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PCFB Repowering Project

ANNUAL REPORT

**For the Period
January 1993 to December 1993**

Prepared by:

**DMEC-1 Limited Partnership
666 Grand Avenue
Des Moines, Iowa 50309**

Prepared for:

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List of Acronyms

DMEC-1	Des Moines Energy Center
PCFB	Pressurized Circulating Fluidized Bed
DOE	Department of Energy
CCT	Clean Coal Technology
MW_t	Thermal Megawatts
MW	Electrical Megawatts
psig	Pounds per square inch gauge
NEPA	National Environmental Policy Act
ACTF	Advanced Ceramic Tube Filter
ORNL	Oak Ridge National Laboratory
EIV	Environmental Information Volume
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute

1.0 Executive Summary

This report provides a summary of activities by the Des Moines Energy Center (DMEC-1) Limited Partnership on the Pressurized Circulating Fluidized Bed (PCFB) Repowering Project during the year 1993. The Project is partially sponsored by the U.S. Department of Energy (DOE) via The Clean Coal Technology (CCT) program. The Round II activity was initiated in August of 1991. This project is in its first budget period of activities where finalizing preliminary design, cost, and business aspects are the focus. In 1993, Budget Period 1 was extended through October 31, 1994 to allow for (1) additional time to complete filter testing which is needed to finalize the design and (2) economic studies to verify the merits of the project for the host utility's good.

In August of 1991, Iowa Power, and Dairyland Power Cooperative, entered into a Cooperative Agreement with DOE. Collectively, the two utilities and the Pyropower Corporation and Black & Veatch initiated the preliminary design of the PCFB Repowering Project. As a result of a July 1992 merger between Iowa Power and Iowa Public Service, Midwest Power was formed and has fully assumed Iowa Power's role at General Partner of the DMEC-1 Limited Partnership. The PCFB Repowering project will demonstrate "First Generation" PCFB technology where steam generated in a PCFB boiler will be used to power a steam turbine and exhaust gases from the PCFB boiler will be expanded through a gas turbine to provide additional power output. This combined cycle system yields high efficiency and superior environmental performance.

The technical and cost baselines of the Cooperative Agreement were based on conceptual engineering and design. These baselines are being refined during the first budget period. Other first budget period activities include tasks to evaluate alternate hot gas filters and the concept of a topping combustor. The Statement of Work for the first budget period of the Cooperative Agreement also includes the development of the preliminary design of the power plant, preparation and submittal of environmental information, performance of studies and system analysis, and refinement of cost and schedule baselines.

The preliminary design is progressing. As the design is refined and modified, cost and schedule baselines have been and will continue to be updated. Environmental information has been obtained and submitted to The DOE with no

significant problems or concerns identified. Testing analysis and evaluations of systems continue.

A key feature of design verification testing has been and will continue to be the selection and testing of ceramic barrier filtration technologies including the Asahi Advanced Ceramic Tube Filter (ACTF) and Westinghouse's Candle Filter. At the time of this report testing has been completed on the Asahi ACTF and testing has been initiated on the Westinghouse filter. All testing is being conducted at Pyropower's 10MW, PCFB pilot plant in Karhula, Finland. In general terms, the Asahi design was successful in reducing the outlet dust loading to required levels but certain problems were encountered which led to some premature ceramic tube failures. To address these problems, some significant modifications were required to the filter. These modifications have been incorporated in the two filters supplied by Asahi for the 70MW Wakamatusu PCFB project in Japan.

Testing of the Westinghouse candle filter was started in the fall of 1992 using Coors mullite candles. After three separate long term tests with the mullite candles, a decision was made in September 1993 to replace the mullite candles with Refractron silicon carbide candles which appeared to be more resistant to thermal shock caused by process transients and pulsing. By the end of 1993 more than 510 hours of operation on coal were achieved without a single candle failure. Further testing is planned for 1994.

This document provides detailed discussion of accomplishments and activities completed primarily during 1993.

2.0 Introduction and Background

This report will provide an overview discussion of the "First Generation" PCFB technology planned for demonstration at DMEC-1. It will summarize the status of each of the activities that has been carried out during the first budget period of the project, primarily in 1993, including the extension of Budget Period 1 and filter testing. Finally, it will discuss the work remaining through the remainder of Budget Period 1. Historical details of the project are discussed in several public documents (See Bibliography listing)

3.0 Project Objectives

The Participant will demonstrate that PCFB combined-cycle technology, when operating at a commercial scale, is a cost effective, reliable, and environmentally superior technology which can achieve significant reductions of SO₂ and NO_x emissions when compared to existing and future coal-burning power plants. The project will be the first commercial scale-up of a pilot plant system. The PCFB process components will be designed and built by Pyropower Corporation of San Diego, California. The technical challenges associated with this project will include the first use of a commercial size PCFB combustor module in a full-scale utility demonstration. The project will be accomplished in three phases; design, construction, and operation. Phase 1 (design) is comprised of two budget periods. Budget Period 1 includes preliminary engineering while Budget Period 2 is detailed engineering. Budget Period 1, the current period, is scheduled to be complete by October 31, 1994.

4.0 Project History

In August of 1991, Iowa Power, Dairyland Power Cooperative, Pyropower Corporation, and Black & Veatch initiated the preliminary design of the PCFB Repowering Project. As a result of a July 1992 merger between Iowa Power and Iowa Public Service, Midwest Power was formed. Midwest Power has assumed the role of General Partner for the DMEC-1 Limited Partnership and has assumed the associated responsibilities of the project. The project is named after the plant's proposed location, i.e., the Des Moines Energy Center (DMEC). The project has been awarded \$93,253,000 of cost sharing from the DOE Round 3 CCT Program.

The PCFB Repowering project is based on the demonstration of "First Generation" PCFB technology to repower an existing steam turbine at the DMEC-1 site with steam provided by the PCFB boiler. Exhaust gases from the PCFB boiler will be cleaned at 1600° F in a ceramic filter and exhausted through a gas turbine which will provide over 20 percent of the resulting plant's net power output. The resulting improvement in the net plant heat rate of the DMEC-1 site will be about 15 percent compared to that of the original steam plant, while emissions will be controlled within New Source Performance Standards.

Repowering of the existing steam turbine at the DMEC-1 will result in approximately 87 MW gross power generation. The plant will be designed to fire a range of coals including high sulfur bituminous coals from Illinois, Iowa, and low sulfur subbituminous Western coal from the Powder River Basin in Wyoming. The PCFB boiler will replace a retired pulverized coal fired boiler by repowering an existing steam turbine. The steam conditions in the PCFB boiler are expected to be 506,200 pounds per hour at 1300 pounds per square inch gauge (psig) and 955° F. Approximately 65 MW will be produced from the steam turbine. The gas turbine will provide an additional 22 MW of power.

The PCFB Repowering Project will combine the new technology of the AHLSTROM PYROFLOW® PCFB process with a conventional steam generation power plant. The unit will be designed and furnished by Pyropower Corporation, San Diego, California, the U.S. subsidiary of A. Ahlstrom Corporation of Helsinki, Finland. The project will be a commercial scale-up from an existing PCFB test facility located in Karhula, Finland. Black & Veatch, Engineers - Architects, Kansas City, Missouri, will be responsible for engineering of the balance of the plant.

Of note, engineering and design aspects of the project were hampered in 1993 because Midwest Power personnel efforts were temporarily refocused to handle a company crisis. In the summer of 1993 there was widespread flooding in the midwest. The DMEC-1 site was affected by the floods in that the floodwall at the cooling tower collapsed and water rose to a level of two inches above the plant operating floor. After repair of the floodwall by the US Army Corps of Engineers, the cooling tower basin will need to be repaired for the project.

5.0 Project Description

The PCFB process utilizes a combined cycle which employs a combination of a gas turbine and steam turbine to generate power. The pressurized combustion

chamber is used to burn coal to produce steam for the steam turbine which produces 75-80 percent of the plant output. The hot flue gases are filtered and expanded through a gas turbine to generate the remaining 20-25 percent of the plant output and to supply the compressed air for the PCFB combustor.

Coal and sorbent are supplied to the PCFB combustor as a paste using a technology similar to that used in pumping concrete. The materials are injected into the PCFB combustor with the assistance of a steam atomizer to distribute the particles. As combustion occurs, sulfur is absorbed by the sorbent. Particles of coal and sorbent become entrained with the flue gas and are collected in a cyclone and returned to the combustor. The finer particles continue with the hot gases to a ceramic filter where final removal of particulates is achieved. The cleaned flue gas is expanded through the gas turbine and remaining useful heat in the exhaust is recovered in a conventional heat recovery unit. The clean exhaust is released to the stack.

5.1 Design Basis

The DMEC-1 facility is being designed with the capability to fire a wide range of different coals including Illinois No. 6, Western sub-bituminous and Iowa coal. The primary long term fuel is expected to be Western coal but performance on other coals will be proven during the two year demonstration period immediately following the construction phase. The wide variation in coal, limestone and ash flow rates can be easily handled by the PCFB boiler but requires special consideration in the design of the material handling and feed systems.

5.2 Budget Period 1 Objectives

The activities in Budget Period 1 include completing the preliminary design, performing studies and system analysis, permitting, and refining cost and schedule baselines for the project. One of the key analyses being addressed in Budget Period 1 is the choice of a filter for the PCFB process.

Specific goals for Budget Period 1 include the following.

- Update and refine preliminary engineering to establish the project cost and schedule baselines.
- Conduct process verification testing providing performance data for hot gas filter options, gas turbine materials and coatings and fuel options.
- Finalize plans for appropriate agreements.

- Complete the preliminary design, site and plant arrangement drawings, Project Design Manual and other documentation.
- Provide information and support for the DOE to satisfy responsibility under the National Environmental Policy Act (NEPA).
- Provide a draft Environmental Monitoring Plan.
- Formalize the permitting plan.
- Preliminary demonstration plan.

5.3 Process Flow Description

Figure 1: PCFB Process Flow Diagram

Figure 1 shows the process flow diagram for the PCFB system based on repowering one existing steam turbine at the DMEC site. Both coal and limestone are mixed with water into a paste using a two stage mixing process. The resultant paste is pumped into the combustion chamber, located inside a pressure vessel, using piston pumps commonly used in the concrete industry. Combustion air is supplied from the compressor section of the gas turbine.

Coal combustion and in-situ sulfur removal take place at approximately 1600°F in the hot loop consisting of the membrane wall combustion chamber and the

refractory lined hot cyclone. Superheater surface, constructed of "Double Omega" tubing, is located in the upper combustion chamber. "Double Omega," a special kind of superheating tubing, has a surface which has been demonstrated successfully in numerous Pyroflow Atmospheric Circulating Fluidized Bed applications as well as in the PCFB pilot plant in reducing the risk of erosion.

The flue gas leaving the cyclones is cleaned in parallel ceramic barrier filters before being expanded through the gas turbine. The gas leaving the turbine is cooled in a conventional finned tube heat recovery unit before entering the stack.

The gas turbine is a standard single shaft, cold end drive industrial machine that has had the center section of the turbine modified. A scroll section has been added to allow for the removal of compressor discharge air from the casing for external firing in the PCFB combustor and to allow for the introduction of hot clean gas back through the casing into the expander section. This air outlet/gas inlet design is commonly used in recuperative gas turbine cycles. The 1600° F gas inlet temperature allows for a simplified turbine shaft and blade cooling system that only consumes approximately 8 percent of the total air relative to the 15-20 percent required for higher inlet temperatures. This provides a greater quantity of air available for firing coal to generate steam in the PCFB combustor, thereby maximizing power output from the cycle.

Approximately 20-25 percent of the gross station output is provided by the gas turbine with the remaining 75-80 percent coming from the steam turbine. This forty year old turbine operates with a 1250 psig, 950° F non-reheat steam cycle and limits the overall cycle efficiency.

6.0 Accomplishments and Results

Budget period 1 was extended to look further into economies of scale associated with plant capital cost and cost of operation as well as to continue with ceramic filter testing and the selection of a filter for commercial demonstration. During 1993, design work continued as several documents were submitted to the DOE.

6.1 Coal Paste Pump Testing

Pyropower solicited bids from three companies for the supply of the paste pumps for the project. As two of the bidders did not have direct experience in coal paste applications, a decision was made to conduct test on Western coal at the

factory of each supplier. Crushed coal was provided by Midwest Power and test programs were mutually developed by both suppliers and Pyropower.

The first two days of each test involved some minor setup problems with the coal water mixing equipment. Following this, both tests were successful in demonstrating the ability of the suppliers' equipment to pump the coal paste. In one case, pump operation over a wide range of moisture contents was demonstrated at high back pressures. Similar testing is planned for the future on the specific coal paste mixers being considered for the project.

6.2 Electrical Work

Black & Veatch developed the electrical design for the repowering of the existing electrical system loads still in service at the Des Moines II station, utilizing an existing 13.8 kV power source on the site. The purpose of the modification was to eliminate the use of the 13.8 kV and 2.4 kV electrical distribution equipment on site. The design included the addition of three single phase 500 kVA transformers to step the 13.8 kV voltage down to 480 volts, for internal distribution of power within the plant. Two new 480 volt distribution panels were added as part of the design.

6.3 PCB Cleanup

The site was contaminated with PCB oil as a result of a plant salvage operation accident. The source of the contamination was the transformer rectifier sets on an electrostatic precipitator, which was demolished and removed from the site. The contamination was limited to soils and rubble around the plant.

The soil and demolition rubble were removed in a controlled manner and shipped to Idaho for disposal. During 1993, the site was subject to a final survey and accepted as clean by the Environmental Protection Agency (EPA).

6.4 Extensions of Budget Period 1

As defined in the Cooperative Agreement, the subject project consists of three phases; design, construction and operation. Phase 1 (design) is comprised of two budget periods. Budget Period 1 originally covered the work associated with the first 13 months of the project. On April 13, 1992 Iowa Power (now Midwest Power) made an application for a ten month extension of Budget Period 1. The purpose of this extension, in part, was to allow completion of filter verification and analysis of

filter test data. DOE subsequently approved this extension. Other activities in Budget Period 1 include completing the preliminary design, performing studies and system analysis, permitting, and refining cost and schedule baselines for the project.

During the summer of 1993, the Midwest region of the United States was subjected to widespread flooding. These and other events resulted in a couple of minor time extensions to allow Midwest Power sufficient time to complete internal discussions regarding the project. On June 23, 1993, Midwest Power submitted an additional one month extension application to allow time for further power supply study and consideration of restructuring or the project in the light of the Clean Coal V announcement. This extension was approved by the DOE. On July 28, 1993 Midwest Power requested an additional extension of the budget period for up to two months to allow preparation of and application for an 18 month extension to budget period 1. The DOE granted this 2 month extension.

On September 28, 1993 Midwest Power submitted an application for an extension to Budget Period 1 to continue the selection process of the ceramic filter and to evaluate the optimum project configuration for the host utility. Midwest Power will conduct studies to determine the merits of the project as it relates to performance data, cost and schedule, and power supply analyses. It has been identified that project economics can be significantly improved by repowering a larger steam turbine than originally planned. The proposed extension will also allow the completion of the NEPA process. Considerable additional work remains to negotiate and finalize the contracts between Midwest Power and Black & Veatch for the balance of plant and between Midwest Power and Pyropower for the PCFB island. The proposed extension will provide the time necessary to finalize these agreements prior to the start of detailed engineering. A 12 Month extension to Budget Period

Figure 2: Project Schedule as of December, 1993

1 was granted by the DOE. This extends Budget Period 1 through October 31, 1994. Figure 2 shows the schedule as of the end of December, 1993.

6.5 Ceramic Filter Testing

A key feature of the pilot plant testing has been and will continue to be the testing of ceramic barrier filtration technologies including the Asahi ACTF technology and Westinghouse's Candle Filter Technology. Testing had been completed on the Asahi ACTF filter and the filter pressure vessel was modified to accommodate a Westinghouse candle cluster.

The configuration of the Asahi filter previously tested is shown schematically in Figure 3. A total of 21 beta cordierite tubes were installed in the vessel between three water cooled tube sheets. Each tube was 170 mm in diameter (OD) and 6210 mm long including the associated sleeves and bellows. Dirty gas entered the top of the vessel and flowed down into the tubes. The ash was deposited on the inside of the tube and the clean gas exited the vessel through the two side gas outlets. Back pulse air used to periodically clean the tubes was introduced through the gas outlets and then preheated in regenerators. Ash cleaned from the tubes fell into the bottom of the vessel and was subsequently evacuated from the vessel by the ash removal system. The Asahi design was successful in reducing the outlet dust loading to the level required by gas turbine manufacturers but some premature ceramic tube failures occurred.

The Westinghouse candle filter arrangement is illustrated schematically in Figure 4. A metallic cluster is supported from a single water cooled tube sheet. This cluster supports three arrays of candles with the candles of each array being connected to an individual plenum. The top and middle arrays of the cluster each have 38 candles while the bottom array contains 52 candles. Each candle is 60 mm in diameter (OD) and 1500 mm long. Dirty gas enters the side of the vessel and flows around a shroud before passing through the candles into the clean gas plenum of each array and out the top of the vessel. The ash that is collected on the outside of the candles is removed periodically with short pulses of high pressure air from the back pulse system.

Shakedown testing of the Westinghouse candle filter was initiated in the fall of 1992 using Coors mullite candles. Following this initial testing, the first of three long-term test segments commenced in November, 1992 and was concluded in June, 1993. In the summer and fall of 1993, a number of modifications were

Figure 3: Asahi Filter Configuration

Figure 4: Westinghouse Filter Configuration

made including the substitution of Refractron silicon carbide candles. The Refractron silicon carbide candles appeared to be more resistant to thermal shock caused by process transients and pulsing. The second test segment was initiated in the beginning of November and was successfully concluded in mid-December, 1993, without the breakage of any of the Refractron filter candles. Approximately 510 hours of operation on Illinois No. 6 and Black Thunder (Powder River Basin) coal was achieved. Further testing will be conducted in 1994.

In August, 1993, at DOE's request, a project steering committee was established to oversee the filter testing program and to focus on major project issues. The committee consisted of senior management representatives of DOE, Midwest Power, Pyropower and Westinghouse.

6.6 Submission of Documents

In June of 1993, the system design specifications, project design manual, environmental monitoring plan, project instruction manual revision, site and plant arrangement drawings were completed. A memorandum of agreement was submitted to the Iowa State Historical Society.

6.7 National Environmental Policy Act (NEPA)

The intent of the CCT Program is to demonstrate the efficient production of energy with significant reductions in the emissions of sulfur dioxide and nitrogen oxides in comparison to existing commercial technologies. Because the project is receiving federal funding through the U.S. DOE CCT Program, the DMEC-1 Project was required to comply with the NEPA. Prior to receiving federal funding for construction or operation NEPA activities must be fulfilled.

In June 1992, the final Environmental Information Volume (EIV) was submitted to DOE in support of the NEPA environmental review process. The EIV provided the background environmental and socioeconomic data characterizing the proposed project and identified the expected impacts from project construction and operation. On July 8, 1992, Midwest Power and Black & Veatch personnel assisted with a public scoping meeting conducted by DOE and held in Pleasant Hill.

At the request of DOE and DOE's support contractor, Oak Ridge National Laboratory (ORNL), additional site environmental investigations were undertaken, including the following:

- Archeological, historic, and cultural resources investigation;
- Ambient noise survey and impacts assessment;
- Threatened and endangered wildlife species investigation; and
- Wetlands, plant communities, and protected plant species investigation.

Formal reports of the additional site investigations were provided to DOE and ORNL. In addition, Midwest Power and Black & Veatch personnel have answered all questions and requests for information from DOE and ORNL to further assist with completion of the NEPA review process. The Environmental Impact Statement is currently being developed by DOE.

7.0 Future Work

The extension of Budget Period 1 is to allow for the completion of the following tasks:

1. Completion of filter testing design verification activities at Karhula and the selection of a viable filter technology for the project including establishment of a steering committee to review and direct filter testing programs.
2. Completion of the NEPA process for the DMEC site.
3. Evaluations to determine optimum project configuration and location including performance data, cost and schedule baselines and power supply analyses.
4. Establishment of definitive commercial terms and conditions for the supply of the PCFB boiler island and balance of plant.

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