United States
Environmental Protection
Agency

Industrial Environmental Research
Laboratory
Research Triangle Park NC 27711

Research and Development

EPA-600/S7-81-150 Oct. 1981

EPA

Project Summary

Feasibility of Coal Burning in Catalytic Combustors

P. M. Goldberg, E. K. Chu, and J. T. Kelly

The results of this study show that pulverized coal can be burned in a catalytic combustor. Pulverized coal combustion in catalytic beds is markedly different from gaseous fuel combustion. Gas combustion gives uniform bed temperatures and reaction rates over the entire bed length and, depending on flow conditions and bed geometry, little combustion may occur downstream of the bed. For the bed configurations, fuel supplies, and test conditions studied, pulverized coal combustion results in significant temperature and reaction gradients over the bed length and substantial combustion downstream of the bed. Thus, for pulverized coal combustion, the bed acts mainly as an initiator and stabilizer of combustion. A significant portion of the combustion process, primarily that associated with char burnout, occurs downstream of the bed.

This Project Summary was developed by EPA's Industrial Environmental 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).

Test results show that the coal was substantially devolatilized by the combustor for all air/fuel ratios tested. Exit gas composition results show that the extent of reaction of the coal is near the theoretical limit, given the available oxygen. Increased bed velocity brings the extent of reaction closer to the theoretical limit.

Catalytic bed operating limits are bounded by bed material upper temperature limits, lower temperature volatilization limits, thermal mass air/fuel ratio limits, and particle deposition preheat limits. Presently available bed materials limit the maximum bed operating temperature to 1900K. Based on the lower temperature results of this study and known relationships between temperature and coal volatilization histories, it appears that 1300K is the minimum bed operating temperature needed to sustain steady combustion. Above an air/fuel ratio of 6.0, bed temperatures decrease with time. This air/fuel ratio roughly corresponds with the stoichiometric air needs for only the coal volatiles. Increases of air flow above this level probably yield thermal mass loads too high for maintenance of steady state combustion conditions.

Front-end bed and air preheat temperatures must be less than 500K to avoid coal deposition on the front of the bed. Above 500K, char deposits rapidly build up on the front of the bed and plug channels. These deposits can be burned off by operating the bed on propane fuel under excess air conditions. However, after several bed cleaning cycles, sufficient ash builds up to plug bed channels. This deposition of char and ash in the bed was the major problem identified in burning pulverized coal in a catalytic combustor. Therefore, low air preheat temperatures and cooled prebed sections which prevent prebed combustion are required to reduce the potential for bed char deposition. During this study, bed channel plugging reduced the useful life of the beds to about 6 hours.

Degradation of the catalyst by chemical attack was not as severe a problem as deposition. This was confirmed by propane tests before and after coal combustion. These tests showed that previously attained gas combustion conditions could be nearly duplicated following a significant amount of coal combustion testing.

Comparison of catalytic coal combustion with conventional premixed coal combustion indicates that the presence of the catalytic bed significantly improves system volumetric heat release based on volatiles. This characteristic of the catalytic combustor could be beneficially used to reduce combustor size for a given volatiles heat release. As indicated previously, coal combustion is only initiated in the limited lengths of the catalytic combustors tested. Therefore, provision for downstream-of-bed coal burnout must be incorporated into any system design. This additional coal burnout volume will be a significant fraction of the total combustion volume.

NO emissions for the catalytic combustor are high even under fuel-rich conditions. The NO formed early under locally lean conditions does not have sufficient time within the combustor to decay under oxygen deficient conditions. No clear trend of NO emissions with extent of prebed combustion could be observed from the data. The effect of the extent of combustion before the bed versus combustion within the bed is within the fairly large data scatter for these tests. Subsequent stages with longer residence times are needed to decay NO concentrations to low levels. As expected, NO levels increase with air/fuel ratio and decrease with increases in residence time.

As indicated previously, the coal-fired catalytic combustor may have some benefit as a high heat release rate, very fuel-rich, initial flameholder which is followed by a non-catalytic coal burnout section. This type of system could have heat release, stability, and emission benefits. However, for this system to be viable, the bed deposition and channel plugging problems must be solved. Recommendations to help solve these problems include:

- Use microsized coal supplies (~1 μm size range) to minimize bed face impact and sticking. The smaller particles would tend to follow gas streamlines and thereby avoid impacts with solid surfaces over which the gas is flowing. Coal supplies could also be blended with oils to widen the operating range of the system. The coal could be ground with the oil and fed into the system as a slurry. This would eliminate grinding and feed problems associated with particles of this size range.
- Employ longer beds with actively cooled front sections to minimize front-end deposition. With a longer bed, the front end could remain cool while the back end is hot for a considerable distance. This should improve extent of reaction and stability characteristics.
- Use thin webbed beds to minimize bed front-surface area off of which coal can be scattered. Also, use round channels to minimize slow moving zones where coal particles can burn and then stick to adjacent surfaces.

These actions might improve operating characteristics and deposition problems considerably. Once this problem is alleviated, a more extensive test program could be undertaken to make a more complete assessment of the performance and emissions benefits of burning coal in a catalytic combustor. For example, complete test systems could be constructed which would consist of a rich-burn catalytic flameholder, similar to those tested herein, plus a conventional burnout section in which additional combustion air is added and heat is extracted. Results achieved with this system could then be compared to existing staged and unstaged premixed pulverized coal results and conventional diffusion flame pulverized coal burners to determine more completely the performance and emissions benefits, if any, of this type of system.

P. M. Goldberg, E. K. Chu, and J. T. Kelly are with Acurex Corporation, 485 Clyde Avenue, Mountain View, CA 94042.
***G. Blair Martin** is the EPA Project Officer (see below).*
The complete report, entitled "Feasibility of Coal Burning in Catalytic Combustors," (Order No. PB 82-102 328; Cost: $9.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Postage and
Fees Paid
Environmental
Protection
Agency
EPA 335

Official Business
Penalty for Private Use $300

☆ U.S. GOVERNMENT PRINTING OFFICE 1981 — 559-017/7...