LPC-II-9

Energy & Mineral Research Center

Fuels & Process Chemistry Research Institute
ND Mining & Mineral Resources Research Institute
Combustion & Environmental Systems Research Institute

Box 8213, University Station / Grand Forks, North Dakota 58202 / Phone: (701) 777-5000 / Fax: 777-5181

September 27, 1988

Mr. Tim Kingstad, Secretary
North Dakota Lignite Council
North Dakota State Land Department
State Capitol Building
Bismarck, ND 58502

Dear Mr. Kingstad:

It is our pleasure to submit this proposal to the North Dakota Lignite Research Council for consideration in Round 2 of project selection. We look forward to the successful programs of the Council advancing and enhancing the many ways in which North Dakota lignite can serve the region's and nation's energy and material needs, now and in the future.

This proposal requests funds as a part of a multi-client program entitled "Project CFB." The objective of this program is to design and operate a circulating fluidized bed combustion test facility to obtain comprehensive, reliable, and accessible data for use by the industrial and utility sectors. Data generated using this test facility will help both the producer and user of North Dakota lignite by providing the information needed to use high-slagging and fouling North Dakota lignite without paying the capital and operating penalties associated with lignite usage in conventional coal-fired systems.

First-year funding for this two-year program was received from the North Dakota Lignite Research Council. This request is for $25,000 for year two. The start date of the project was May 16, 1988. The total cost of the project is $750,000, requiring fifteen sponsoring organizations. Industrial commitments have been obtained from ten organizations at this time.

I look forward to the Council's positive endorsement of this proposal.

Sincerely,

Doug Hajicek for M Mann

Michael D. Mann
Research Supervisor
Combustion Systems

Alex Kotch

Alex Kotch, Director
Office of Research and Program Development

MDM/clh
Enclosures

PROJECT CFB

The Design and Operation of a CFBC Test Facility to Generate Comprehensive, Reliable, and Accessible Data for Utility and Industrial Clients

submitted by:

Michael D. Mann, Principal Investigator

Energy and Mineral Research Center
University of North Dakota
Grand Forks, North Dakota

October 1, 1988

Amount Requested: $25,000

SUMMARY

Project CFB is a multi-client study to design and operate a circulating fluidized-bed combustion (CFBC) test facility. The objective of the study is the design and operation of a CFBC test facility to provide comprehensive, reliable, and accessible data for utility and industrial applications.

Circulating fluidized bed combustion is a growing technology that is rapidly gaining acceptance for the combustion of a wide range of coals. Extremely low levels of gaseous emissions of SO_x and NO_x can be achieved using this technology. Using sorbents in the bed for SO_2 control and low operation temperatures to limit NO_x production, this technology has the potential to meet all proposed emission standards when burning North Dakota lignites. At this time, only one test facility is available in the United States, and this facility is operated by a boiler vendor.

The ability to operate with a wide variety of coals is one of the notable characteristics of CFBC. North Dakota lignites have been labeled as coals with ash deposition problems. This results from high levels of sodium found in many of these fuels. Fluid bed technology offers the opportunity to burn these high sodium fuels without the capital equipment and operating cost penalties normally associated with lignite fired plants.

The project was initiated on May 16, 1988, and will require two years to complete. The study is designed to have fifteen participants resulting in a cost of $25,000 per year per sponsor for the two years, for a total project cost of $750,000.

Sponsor commitment at this time includes Northern States Power, Consolidated Edison, Texas Utilities, Electric Power Research Institute, Department of Energy (two shares), and the Empire State Electric Energy

Research Corporation, ARCO Coal Company, Otter Tail Power Company, and the North Dakota Lignite Research Council (first year).

During the first phase of the project, an extensive literature review and design effort was undertaken. The result of this effort is the design of a CFBC pilot facility capable of burning any rank of coal while simulating the design configuration of any of the major boiler vendors. The most important part of this study, testing of the candidate coals, will be performed during the second year of the program.

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1.0 OBJECTIVES

Project CFB is a multi-client study to design and operate a circulating fluidized-bed combustion test facility. The objective of the program is the design and operation of a CFB test facility to provide comprehensive, reliable, and assessable data for utility and industrial applications. In meeting this objective, the program will have established an independent laboratory for the development of circulating fluidized bed combustion design and operational data. Being free from boiler vendor bias, results from this study will give those industries and utilities considering retrofit or new construction a total information package to evaluate the various CFB options available.

Project CFB is expected to be beneficial to both the producers and users of North Dakota lignite. Circulating fluidized bed combustion offers a method of utilizing high sodium coals without the serious implications of slagging and fouling. SO_2 and NO_x emission limits can easily be met without the need for expensive back end cleanup devices. Because CFB has the capabilities to burn lignite efficiently, the impetus for using coals from other regions such as the Powder River Basin is greatly reduced.

Circulating fluidized bed combustion is a promising candidate for new construction and retrofit applications on the institutional, industrial, and utility scale. The information generated during this program will allow these sectors to accurately evaluate various CFB options available, and choose a strategy that can provide them will the most efficient method to generate steam or power, while utilizing North Dakota lignites. Thus, both the producer and user of North Dakota lignite can realize the benefits of this program. Other benefits of participating in the program include:

- Rapid access to a compilation of available literature on the current state of the knowledge on all aspects of CFBC.

- Cost-effective information from an independent source at a fraction of the cost available to a single company.
- Opportunity to assist in the selection of coals to be tested and the design of test matrixes.
- Information to make prudent choices for future generation capacity.
- Ability to effect rapid transfer of information and data through consultation with UNDEMRC staff and sponsor personnel.
- Interaction with other sponsors and with personnel interested in CFBC.

2.0 BACKGROUND

Circulating Fluidized Bed Combustion (CFBC) is a growing technology that has rapidly gained industrial acceptance for the combustion of coal and other fuels in the last couple of years. A couple of the larger current users of operational industrial scale CFBC systems include the Scott Paper Company (650,000 lbs/hr) in Chester, Pennsylvania, and General Motors Corporation (300,000 lbs/hr) in Pontiac, Michigan. On the utility scale, Colorado-Ute Electrical Association is currently engaged in demonstrating operability with its 110-MW CFBC at the Nucla generating station. The reason for CFBC's popularity over bubbling AFBC systems is its potential for increased limestone utilization, lower nitrous oxide emissions, greater fuel flexibility, decreased fuel feed problems, a wide range of turn-down, and decreased cross-sectional area of the combustor. These advantages mean that North Dakota lignites can be burned in a CFBC without paying the heavy capital and operational expense penalties caused by the fouling, deposition, and emissions associated with the use of lignite in conventional combustion systems.

While CFBC's are gaining rapidly in popularity, there is generally a dearth of information available to allow the engineer or user to make an educated selection on the appropriate design and operational conditions for the design fuels. There is a limited amount of CFBC design and operational

data available and most of this is presently proprietary data. The operational and design philosophies of CFBC vendors vary in a number of areas including the use of an external heat exchanger (EHE), recycle rates and methods, the amount of refractory coverage required in the lower combustion section, the appropriate flue-gas velocity, the required calcium-to-sulfur ratio to meet NSPS, overall heat-transfer surface area required, and solids inventory at rated capacity. Vendors also vary on the amount of turndown they will guarantee.

The University of North Dakota Energy and Mineral Research Center (UND EMRC) is one of the world's major coal research facilities. Since its founding in 1951, the Center has conducted research, testing and evaluation of coals and associated combustion and conversion technologies. The Center's transfer from the U.S. Department of Energy to the University of North Dakota in 1983 has made it possible for the Center's staff to work directly for industry to provide needed data and practical solutions for the specific problems and challenges they are encountering. Today, the Center is the leading organization in the U.S. doing contract research on the characterization and utilization of lignitic coals. The Center possesses state-of-the-art analytical equipment and extensive pilot-plant facilities providing unique capabilities for research programs.

A research program was initiated at the Energy Research Center in 1975 for the study of fluidized bed combustion of low-rank coals. Atmospheric Fluidized Bed Combustion (AFBC) research has been performed providing information on limestone utilization and sulfur capture; nitrous oxide emissions; particulate capture; combustion efficiencies; heat transfer; characterization of fluidized bed solid waste; bed material agglomeration promoted by high-sodium coals; corrosion and/or erosion of metal surfaces in

the bed, splash zone, and convective pass; and the combustion of slurried fuels. Presently there are two AFBC test facilities at UNDERC; both operate in the bubbling mode. They include an 18 by 18 inch square combustor primarily being utilized for coal characterization and slurry combustion research and an 8- by 8-inch combustor that was designed and constructed specifically for corrosion/erosion studies.

This application for funds details a two-year, multi-client program to design, construct and operate a CFBC pilot plant facility at EMRC. The purpose of this program is to provide participating clients the opportunity to obtain needed design and operational information on how a CFBC system can be expected to perform with selected coals. This study is expected to benefit industrial and utility companies and North Dakota coal producers by providing the design and operational information needed to ensure an increased utilization of one of our state's greatest resources.

During the first phase of this project, an extensive literature survey of existing and planned CFBC facilities was performed. Site visits were made to operational facilities of all sizes to gather design information and further refine those aspects of CFBC most needing research. Results from the literature survey and site visits were used to design a versatile pilot-scale CFBC facility. This facility is designed to burn any rank of coal, and to be operated in configurations similar to any of the units currently sold by the major boiler vendors. Construction of the facility will take place during the winter and spring of 1989, with testing to commence during year 2.

3.0 GOALS

The goal of this project is twofold. The first and most immediate goal is to provide the sponsor with a technical information base that can be used in evaluating the various CFB options available. A second and more long term

goal is to develop a facility, independent of vendor bias, that is readily available to the industrial and utility sectors to use as a tool for answering questions specific to their particular applications. The intended results of the program are listed below. The methodology of obtaining these results is discussed in Section 4.0.

A. Provide a centralized resource containing the following information on CFB:
   - A data base containing published information on CFB technology, with summaries for all articles included;
   - Location of existing and planned pilot-scale, commercial, and utility scale facilities; and
   - All available CFB design and operational data from existing facilities

B. Design a CFB with the following capabilities:
   - Optimal design for reliable data at a reasonable cost;
   - Generic design to provide data representative of various vendor designs;
   - Capable of varying the following parameters:

     Superficial gas velocity
     Operational temperature
     Ratio of overfire to combustion air
     Bed particle size and distribution
     Fuel type
     Sorbent type
     Alkali-to-sulfur ratio
     Operation with or without external heat exchanger

   - Capable of determining the following:

     Required operation with or without external heat exchanger
     Required sorbent add rate
     Combustion efficiency
     Nitrous oxide emission
     Solid-to-gas ratios throughout the system
     Particulate collectability
     Range and method of turndown
     Bed particle stability
     Reliability of recirculation system
     Fuel flexibility
     Disposal of solid wastes
     Erosion potential

C. Perform parametric testing to develop baseline data on the operation of a CFB.
   - Coal selection to be approved by Advisor Committee.

- Statistically designed test matrix to be used.
- Parameters listed above to be evaluated.

D. Prepare a final report discussing the following aspects of the project:
   - Summary of literature survey and data base development;
   - Design drawings and specifications;
   - Results of parametric testing; and
   - An evaluation of the various design and operational variables considered.

The Advisory Committee, made up of one representative from each sponsor, has the responsibility of reviewing all work performed to determine whether each goal has been met according to the standard established in this prospectus.

During the first four months of this program, efforts have focused on achieving the objectives laid out in items A and B. An extensive collection of published information has been reviewed and summarized. Information on existing CFBC plants is being gathered and correlated to guide the efforts of design and test worik. A preliminary design of all major ocmponents has been completed and will be reviewed at the next Advisory Committee meeting. All of the objectives of part B have been met in this design.

4.0 METHODS

The study is divided into six tasks. The first task will be devoted to an assessment of the state of the knowledge on CFBC's. Design and construction (Tasks 2 and 3) of the facility will be completed in the first year. Year 2 (Tasks 4, 5, and 6) will be used to shakedown the facility, conduct parametric testing on two candidate coals, and write a final report. Progress status letter reports will be supplied to each sponsor every other month during the two-year program.

Task 1. Technology Assessment

Available information on CFBC's will be obtained and compiled to provide a centralized resource that can be consulted by personnel at the Center or at the sponsoring organization throughout the project. This will include the location of existing and planned pilot scale, commercial, and utility scale CFBC facilities throughout the world and available design and operational data. This resource will be updated throughout the project.

Task 2. Design

Options will be evaluated as to what is an appropriate and cost effective design of the system. The location of the system, its size and geometry, and system components will be identified. Construction drawings and a construction schedule including specific activities, costs, scheduling, and decision points will be completed. The system shall be designed to demonstrate fuel flexibility, and should demonstrate that lignite can be efficiently utilized in the CFBC.

Task 3. Construction

Procurement of the required supplies and equipment and the construction and fabrication will be completed. Construction activities will be performed by EMRC personnel using existing facilities and equipment whenever feasible. The CFBC system will be housed in existing EMRC facilities.

Task 4. System Shakedown

Shakedown of components will be performed in an orderly manner to insure the overall system is in operational status to provide data of high integrity. A coal will be selected for shakedown with which EMRC has had previous AFBC operational experience, and which does not possess atypical properties that could promote unique operational problems. EMRC has a large AFBC data base

burning North Dakota lignites and Powder River Basin coals. Final selection of the shakedown coal will be from a list supplied by EMRC and voted on by the Advisory Committee.

Task 5. Parametric Testing

Two or more coals, in addition to the coal used for shakedown testing, will be selected for parametric testing. The parametric test matrix will be statistically designed to maximize the amount of data obtained for the minimum amount of tests performed. The coal types, number of test coals, and test matrix will be approved by the Advisory Committee prior to initiation of the testing. Data will be analyzed using regression analysis. A test program conducted for the Department of Energy (DOE) using statistically designed test matrixes and regression analysis for the characterization of five coals (four low-rank coals and one bituminous) in our 18-by-18-inch bubbling AFBC has been completed in an extremely successful and cost-effective manner.

Task 6. Final Report

A final report will be written detailing the results of parametric testing. This report will document the design and operational performance of the circulating fluidized bed combustion for the coals and parameters studied. It is expected that this information will provide planners with the information needed to make prudent decisions for future steam or power generation options.

5.0 SCHEDULE AND DELIVERABLES

The tentative schedule for each of the project's six tasks is presented in Table 1. The project was initiated on May 16, 1988. Task reports will be submitted to the project sponsors at the completion of each task. Bimonthly letter reports will provide updates on the overall project status. Planning

and review meetings will be held twice in the first year and at least once in the second year to review work completed and to aid in planning of subsequent tasks. The draft final report will be submitted to the project sponsors for review one month prior to the final review meeting. The reviewed and edited task reports will be major inputs into the final report.

TABLE 1. Project Schedule and Budget

No.	Task Description	Schedule by Project Quarters 1 2 3 4 5 6 7 8	Estimated Cost ($000)
1.	Assessment of CFBC Knowledge	____*	20
2.	Design	_____*	100
3.	Construction	_____*	300
4.	Shakedown	____*	100
5.	Parametric Testing	____*	200
6.	Final	0 0	30
			$750
	Planning and Review Meetings	# # # #	

Deliverables
* Task Reports
o Draft Final Report & Final Report

6.0 PERSONNEL AND FACILITIES

The Principal Investigator for the project will be Mr. Michael D. Mann. Mr. Mann (M.S. Chemical Engineering and M.B.A.) joined the Center in 1981 and is involved in research related to fluidized bed combustion, ash fouling and deposition, and advanced concepts for utilizing low-rank coals. He is currently the supervisor of the Combustion Systems Group in the Combustion and Environmental Systems Research Institute and has been actively involved in coal-related studies using pilot scale equipment for most of his career. Mr.

Mann would be responsible for overall technical management of the program, including monitoring project schedules and budgets. He will spend approximately 40 percent of his time dedicated to this project.

Mr. Hajicek (B.S. Mechanical Engineering) joined the Center in 1976, and is primarily involved with a program assessing the occurrence of corrosion and/or erosion in fluidized bed combustion systems utilizing low-rank coals. He has been responsible for, as well as actively involved in, design, construction, operation, and modification of several of EMRC's major pilot plant systems, including the 8- by 8-inch and 18- by 18-inch bubbling FBC systems. Mr. Hajicek will dedicate over 80 percent of his time to this project and will take the lead responsibility for tasks 2, 3, 4 and 5.

Technical and operational personnel for this project will be drawn from the Center's existing staff. This staff is highly experienced with the design, construction, operation, and maintenance of pilot-scale combustion systems including fluidized bed combustors. The technical staff is experienced with the design and implementation of parametric test matrixes designed to obtain maximum data with minimal testing. A fully-staffed and equipped coal analysis laboratory is on site for responsive supply of all standard coal analyses. There are also highly-trained personnel that have a complete array of state-of-the-art analytical equipment available for any specialized analyses that would be useful for this project.

The proposed location for the CFBC test facility would be at EMRC in either the pilot-plant or in the adjacent gasifier tower. Additional information on the Center's programs, personnel, and facilities is available upon request.

7.0 QUALIFICATIONS OF APPLICANT

The Combustion and Environmental Systems Research Institute of EMRC is currently engaged in a wide array of projects. The U.S. Department of Energy is the largest single client, and the Combustion and Environmental Systems Research Institute works with both the Morgantown and Pittsburgh Energy Technology Centers on projects ranging from basic studies of coal combustion chemistry and mineral matter transformations to studies of corrosion/erosion in fluidized bed combustion and methods of controlling the gaseous and particulate emissions from coal combustion systems. Additionally, work is underway on emerging technologies using coal, including diesel engines and coal-fired gas turbines.

Although the majority of the current projects are being performed for the government, the Combustion and Environmental Systems Research Institute has been very successful in the transfer of knowledge to the private sector. Projects involving ash deposition have been completed for many companies, including Houston Power and Light, Detroit Edison Co., and Northern States Power. The Combustion Systems Group has been working with Montana-Dakota Utilities and Northern States Power to provide information on fluidized bed combustion for their newly-commissioned FBCs. Studies of emission control issues have been an important part of the Environmental Systems Group when working with companies such as EPRI, Westinghouse, 3M, Owens-Corning, Montana-Dakota Utilities, and American Crystal Sugar. By enhancing the basic understanding of combustion-related processes, the Combustion and Environmental Systems Research Institute has successfully solved problems specific to the various segments of the private sector.

The EMRC has been involved in an array of fluidized bed combustion (FBC) projects for both governmental and private entities. A listing of specific

FBC experience is given in Table 2. A summary of each project is provided in the Appendix.

TABLE 2. EMRC FLUIDIZED BED COMBUSTION EXPERIENCE

Fluidized Bed Combustion Testing of Iowa Bituminous Coal	Stanley Consultants/Iowa Energy Policy Council
Fluidized Bed Combustion Test Support	Burns & Roe
Consultation on Testing of a North Dakota Lignite at B&W	Montana-Dakota Utilities
Petroleum Coke FBC Characterization	Northern States Power
Utilization of Agriculture Wastes as Stationary Power Source	Valmont Industries/USDA
AFBC Low-rank Coal Characterization	Department of Energy
Evaluation of Corrosion and Erosion from AFBC of Low-rank Coals	Department of Energy
Study of Agglomeration in Fluidized Bed Combustion	Department of Energy
Development of Heat Transfer Equations in Fluidized Bed Combustion	Department of Energy
Firing Low-rank Coal/Water Slurry in a FBC	Department of Energy
Technology Transfer Report: Fluidized Bed Combustion of Low-rank Coals	Department of Energy

8.0 BUDGET

The estimated cost of the proposed research program is $750,000 over a 24-month period. The estimated cost per task is presented in Table 1. The cost per participating company will be $25,000 per year, thus requiring support from 15 companies to execute the full program. EMRC will initiate a reduced-scale program with funding from less than 15 companies with a minimum of eleven being required to proceed with an effective reduced-scale program.

If more than 15 sponsors are obtained, the Advisory Committee will decide to refund an equal share of the excess funds or to enhance the planned program. The North Dakota Lignite Research Council funded the first year of this program as part of Round 1 solicitations. This request is for one share for year two of Project CFB. A budget summary by category for each year is presented in Table 3.

TABLE 3. ITEMIZED BREAKDOWN OF YEARLY PROJECT CFB COSTS

	Per Share	Total
Personnel	$10,932	$163,980
Operating Expenses	7,389	110,835
Equipment	2,667	40,005
Indirect Cost	4,012	60,180
Total Cost Per Share	$25,000	$375,000

APPENDICES

Summary of Related Experience

PROJECT SUMMARY

Project Title: Development of a Fluidized Bed Combustion Data Base for Low-Rank Coals

Client: U.S. Department of Energy, Office of Fossil Energy
Contact: Harvey Ness

Objective: To develop an engineering data base for use in tailoring FBC processes and systems to low-rank coals, including assessment of solutions to identified problems and evaluation of corrosion/erosion of heat exchange surfaces.

Activities: Pilot testing is being performed to determine the effect of coal feed method, bed material, sodium level in the coal, and excess air on bed agglomeration. Laboratory studies include sintering and basic furnace tests with ash and bed materials to determine the mineral phase transformations and elucidate agglomeration mechanisms. The freeboard, splash zone, and radiative portion of the heat transfer, and bed material emissivity have been measured and predictive equations are being developed. An evaluation of low-rank coals from high-industrial growth areas will provide data on gaseous and particulate emissions, in-bed and freeboard heat transfer performance, and overall combustor performance under a variety of conditions required for turndown.

A smaller FBC test unit has been designed and constructed for evaluation of corrosion and erosion of the heat transfer surfaces. Four 1000-hour duration tests are scheduled.

Publications: Grewal, N.S. and G.M. Goblirsch. "Heat Transfer to Horizontal Tubes in a Pilot-Scale Fluidized-Bed Combustor Burning Low-Rank Coals", ASME Annual Meeting, July 1983.

Bobman, M.H., D.R. Hajicek, and B.J. Zobeck. "A Study of Bed Agglomeration Resulting From the AFBC of Low-Rank Coals", 8th International Conference on Fluidized Bed Combustion, March, 1985.

Perkins, D., III, D.W. Brekke, and F.R. Karner. "Analysis of Atmospheric Fluidized Bed Combustion Agglomerates", DOE/FC/10120-1608, April 1984.

Grewal, N.S. "Development of Reliable Predictive Heat Transfer Correlations for Low-Rank Coal-Fired Fluid Bed Combustor", DOE/FC/10489-1694, February 1984.

Client Reports

Supervisor: M.D. Mann

Cost: $2,359,000

Period: April 1, 1983-June 30, 1986

Descriptors: Fluidized Bed Combustion, Air Pollution Control

PROJECT SUMMARY

Project Title: Technology Transfer Report Fluidized Bed Combustion of Low-Rank Coals

Client: U.S. Department of Energy/Office of Fossil Energy
Contact: Harvey Ness, GFPO

Objective: The objective of this effort was to publish results of the DOE-funded low-rank coal program on atmospheric fluidized bed combustion, performed at the Grand Forks Energy Technology Center (GFETC). The purpose of this report was to include background information on the state-of-the-art of AFBC, results and discussion of work performed by GFETC, identification of items requiring additional research, and recommendations of the approach to be followed in meeting these needs.

Activities: Results from the GFETC/DOE programs on AFBC of low-rank coal (LRC) are presented from the first tests in 1975 until the transfer of GFETC from DOE to the University of North Dakota in April of 1983. Program emphasis was on the environmental performance of the test systems, primarily SO_x emissions, as a function of inherent ash and/or added sorbents. Operational problems associated with the use of lignites and subbituminous coals were stressed. Other data such as heat transfer coefficients were of secondary importance but are an important part of the data base. Both technical and economic considerations were addressed. This 422 page report also presents information on current technology for AFBC, special properties of LRC, identification and estimated amounts of LRC deposits, conventional combustion systems, and considerations in firing LRC's.

Publications: Hajicek, D.R. et. al., "Performance of Low-Rank Coal in Atmospheric Fluidized Bed Combustion," Technical Information Center, U.S. Department of Energy, DOE/FE/60181-1869, October 1985.

Supervisor: D.R. Hajicek

Cost: $80,000

Period: April 1983 - April 1985

Descriptors: Fluidized Bed Combustion

PROJECT SUMMARY

Project Title: Evaluation of Corrosion and Erosion from AFBC of Low-Rank Coals

Client: U.S. Department of Energy/Office of Fossil Energy
Contact: Harvey M. Ness, GFPO

Objective: Experience in operation of FBC has indicated that corrosion and erosion of heat transfer surfaces can be a problem. Systematic studies are being performed to investigate the effects of the alkaline ash and high ash content of low-rank coals on corrosion and erosion in the AFBC.

Activities: To evaluate the corrosion and erosion potential of low-rank coal ash on AFBC heat transfer surfaces, four 1000-hour tests are being performed on a pilot scale AFBC specially designed for this purpose. This program will evaluate several different metallurgies - carbon steel, 304, 310, 316, and 347 stainless steel and Incoloy Alloy 800 -- at tube wall temperatures ranging from 250 to 1550°F. Tubes and coupons are located in the bed, splashzone, freeboard, and convective section of the boiler. Post test examination of the heat transfer surfaces are being performed using a number of advanced analytical techniques to determine both the extent and mechanism of corrosion and erosion observed.

Publications: None

Supervisor: M.D. Mann

Cost: $409,000

Period: December 1984 - June 1986

Descriptors: Fluidized Bed Combustion, Material Science

PROJECT SUMMARY

Project Title: Fluidized Bed Combustion Testing of Iowa Bituminous Coal

Client: Stanley Consultants (subcontract to Iowa Energy Policy Council)
Contact: Cabot Thunem

Objective: Evaluate operating characteristics and gaseous and particulate emissions of washed and unwashed Iowa coal in a pilot-scale AFBC using an Iowa limestone for bed material.

Activities: Samples of bituminous Iowa unwashed and washed coal were successfully combusted at UNDERC. The washed coal had a significantly lower ash and sulfur content and a higher heating value than the unwashed coal. The combustion characteristics of both coals were good. However, problems were encountered with elutriation of the Iowa limestone which was used as bed material and sorbent during the test.

Sulfur retentions of approximately 90% were obtained during all four periods of the test. Total Ca/S mole ratios (including Ca from coal and limestone) ranged from 1.56 to 2.94 to achieve the required sulfur retentions. Calcium utilization was high, ranging from 31.0% to 58.4% for the test periods. Emissions of NO_x varied from 0.39 to 0.65 lb $NO_x/10^6$ Btu.

Very little difference was noted between the size distribution of the flue gas particulate collected when burning washed coal as compared to the unwashed coal.

Publications: Client Report

Supervisor: D.R. Hajicek

Cost: $15,936

Period: May 1984-November 1984

Descriptors: Fluidized Bed Combustion

PROJECT SUMMARY

Project Title: Fluidized Bed Combustion Test Support

Client: Burns & Roe, Inc. (subcontract to Agency for International Development
Contact: Egon Kimel

Objective: To perform AFBC pilot and laboratory testing to determine the technical and economic feasibility of a potential power plant in Thailand.

Activities: Laboratory analysis and pilot-scale combustion will be performed to determine the basic behavior and required design parameters for firing a lignite from Thailand in an AFBC. The results of this work will provide design information that can be used for a conceptual design and budget estimate for the 50 MWe AFBC. Information will be provided to allow designers to determine the feed method, type of boiler, bed temperature, heat transfer surface allocations, bed superficial velocity, bed plan area, freeboard height and plan area, limestone feed rate, convective pass velocity, excess air, coal preparation method and feed size, ash handling capabilities, sulfur capture efficiencies, unburned carbon in the fly ash, and bed drainage method.

Publications: Client Report

Supervisor: M.D. Mann

Cost: $45,000

Period: January 1986 - March 1986

Descriptors: Fluidized Bed Combustion

PROJECT SUMMARY

Project Title: Consulation on Testing of a North Daktoa Lignite at Babcock and Wilcox

Client: Montana Dakota Utilities
Contact: Earl Backhaus

Objective: To observe and provide advice during fluidized bed combustion testing of a North Dakota lignite performed by Babcock and Wilcox.

Activities: Montana Dakota Utilities is considering converting one of their stoker-fired units to a fluidized bed combustor. Tests were performed at Babcock and Wilcox's 6'x6' test facility to provide the design data necessary to make a full evaluation of the project. The fuel and bed material that would be used in the commercial unit were evaluated--a North Dakota lignite high in sodium and a river sand. Based on previous testing at UNDERC, this combination of fuel and bed material represented a potential operating problem in the form of bed agglomeration.

During the testing an UNDERC engineer was on site at Babcock and Wilcox to observe the test. Technical assistance was provided during the test and recommendations made as to how to limit the formation of agglomerates and how to best control build up of agglomerates in the bed. The potential problems needing evaluatation were identified and discussed with the client.

Publications: Client Report

Supervisor: Michael D. Mann

Cost: $7,654

Period: June 1985-August 1985

Descriptors: Fluidized Bed Combustion, and Air Pollution Control

PROJECT SUMMARY

Project Title: Design and Construction of AFBC PDU for Corrosion and Erosion Studies

Client: U.S. Department of Energy/Office of Fossil Energy
Contact: Harvey Ness

Objective: To design and construct an atmospheric fluidized bed combustor for use in long term tests (1000 hours) evaluating the corrosive and erosive nature of low-rank coals on heat transfer tubes and support surfaces.

Activities: A test program has been initiated at UNDERC to evaluate the corrosion and/or erosion of heat transfer surfaces when burning Western low-rank coals in an AFBC. To accomplish this goal, a pilot-scale AFBC system has been designed and constructed. The operation of the unit will provide indicative data, as a function of fuel properties, on the degree of corrosion and erosion that can be expected with typical materials of construction used in an AFBC.

Publications: None

Supervisor: Michael D. Mann

Cost: $125,000

Period: December 1984 - September 1985

Descriptors: Fluidized bed combustion, Equipment Design and Fabrication and Materials Science

PROJECT SUMMARY

Project Title: Study of Agglomeration in Fluidized Bed Combustion

Client: U.S. Department of Energy, Office of Fossil Energy
Contact: Harvey Ness, Grand Forks Project Office

Objective: Agglomeration of bed material has been identified as a potentially serious problem in the FBC of low-rank coal containing ash high in sodium. Both laboratory and pilot-testing has been performed to elucidate a mechanism for the formation and to develop a solution for the problem.

Activities: Testing was performed on the 2.25 ft^2 AFBC to determine the effect of different coal feed methods on bed material agglomeration. Moisture and coal size were also examined. Other agglomeration related testing on this unit include a study of the effect of different bed materials, the effect of sodium level in the coal, and the effect of excess air on bed agglomeration. Laboratory studies currently being performed include sintering tests and basic furnace tests. Ash and bed materials from the pilot FBC and mixtures of two and three pure component minerals are being studied to determine the mineral phase transformations to elucidate agglomeration mechanisms. Small bench-scale testing is also being performed in a 2" diameter reactor.

Publications: Bobman, M.H., D.R. Hajicek, and B.J. Zobeck. "A study of Bed Agglomeration Resulting from the AFBC of Low-Rank Coals," 8th International Conference on Fluidized Bed Combustion, Houston, Texas. DOE/METC-85/6021, Vol. 3, pp 1399-1407. March, 1985.

Perkins III, D., D.W. Brekke, and F.R. Karner. "Analysis of Atmospheric Fluidized Bed Combustion Agglomerates," Technical Information Service, U.S. Department of Energy, DOE/FC/10489-1694, April 1984.

Goblirsch, G.M., et. al. "AFBC Bed Material Performance with Low-Rank Coals," 12th Biennial Lignite Symposium, Grand Forks, North Dakota, DOE/METC/84-13 Vol. 2, pp. 557-581. February 1984.

Supervisor: M.D. Mann

Cost: $835,000

Period: April 1983 - June 1986

Descriptors: Fluidized Bed Combustion, Agglomeration

PROJECT SUMMARY

Project Title: AFBC Low-Rank Coal Characterization

Client: U.S. Department of Energy, Office of Fossil Energy
Contact: Harvey M. Ness, Grand Forks Project Office

Objective: The most promising market for the use of low-rank coals (LRC) in FBCs is for applications in high industrial growth regions such as the Gulf Coast. However, little work has been done in characterizing LRC that exist in these areas as they relate to usage in the FBC. Therefore, coals from four industrial regions will be evaluated in various modes of operation to develop an assessment of the environmental issues and the performance and reliability of the coals in FBC.

Activities: A parametric study is being performed using two lignites and two subbituminous coals from areas with high industrial growth. Parameters varied during each test include bed temperature, bed velocity, and bed height using heat transfer bundles that are representative of heat transfer surfaces in a fluid bed boiler. Changes in the heat transfer rate and operability are determined for the characteristic methods of achieving turndown for each coal tested. Gaseous and particulate emissions are measured during the parametric testing to characterize the effects on combustion efficiency, sulfur capture, NO_x emissions, and particulate collectability. Ash and bed materials are collected for waste characterization.

Publications: None

Supervisor: M.D. Mann

Cost: $808,000

Period: December 1984 - June 1986

Descriptors: Fluidized bed combustion

PROJECT SUMMARY

Project Title: Development of Heat Transfer Equations in Fluidized Bed Combustion

Client: U.S. Department of Energy, Office of Fossil Energy
Contact: Harvey M. Ness, Grand Forks Project Office

Objective: To measure in-bed and freeboard heat transfer coefficients, to determine the radiative contribution to heat transfer, to determine the emissivity of various bed materials, and to use this data to develop equations to accurately predict in-bed and freeboard heat transfer in low-rank coal AFBC.

Activities: Heat transfer coefficients were measured in the bed, splashzone, and freeboard during combustion tests using low-rank coal and predictive equations have been developed. Specially designed heat transfer probes were developed and tests performed to measure the radiative portion of heat transfer over a wide range of operating conditions. The emissivity of an ash and limestone bed material have also been determined. This information is currently being used to refine the predictive heat transfer equations.

Publications: Grewal, N.S. and G.J. Goblirsch, "Heat Transfer to Horizontal Tubes in a Pilot-Scale Fluidized Bed Combustor Burning Low-Rank Coals." ASME Annual Meeting, Seattle, Washington, July 1983.

Grewal, N.S., "Development of Reliable Predictive Heat Transfer Correlations for Low-Rank Coal-Fired Fluid Bed Combustor," U.S. Department of Energy, Office of Fossil Energy, DOE/FC/10489-1694, February, 1984.

Supervisor: M.D. Mann

Cost: $102,000

Period: April 1983 - June 1986

Descriptors: Fluidized Bed Combustion, Heat Transfer

PROJECT SUMMARY

Project Title: Fluidized Bed Combustion of Low-Rank Coals

Client: U.S. Department of Energy/Office of Fossil Energy
Contact: Thomas Dorchak

Objective: To conduct research and development programs aimed at providing a technology data base so that industry can bring economically competitive and environmentally acceptable coal technology options into the marketplace. Research will address those areas where data gaps exist in fuel flexibility and performance, potential operating problems, environmental compliance, and in the use of coal water slurry applications.

Activities: Research addressing data gaps in fuel flexibility and performance and environmental compliance will involve parametric studies using selected coals over a range of operating conditions including bed temperature, gas velocity, bed depth, ash recycle rates, and sorbent addition rates. Corrosion and erosion of heat transfer surfaces is one of the potential operating problems that is being investigated. Tests 1000 hours in duration are being performed to investigate the effects of various low-rank coal properties on corrosion and erosion in the AFBC. Bed material agglomeration is another potential operating problem being investigated, with work in this area being performed on the bench scale. The use of slurry as a potential feedstock for AFBC is also being studied. Several slurries will be tested using coals previously tested in the dry form to allow a direct comparison of the two feed methods. Long range activities will involve advanced concepts and special applications.

Publications: Quarterly Technology Transfer Reports

Supervisor: M. D. Mann

Cost: $257,900 (FY 86)

Period: April 1986 - April 1991

Descriptors: Fluid Bed Combustion, Air Pollution Control, Materials Science

PROJECT SUMMARY

Project Title:	Characterization Study of Waste Wood in an AFBC System
Client:	Valmont Industries, Inc./USDA
Objective:	Provide design information for an AFBC system that will burn biomass using an in-bed heat pipe for energy extraction. Specifically over a range of selected test conditions determine how well wood chips can be burned in an AFBC system, the oxygen-to-fuel ratios required for successful and environmentally safe combustion, the superficial gas velocity that will be required to remove ash from the bed without significant carry-over of unburned wood, and rate of heat release to water-cooled and air-cooled heat transfer surfaces in the bed.
Activities:	Testing was conducted over a series of test periods at three velocity rates, three excess air levels, and with three moisture contents with the soft wood chips. A single test period was completed with hard wood chips. All testing was at a bed temperature of about 1600 degrees F. A final report was prepared including results for each test period on carbon combustion efficiencies obtained, temperature distribution throughout the bed and freeboard, in-bed heat transfer coefficients, and exhaust particulate and gaseous emission levels.
Publications:	Atmospheric Fluidized Bed Combustion of Wood Chips for Valmont Industries
Supervisor:	D.R. Hajicek
Cost:	$22,437
Period:	October 1987 - February 1988
Descriptors:	Fluid Bed Combustion, Biomass Combustion, Heat Transfer