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FBC COMES OF AGE

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edited by

JOHN P. MUSTONEN

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
United Engineering Center 345 East 47th Street New York, N.Y. 10017

FOREWORD

The Ninth International Conference on Fluidized Bed Combustion is intended to promote the exchange of technical, economic and scientific information pertaining to all aspects of fluidized bed combustion (FBC) in support of increasing applications and scale-up of this technology for the clean and economical combustion of coal and other fuels.

The theme of the conference is "FBC Comes of Age" and the many technical papers included in these proceedings report on a number of significant developments which have ocurred since the last International FBC Conference (March 1985) bringing FBC technology closer to full commercialization.

The proceedings include approximately 180 papers presented formally or in poster session addressing the following general subjects:

AFBC AND PFBC Applications
Fuels
Sorbents
R&D Fundamentals
FBC Plant Components
Environmental
Advanced Concepts

The Conference is sponsored and coordinated this year for the first time by the American Society of Mechanical Engineers, Advanced Energy System and Division which has assumed this responsibility from the U.S. Department of Energy. Co-sponsoring the Conference, as in recent years, are the Electric Power Research Institute and the Tennessee Valley Authority, in cooperation with American Institute of Chemical Engineers, the Council of Industrial Boiler Owners, and the U.S. Department of Energy.

Our appreciation is extended to J.W. Byam, U.S. Department of Energy, who was Chairman of the Eighth International Conference on Fluidized Bed Combustion held in March, 1985. Mr. Byam provided enthusiastic support and benefit of his prior experience to the organizers of the Ninth International and generally eased the primary conference sponsorhhip responsibility transition from the U.S. Department of Energy to the American Society of Mechanical Engineers.

J. P. Mustonen
Conference Chairman
Steering Committee Chairman

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The task of organizing and coordinating the conference as well as reviewing and selecting abstracts was shared by the members of the Steering Committee for the Ninth International Conference on Fluidized Bed Combustion. Our appreciation is extended to:

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Edward A. Zielinski	Combustion Engineering, Inc.

TOPIC COORDINATORS

The nine Topic Coordinators arranged the actual sessions and coordinated the review of the technical papers within their topical areas. Our appreciation is extended to them as follows:

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S. Erlich, Electric Power Research Institute – Advanced Concepts
D. L. Keairns, Westinghouse R&D Center – Poster Session
A. M. Manaker, Tennessee Valley Authority – Components
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M. J. Mudd, American Electric Power Service Corporation – PFB
O. J. Tossicker, Electric Power Research Institute – Environmental
E. S. Taylor, Pyropower Corporation – Fuels
E. A. Zielinski, Combustion Engineering Inc. – AFB

And a most special thanks to A.M. Manaker who in addition to his role as a Topic Coordinator, also devoted endless hours of work as the Secretary of the Steering Committee and organized all of the sessions into a cohesive conference technical program.

SESSION CO-CHAIRMEN

In addition to chairing the various technical sessions of the conference, the task of reviewing all of the technical papers was shared by the Session Co-Chairman with the assistance of the papers review coordinator, G. Weth, U.S. Department of Energy. Our appreciation is extended to:

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Also, a special thanks to W. Campbell, of Foster Wheeler Energy Corporation who coordinated recruitment of the many session co-chairmen.

CONTENTS

SORBENTS

DESIGN, PERFORMANCE AND COST OF ATMOSPHERIC FLUIDIZED BED COMBUSTION POWER PLANTS

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ABSTRACT

The U.S. electric utility industry is actively supporting development and demonstration of atmospheric fluidized bed combustion (AFBC) technology for utility application. In support of the program, a design, performance, and cost evaluation was prepared for coal-fired AFBC power plants. The objective was to evaluate and compare alternate AFBC steam generation configurations, and specifically to compare AFBC boilers with underbed vs. overbed feed of coal and limestone. In addition, reference pulverized coal plants with wet limestone flue gas desulfurization systems were evaluated.

Major design assumptions included 1x200 MW and 2x500 MW plant size, East-Central U.S. plant location, high-sulfur Illinois bituminous coal, and 1979 New Source Performance Standards. After an initial screening evaluation of alternate AFBC-overbed feed boiler configurations, detailed evaluations were prepared of the design, performance, resource requirements, and capital, operation and maintenance, and levelized busbar costs of the reference PC/FGD, AFBC-underbed feed, and AFBC-overbed feed power plants. In addition, a sensitivity analysis of the impact of coal type was prepared for a range of coals, including Illinois and West Virginia bituminous, Wyoming subbituminous, and Texas and North Dakota lignites. In general, the evaluation indicated a small capital and levelized busbar cost advantage for the AFBC-overbed feed system at the 200 MW unit scale and confirmed that the AFBC technology is competitive with conventional pulverized coal technology with wet flue gas desulfurization.

INTRODUCTION

The development of Atmospheric Fluidized Bed Combustion (AFBC) technology for utility application is proceeding rapidly. Several large utility-scale AFBC pilot and demonstration plant projects are underway, including:

- Construction and startup in 1982 of the 20 MW AFBC pilot plant at the Tennessee Valley Authority's (TVA) Shawnee Station in Paducah, Kentucky.
- 125 MW AFBC boiler conversion at Northern States Power Company's Black Dog Station near Minneapolis, Minnesota (1986 startup).
- 110 MW AFBC circulating fluidized bed boiler at Colorado Ute Electric Association's Nucla Station in western Colorado (1987 startup).
- 160 MW AFBC-bubbling bed at TVA's Shawnee Station (1988 startup).

The principal incentives for development of the AFBC technology include the ability to control both sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions in-situ without requiring flue gas desulfurization (FGD) and special low NO_x burners, and the ability to burn a wide range of fuels including high fouling coals and waste fuels without slagging or fouling problems. These advantages are based on the following characteristics of fluidized bed combustion:

- In-situ capture of SO_2 in a fluidized bed of limestone or other sorbent.
- Low combustion temperatures, well below the fusion point of coal ash.
- Reduced formation of NO_x during combustion.

Application of fluidized bed combustion also eliminates the need for coal pulverizers and produces a dry solid waste instead of wet FGD sludge.

The evaluation presented in this paper was prepared in support of the AFBC development program and the design of the three AFBC demonstration projects. The impacts of boiler design options such as overbed vs. underbed feed on balance of plant costs, boiler efficiency, auxiliary power, and reliability had not been evaluated prior to this evaluation. The results were intended to be used to assess the tradeoffs between efficiency and

capital cost in making design decisions for the demonstration projects, to support testing at the 20 MW pilot plant, and to develop a reference plant for future AFBC design evaluations.

OBJECTIVE AND SCOPE

The objective of this study was to assess the impact of using alternate boiler configurations on the efficiency, capital cost, levelized busbar cost, and resource requirements of AFBC power plants.

Conceptual designs, performance, and cost estimates were prepared for both AFBC and conventional pulverized coal-fired (PCF) power plants in both 1x200 MW and 2x500 MW plant sizes. Other major assumptions of the base case evaluation included a Kenosha, Wisconsin plant location, subcritical steam cycle (2400 psig/1000°F/1000°F), a high-sulfur Illinois bituminous coal containing 4% sulfur, and 1979 EPA New Source Performance Standards. AFBC and PCF steam generator designs and estimates were prepared by Babcock & Wilcox Company (B&W)[1], and balance of plant designs, performance, and cost estimates were prepared by Bechtel Power Corporation.[2]

The AFBC steam generator designs were first developed using AFBC process data available in 1982, but were later updated to account for recent performance and design data from the TVA 20 MW AFBC pilot plant and the AFBC demonstration projects.

The evaluation focused on comparing underbed vs. overbed feed of coal and limestone and was prepared in three stages. The first stage was a screening evaluation in which several AFBC designs using gravimetric, pneumatic, and mechanical overbed feed systems were compared. The second stage was a detailed evaluation of PCF, AFBC-underbed feed, and AFBC-overbed feed designs selected in the screening evaluation. The third stage was a sensitivity analysis of power plant design, performance and costs of burning a wide range of coals.

DESIGN AND ECONOMIC ASSUMPTIONS

The design and economic assumptions are based on the 1987 EPRI economic premises[3] and the 1986 EPRI Technical Assessment Guide[4].

- Reference year of costs: End-of-year 1984 dollars
- Plant startup: January 1985
- 1987 EPRI Economic Premises:
  - --Average inflation rate (1985-2014): 6.0%/year
  - --Discount rate : 12.5%/year
  - --Fixed charge rate: 17.3%/year
- Book life: 30 years
- O&M levelization factor: 1.748
- Fuel levelization factor: 1.92
- Coal cost is 1.55 $/MBtu for Illinois coal (see table 1 for others)
- Limestone cost: 15 $/ton
- Lime cost: 65 $/ton
- Dry waste disposal cost: 8 $/ton dry solids
- FGD sludge disposal cost: 9.25 $/ton dry solids
- Process water cost: 0.60 $/1000 gal
- Capacity factor: 65%
- 1979 New Source Performance Standards:
  - --70 to 90% SO_2 Removal
  - --0.5 to 0.6 lb NO_x/MBtu
  - --0.03 lb particulate/MBtu

Coal and limestone coal properties are shown in table 1.

SCREENING EVALUATION

The feasibility of the overbed feed design appeared to be sensitive to the mechanical arrangement of silos, bunkers, and structural steel. Consequently, the screening evaluation was performed to assess the design, performance, and balance of plant cost for alternate AFBC boiler configurations using various overbed coal and limestone feeding systems for both 200 MW and 500 MW units. In addition, the reference PCF and AFBC-underbed feed plants were evaluated for comparison. The screening evaluation was based on previous TVA and EPRI studies and data from the EPRI 2 MW 6' x 6' AFBC Development Facility in Alliance, Ohio.

Initially, the number of alternate overbed feed AFBC configurations were reduced to four 200 MW designs and two 500 MW designs by eliminating those with limited practical potential, possible operating or control problems, or little or no potential improvement in performance or cost. As a result, the pneumatic overbed feed systems were eliminated due to no advantage over the pneumatic underbed feed systems, and all except one gravimetric and one mechanical spreader stoker systems were eliminated due to potential operating problems.

The remaining alternate configurations were screened based on the boiler building height, area, and volume and the balance of plant design and cost. The mechanical overbed and underbed feed configurations were selected for the 200 MW and 500 MW AFBC steam generators for detailed evaluation.

DETAILED EVALUATION

Conceptual design, performance, resource requirements, total capital requirement, operation and maintenance (O&M) cost, and levelized busbar cost estimates were prepared for 1x200 MW and 2x500 MW power plants in each of the following configurations:

- Conventional pulverized coal with wet limestone flue gas desulfurization (PCF).
- AFBC with underbed feed (AFBC-UB).
- AFBC with overbed feed (AFBC-OB).

The steam generator design and performance specifications are based on Bechtel standards, modified to account for the special requirements of an AFBC boiler. The balance of plant designs were developed from EPRI Report PE-1865, "Coal-Fired Power Plant Capital Cost Estimates."[5]