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Project Summary

Particulate Emissions and Control in Fluidized-Bed Combustion: Modeling and Parametric Performance

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A model was developed to describe the physical characteristics of the particulates emitted from fluidized-bed combustion (FBC) systems and to evaluate data on FBC particulate control systems. The model, which describes the particulate emissions profile from FBC, considers the attrition of the bed material and the recycling of the elutriated fines in addition to other FBC phenomena. For a given combustor design and set of operating conditions, the particle profile program projects the mass rate and size distribution of the solids in the bed draw-off and carry-over streams, as well as those emitted from particle removal devices of any given configuration.

Examples of particulate emission and control are given for both atmospheric-pressure and pressurized FBC systems. The effect of calcium-to-sulfur ratio, rate of sorbent attrition, superficial gas velocity, and recycle cyclone efficiency was examined by using the model. A manual for the particle profiles program comprising a quick-reference user's section, as well as a more detailed descriptive section, is provided in the full report.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The fluidized-bed combustion (FBC) of coal offers the potential for a more thermally efficient, environmentally superior, and more economical way to use coal resources to generate electric power and to produce industrial steam than do conventional methods of coal utilization.

Many different FBC concepts have been proposed having significantly different emission behavior and control requirements. FBC concepts can be used for atmospheric (AFBC) or pressurized (PFBC) operation and for industrial or utility applications.

The conventional FBC boiler concept integrates coal combustion, sulfur control, and temperature control in a single component. In both AFBC and PFBC boilers, coal and sulfur sorbent (limestone or dolomite) are fed into a FB reactor, where the combustion of coal occurs, accompanied by the release of heat, ash, and sulfur as sulfur oxides (SO_x). The sorbent in the bed reacts with the sulfur to form a solid product, thereby reducing the release of the sulfur pollutant to the atmosphere. Most of the ash, together with some sorbent and char, is carried overhead and out of the reactor with the off-gas. The bulk of these particulate emissions may be captured in a cyclone and recycled to the bed to achieve higher carbon and sorbent utilization. Heat is extracted from the reactor by immersing the heat transfer surface in the bed to generate steam. For industrial applications the steam so generated finds use as process heat or as process feedstock. For utility applications the steam is expanded through a steam turbine for power generation. Additionally, in the case of PFBC for utility applications, the hot pressurized gas from the reactor is cleaned of particulate matter by passing it through a train of particle removal devices and then expanding it through a gas turbine for power generation. Particle emissions from PFBC processes utilizing gas turbine expanders for power generation must therefore be controlled at levels that are acceptable for reliable turbine operation. Particulate control is, therefore, a vital aspect of FBC technology.

Results and Recommendations

The particulate control problem as it relates to FBC is threefold: (1) the particle emission characteristics of FB combustors need to be determined; (2) acceptable levels of particle loadings and size distributions, from the standpoints both of environmental constraints and, for PFBC, of the requirements for reliable gas turbine operation, need to be established; and (3) an appropriate train of particulate control devices needs to be identified for reducing the particle emissions to acceptable levels.

The present work addresses two of these areas of concern. A particle profile model, incorporating the FB combustor and particulate control subsystems, has been developed that permits rational and consistent projections of solid sizes and loadings from the FB combustor and throughout the FBC system. The model considers particle attrition and the recycling of elutriated fines, in addition to other FBC phenomena, and is able to simulate gas cleaning equipment of any desired configuration.

The particle profile model is illustrated by providing some initial perspective on particle emission and control for AFBC and PFBC systems. The results of parametric studies with respect to calcium-to-sulfur (Ca/S) ratio, rate of sorbent attrition, superficial gas velocity, and recycle cyclone efficiency are described.

The particle profile model developed is highly useful for evaluating FBC design and operating conditions that relate to particulate emissions from the combustor. Particle control devices and systems integrated with FB combustors can be assessed for their ability to satify environmental standards and/or gas-turbine protection requirements. Particle attrition (sorbent and ash) represents the greatest uncertainty in the model. This could be clarified by:

- Further studies to develop increased understanding of attrition and elutriation.
- Comparison of model projections with available plant data to establish its validity and to identify and characterize controlling phenomena.

The application of the particle profile program to particle emission and control for AFBC and PFBC systems results in the following conclusions:

- The final particulate control device is of primary importance, since this filter stage determines the particle size distribution and loading released to the environment or presented to the turbine.
- FBC design and operating conditions (and resulting Ca/S ratio) have little effect on the size distribution of emitted particles for the final-stage control devices examined here.
- The selection of coal, sorbent, and FBC design will significantly affect the particle loading to the environment or to the turbine for a given final-stage device performance. The coal-ash particle size distribution, the sorbent attrition rate, and the attrited sorbent particle size distribution are important performance factors.
- The design of the FBC to minimize sorbent consumption (Ca/S) and particle attrition is important for minimizing the quantity of particles emitted to the environment or turbine.
- The recycle cyclone performance strongly influences the rate of recycling solids. The use of a high-efficiency recycle cyclone results in high solid recycle rates, but does not affect the particulate emission from the final cleaning device. The relation between recycle rate and FBC combustion and sulfur removal performance is not generally predictable. To minimize both the recycled solids handling requirement and the erosion of convective heat transfer surface above the bed, a medium-efficiency, rather than a high-efficiency, recycle cyclone should be used.
- For AFBC, commercial, final-stage particulate control devices (i.e., fabric filters and electrostatic precipitators) are available that will perform satisfactorily to meet environmental standards. Some technical problems remain to be dealt with for both fabric filters and electrostatic precipitators. Staged cyclones will be insufficient to meet environmental standards except in cases of unusual coals and sorbents.
- For PFBC, many technical and economic considerations can result in either the environmental standards or the turbine protection requirements being the most stringent and controlling the selection and design of a particulate control system. Final-stage particulate control devices are being developed for this application, but their performance and economic feasibility are not yet established

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The complete report, entitled "Particulate Emissions and Control in Fluidized-Bed Combustion: Modeling and Parametric Performance," (Order No. PB 85-152 973/AS; Cost: $14.50, subject to change) will be available only from:
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