,220 to 2,380. Lower flow rates could not be obtained without burning out the heater and would, in any case, not be relevant to practical systems. Heat losses between the heater and the fluidized bed were found to increase with increasing pulsation amplitudes. However, the output from the heater was adjusted to maintain a constant inflow temperature and, therefore, a constant enthalpy flux into the fluidized bed facility.

Early test have shown that as the flow rate of the air through the fluidized bed is increased the heat transfer from the hot air in the simulated pulse combustor tail pipe to the bed increases steadily until the bed is fully fluidized. At that point any further increase in fluidizing air flow rate has no significant effect on the heat transfer. Pulsations caused the heat transfer to increase in all cases. The precise degree of heat transfer enhancement was found to depend on the air flow rates both in the bed and in the heat pipe. These data have not yet been fully analyzed. However it is already apparent that, as expected, heat transfer coefficients could be increased both by applying pulsations and by increasing the flow rate and, therefore, the level of turbulence in the heat pipe. However, the enhancement due to pulsations dominates that due to higher Reynolds numbers for all conditions investigated so far. This is an important result since flow in practical pulse combustor tailpipes will be turbulent.

In parallel to the above experiments, heat transfer rates from the hot gases to the inner pipe walls and from the outer pipe walls to the fluidized bed are being calculated using the theoretical model that has been developed. Heat transfer coefficients are being calculated with and without pulsations in the heat pipe. Similar to the
experimental results these calculations have shown that pulsations increase heat transfer from the gas to the inner walls. A complete, quantitative comparison with experimental data must await their complete analysis. Preliminary comparison has, however, shown that the measured heat transfer enhancement appears to be somewhat larger than that predicted.

The work related to firing the pulse combustor with gasification products has been successfully presented at the Fall Meeting of the Eastern Section of the Combustion Institute in Worcester, MA on October 17. A manuscript will be submitted to the next International Symposium on Combustion to be held in Naples, Italy before the deadline on January 15, 1996.

Future Work:

During the next performance period heat transfer experiments and their analysis will be continued. Spatial resolution of the measurements will be improved and the measurements will be extended to heat transfer within the bed.

Predictions of the model will be compared with experimental data and, following successful validation, the model will be used to guide further experimental efforts.

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