DOE/FE-0078
CCT/87 MC 24132

Comprehensive Report To Congress Clean Coal Technology Program

Tidd PFBC Demonstration Project

A Project Proposed By
American Electric Power Service Corporation
On Behalf Of
The Ohio Power Company

February 1987

U.S. Department of Energy
Office of Fossil Energy
Washington, D.C. 20545

COMPREHENSIVE REPORT TO CONGRESS
ON THE CLEAN COAL TECHNOLOGY PROJECT

"TIDD PFBC DEMONSTRATION PROJECT"

Proposed by: American Electric Power Service Corporation
On Behalf of: Ohio Power Company

February 1987

U. S. Department of Energy
Assistant Secretary for Fossil Energy
Washington, D.C. 20585

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

1.0 EXECUTIVE SUMMARY

New emerging clean coal technologies offer the promise of making a major contribution toward meeting electric power demands in the mid 1990's and beyond. However, these technologies are not yet sufficiently demonstrated to have gained the confidence of either the electric utility industry or the Governmental agencies that regulate it. To be available for deployment in the 1990 to 2000 time frame, demonstrations involving clean coal technologies must occur now.

One technology with high potential for meeting the end-of-century requirements for large power generation applications is combined-cycle pressurized fluidized bed combustion (PFBC). PFBC permits the combustion of a wide range of coals, including high sulfur coals, with a sorbent, such as limestone or dolomite, in a fluidized bed combustor at an elevated pressure. The sorbent captures most of the sulfur emissions during the combustion process itself which greatly reduces or completely eliminates the need for expensive downstream sulfur control equipment. PFBC produces a dry solid sorbent waste which is easily disposed of in an environmentally acceptable manner. In addition, the lower operating temperature substantially reduces nitrogen oxide emissions .

In addition to these environmental features, PFBC components and plant facilities are considerably smaller than nonpressurized or conventional units of equal generating capacity. Thus, PFBC readily adapts to modular design which leads to lower costs. Modular construction of PFBC generating plants will permit utilities to economically add increments of capacity to match load growth and reduce utility financing requirements. Prospects for repowering of existing facilities are also greatly enhanced by the modular approach to PFBC systems.

To further the development of PFBC, the Department of Energy and Ohio Power Company (OPCo), a wholly owned subsidiary of American Electric Power Company, Inc. (AEP), have negotiated a Cooperative Agreement to construct and operate a 70 megawatt (MWe) PFBC combined-cycle demonstration plant (Figure 1). The facility will be located in Brilliant, Ohio, which is on the Ohio River approximately 76 miles downstream from Pittsburgh, Pennsylvania (Figure 2). Originally built in 1943, the Tidd Facility was shut down in 1976 because it was not economical to retrofit the plant with electrostatic precipitators to meet emission standards. This project involves the repowering of the Tidd Facility with PFBC which will meet all current environmental standards.

The work to be performed under the Cooperative Agreement covers the design, construction, and operation of the demonstration plant. The project is estimated to cost $167,500,000 with the Government share being $60,200,000. OPCo has agreed to absorb any cost overruns and has agreed to a plan to repay the Government's contribution. Construction is scheduled to commence by the end of 1987 with the three year operation phase starting in early 1990.

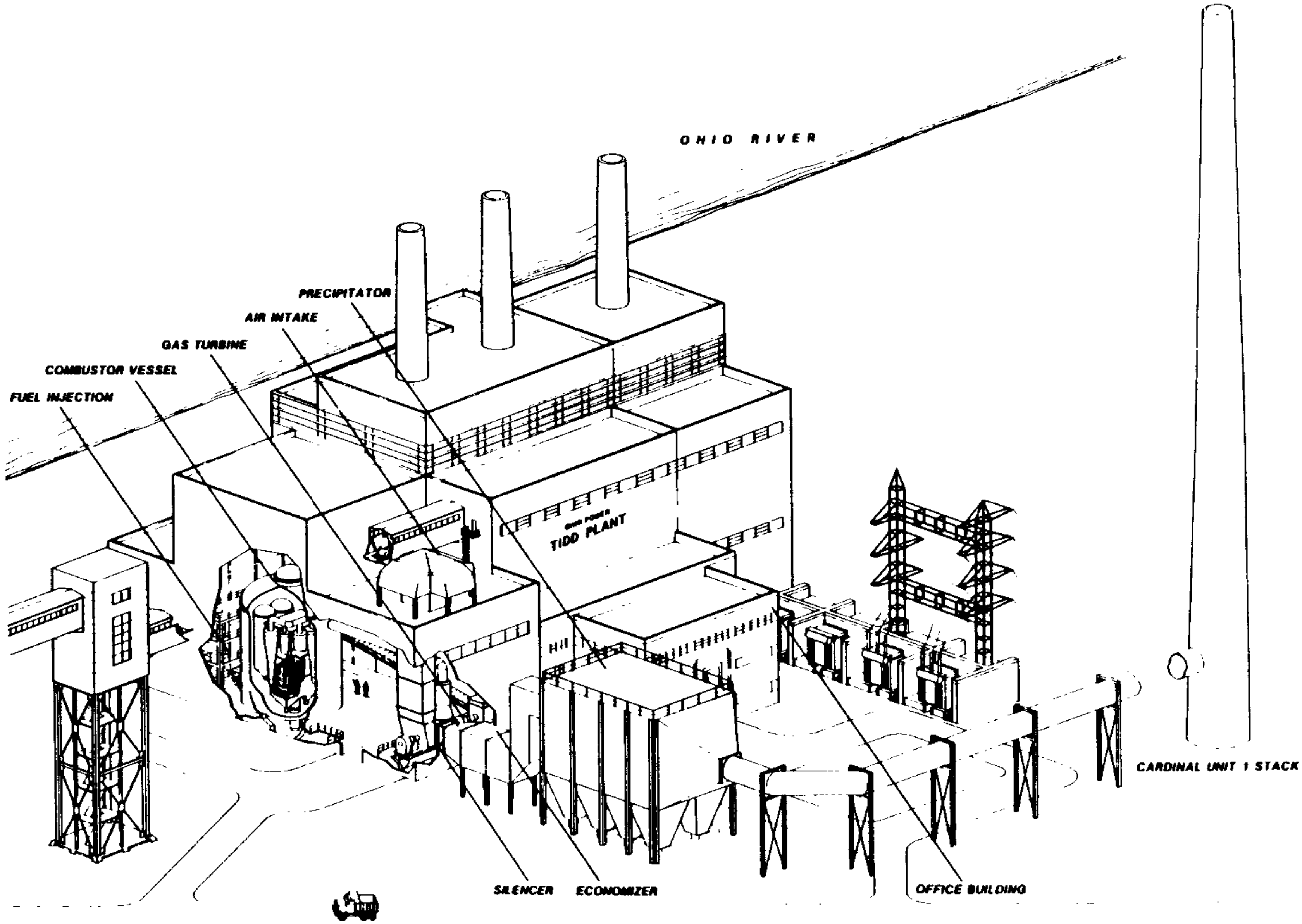

Figure 1. Tidd PFBC Demonstration Plant

C87-513-A CCT4

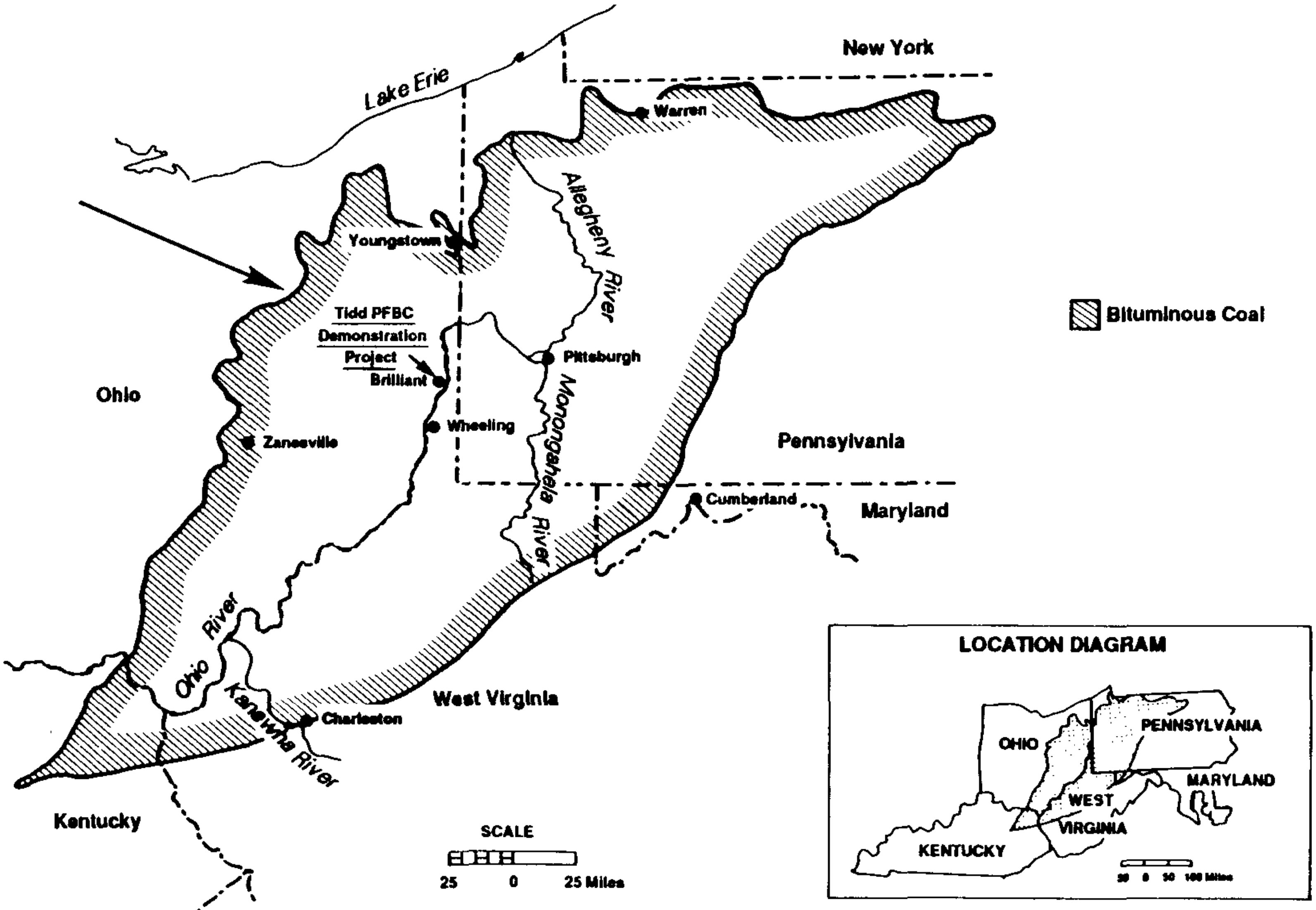

Figure 2. Tidd PFBC Demonstration Project Location

87-492-A CCT4

1.1 PROJECT OBJECTIVES

The overall objective of this project is to demonstrate PFBC technology at a large scale for use in commercial electric generating plants. The specific goal of this project is to demonstrate that combined-cycle PFBC technology is a cost-effective, reliable, and environmentally superior alternative to conventional coal fired electric power generation with flue gas desulfurization.

1.2 PROPOSED PROJECT

OPCo will repower Unit 1 of the Tidd power plant in Brilliant, Ohio, with a combustor, gas turbine, and related auxiliary equipment using high sulfur U.S. coal. Construction is projected to begin in late 1987 with initial operation in late 1989. A three year test period has been planned to begin in early 1990.

1.3 PROJECT PARTICIPANTS

a. OPCo -- OPCo will own and operate the Tidd PFBC Demonstration Project (TPDP).

b. American Electric Power Service Corporation (AEPSC) -- Agent for OPCo and Project Manager. AEPSC will design, engineer, and provide the construction management for the demonstration plant and provide technical services to OPCo throughout the operating life of the plant.

c. ASEA Babcock PFBC (ABP) -- Subcontractor to OPCo for PFBC-related equipment. ABP is a partnership consisting of ASEA PFBC AB and ASEA Stal AB, both of Sweden; and The Babcock and Wilcox Company (B&W), a McDermott company of New Orleans, Louisiana.

d. DOE -- DOE will provide funding and technical advice, approve advancements into each subsequent phase, monitor the project and disseminate information which will lead to future commercialization.

e. State of Ohio -- The State of Ohio will provide $10,000,000 to the project.

1.4 PROJECTED COSTS

The projected cost is $167,500,000. The total DOE share of estimated project cost is $60,200,000 or 35.9 percent. If the actual amount for cost sharing of this project becomes less than $167,500,000, the Government's contribution is proportionately reduced, in accordance with a 35.9 percent cost share by the DOE. If the actual amount for cost sharing of this program exceeds $167,500,000, OPCo will absorb any cost overruns. In summary, the U.S. Government's contribution is capped at $60.2 million.

1.5 PROJECT SITE

The TPDP site consists of approximately 36 acres and contains appurtenant structures for unloading, storing, and handling coal and dolomite as well as a

138,000 volt switchyard for dispatching the electric power into AEP's transmission system.

The steam cycle of the TPDP will utilize many of the existing conventional components from the original Tidd plant including the steam turbine generator, steam condenser, condensate and feedwater heaters and pumps. Since it is necessary to demonstrate that PFBC can operate in a combined cycle mode, these conventional components are a necessary part of the demonstration project.

1.6 USE OF U.S. COALS

The PFBC process can handle a much wider range of coals than can be used in conventional combustion processes. A broad spectrum of coals has already been tested in pressurized fluidized bed combustors during various stages of PFBC development. A number of English and U.S. coals were tested at the Grimethorpe and Leatherhead PFBC test facilities in the United Kingdom and at the Component Test Facility in Sweden.

PFBC is well suited to utilize high-sulfur coal, including eastern bituminous coal. This could result in a revitalization in many segments of the coal industry, leading to improvement in regional and national economics. If, by the year 2010, PFBC combined-cycle power plants are utilized for only 25 percent of the new coal fired power plants, this could translate to the consumption of over 100 million tons of high-sulfur coal being consumed annually in the United States.

2.0 INTRODUCTION AND BACKGROUND

The domestic coal resources of the United States play an important role in meeting current and future energy needs. During the past 15 years, considerable effort has been directed to developing improved coal combustion, conversion, and utilization processes to provide efficient and economic energy options. These technology developments permit the attainment of environmental acceptability as well as the efficient utilization of coal resources.

2.1 REQUIREMENT FOR REPORT TO CONGRESS

In December 1985, Congress made funds available for a Clean Coal Technology (CCT) Program in Public Law No. 99-190, An Act Making Appropriations for the Department of the Interior and Related Agencies for the Fiscal Year Ending September 30, 1986, and for Other Purposes. This Act provided funds "... for the purpose of conducting cost-shared Clean Coal Technology projects for the construction and operation of facilities to demonstrate the feasibility for future commercial applications of such technology ..." and authorized DOE to conduct the CCT program. Public Law No. 99-190 provided $400 million "... to remain available until expended, of which $100,000,000 shall be immediately available; (2) an additional $150,000,000 shall be available beginning October 1, 1986; and (3) an additional $150,000,000 shall be available beginning October 1, 1987." However, Section 325 of the Act reduced each amount of budget authority by 0.6 percent so that these amounts became $99.4 million, $149.1 million, and $149.1 million, respectively, for a total of $397.6 million.

In addition, in the conference report accompanying Public Law No. 99-190, the conferees directed DOE to prepare a comprehensive report on the proposals received, after the projects to be funded had been selected. The report was submitted in August 1986 and was titled "Comprehensive Report to Congress on Proposals Received in Response to the Clean Coal Technology Program Opportunity Notice," DOE/FE-0070. Specifically, the report outlines the solicitation process implemented by DOE for receiving proposals for CCT projects, summarizes the project proposals that were received, provides information on the technologies that were the focus of the CCT program, and reviews specific issues and topics related to the solicitation.

Public Law No. 99-190 also directed DOE to prepare a full and comprehensive report to Congress on any project to receive an award under the CCT program. This report is in fulfillment of this directive and contains a comprehensive description of the Ohio Power Company's (OPCo) Tidd PFBC Demonstration Project (TPDP).

2.2 EVALUATION AND SELECTION PROCESS

DOE issued a Program Opportunity Notice (PON) on February 17, 1986, to solicit proposals for conducting cost-shared CCT demonstrations. Fifty-one proposals were received. All proposals were required to meet preliminary evaluation requirements identified in the PON. An evaluation was made to determine if each proposal met those preliminary evaluation requirements and those proposals that did not were rejected.

Of those proposals remaining in the competition, separate evaluations were made for each offeror's Technical Proposal; Business and Management Proposal;

and Cost Proposal. The PON provided that the Technical Proposal was of significantly greater importance than the Business and Management Proposal and that the Cost Proposal was minimal; however, everything else being equal, the Cost Proposal was very important.

The Technical Evaluation Criteria were divided into two major categories. The first major category, "Commercialization Factors," addressed the projected commercialization of the proposed technology. This was different from the proposed demonstration project itself and dealt with all of the other steps and factors involved in the commercialization process. The subcriteria in this section allowed for consideration of the projected environmental, health, safety, and socioeconomic impacts (EHSS); the potential marketability and economics of the technology; and the plan to commercialize the proposed technology subsequent to the demonstration project.

The second major category, "Demonstration Project Factors," recognized the fact that the proposed demonstration project represents the critical step between "pre-demonstration" scale of operation and commercial readiness, and dealt with the proposed project itself. Subcriteria in "Demonstration Project Factors" allowed for consideration of technical readiness for scale-up; adequacy and appropriateness of the demonstration project; the EHSS and other site related aspects; and the reasonableness and adequacy of the technical approach and quality and completeness of the Statement of Work.

The Business and Management Proposal was evaluated to determine the business and management performance potential of the offeror and was used as an aid in determining the offeror's understanding of the technical requirements of the PON. The Cost Proposal was evaluated to assess whether the proposed cost was appropriate and reasonable and to determine the probable cost of the proposed project to the Government. The Cost Proposal was also used to assess the validity of the proposer's approach to completing the project in accordance with the proposed Statement of Work and the requirements of the PON.

Consideration was also given to the following program policy factors:

a) The desirability of selecting for support a group of projects that represent a diversity of methods, technical approaches, or applications;

b) The desirability of selecting for support a group of projects that would ensure that a broad cross section of the U.S. coal resource base is utilized, both now and in the future;

c) The desirability of selecting for support a group of projects that represents a balance between the goals of expanding the use of coal and minimizing environmental impacts.

An overall strategy for compliance with NEPA was developed for the CCT Program, consistent with the Council of Environmental Quality NEPA regulations and the DOE guidelines for compliance with NEPA. This strategy includes both programmatic and project specific environmental impact considerations, during and subsequent to the selection process.

In light of the tight schedule imposed by Public Law No. 99-190 and the confidentiality requirements of the competitive PON process, DOE established alternative procedures to ensure that environmental factors were fully evaluated and integrated into the decision-making process to satisfy its NEPA responsibilities. Offerors were required to submit both programmatic and project specific environmental data and analyses as a discrete part of their proposal.

This strategy has three major elements. The first involves preparation of a comparative programmatic environmental impact analysis, based on information provided by the offerors and supplemented by DOE, as necessary. This environmental analysis ensures that relevant environmental consequences of the CCT Program and reasonable programmatic alternatives are evaluated in the selection process. The second element involves preparation of a preselection project specific environmental review. The third element provides for preparation by DOE of site specific documents for each project selected for financial assistance under the PON.

No funds from the CCT Program will be provided for detailed design, operation, and/or dismantlement until the third element of the NEPA process has been successfully completed. In addition, each Cooperative Agreement entered into will require an Environmental Monitoring Plan to ensure that significant site and technology specific environmental data are collected and disseminated.

After considering the evaluation criteria, the program policy factors, and the NEPA strategy, the proposal submitted by AEPSC, on behalf of OPCo, was one of the proposals selected for award.

3.0 TECHNICAL FEATURES

3.1 PROJECT DESCRIPTION

This project will utilize PFBC technology developed by ASEA PFBC AB and marketed in the U.S. by ASEA Babcock PFBC (ABP), a partnership among ASEA PFBC AB, ASEA Stal AB, and The Babcock and Wilcox Company. The combined-cycle plant will operate at 1,580 degrees F and a pressure of 12 atmospheres with off gases expanding through an ASEA Stal GT-35P gas turbine with a steam turbine bottoming cycle. The TPDP will be retrofitted into a mothballed, coal fired power plant and will utilize the existing steam turbine and site utilities.

3.1.1 Project Summary

a.	Title	--	Tidd PFBC Demonstration Project (TPDP)
b.	Location	--	Brilliant, Ohio -- Jefferson County
c.	Technology Utilized	--	Pressurized Fluidized Bed Combustion
d.	Application	--	Electric Utility (New/Retrofit)
e.	Product	--	Electricity
f.	Type of Coal Used	--	Ohio High Sulfur Bituminous
g.	Size	--	70 MWe

h. Proposed Starting Date -- February 9, 1987

i. Period -- 74 months

3.1.2 Project Participants and Cost

a. Project Participant -- Ohio Power Company

b. Co-Funders:

1. Ohio Power Company
2. State of Ohio
3. U.S. DOE

c. Project Cost and Participant Cost Share

The projected capital cost of the TPDP is $133,567,000. The projected cost of the 3 year demonstration program is $33,933,000 for a total project cost of $167,500,000.

OPCo requested $60.2 million or 35.9 percent of the cost shareable amount from the DOE. These costs are comprised of new investment only: no value of existing facilities or land is included in that cost. If the actual amount for cost sharing of this project becomes less than $167,500,000 DOE contribution is proportionately reduced, in accordance with a 35.9 percent cost share by the DOE. If the actual amount of this project exceeds $167,500,000, OPCo has agreed to absorb any cost overruns. The U.S. Government's share is capped at $60.2 million.

3.2 PROCESS DESCRIPTION

3.2.1 General Description

A fluidized bed consists of a mass of granular particles with an air stream flowing upward through the particles. As the velocity of the air increases to about 3 feet per second, the particles become entrained in the air flow and are maintained in a highly turbulent suspended state. The bed in this state is said to be fluidized and, in general, behaves like a fluid. PFBC is achieved by incorporating a fluidized bed within a pressure vessel (Figure 3).

This fluidized motion permits excellent surface contact between the air and the particles. When a combustible material, such as coal, is introduced into the bed, this mixing leads to efficient combustion. During combustion, sulfur in coal reacts with oxygen to form sulfur dioxide (SO_2).

In PFBC, SO_2 is removed during combustion by adding dolomite or limestone to the bed. Dolomite will be used for the TPDP although limestone may also be tested.

Nitrogen oxides (NO_x) emissions are lower than from a conventional pulverized coal fired (PCF) boiler. This is due to the low combustion temperature in a fluidized bed which minimizes NO_x generation. A conventional PCF boiler

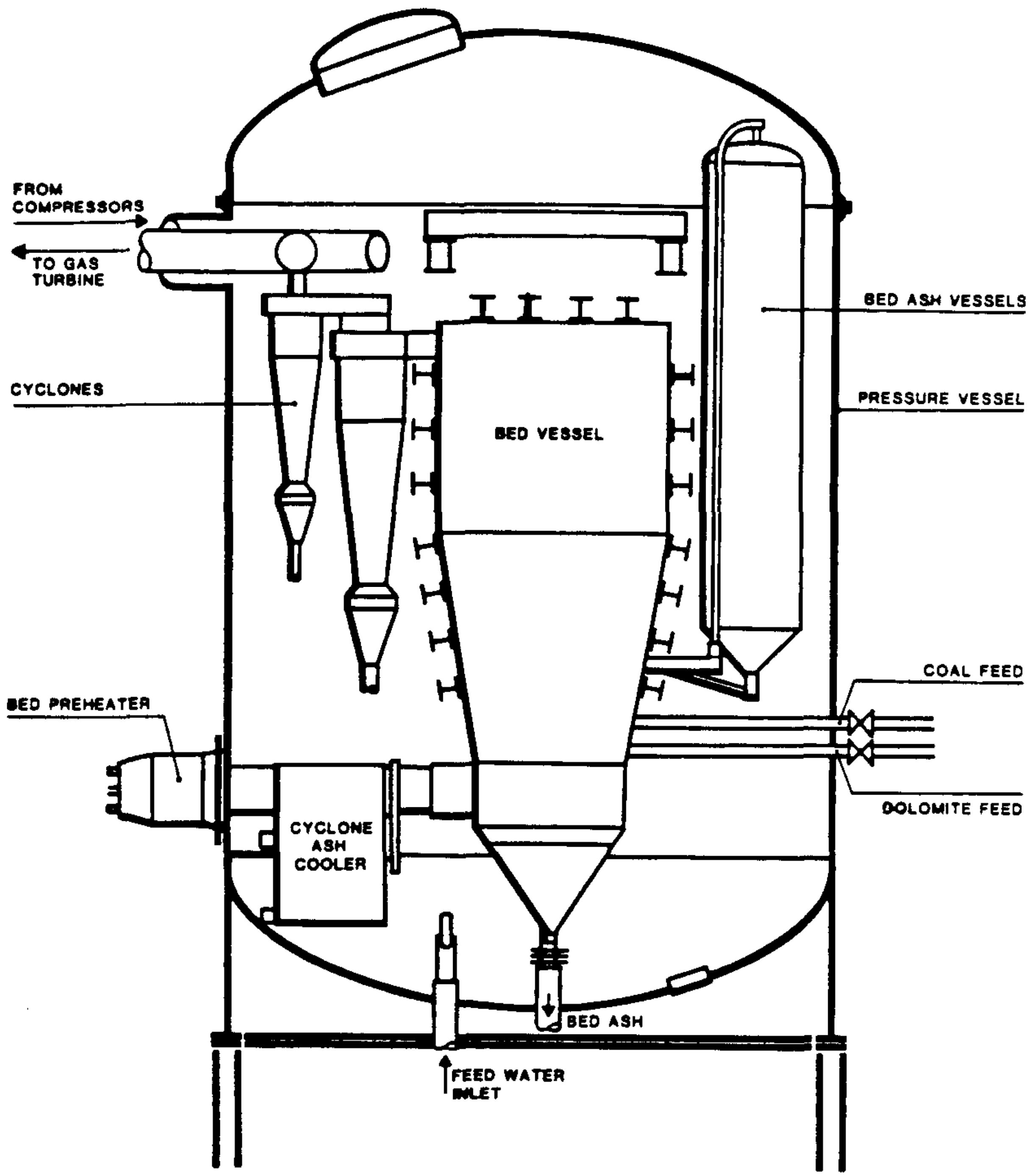

Figure 3. PFBC Demonstration Plant Combustor Vessel Assembly

C87-513-B CCT4

typically generates NO_x emissions of 0.6 to 0.7 pounds per million Btu; a fluidized bed which has a combustion temperature of typically less than 1,600 degrees F emits approximately 0.3 pounds of NOx per million Btu.

At the higher operating pressure of PFBC versus conventional combustion, the exhaust gases from a PFBC have sufficient energy to drive a gas turbine while the steam generated drives a steam turbine. This combined-cycle configuration allows a power plant design which is more economical and efficient than conventional coal fired power plants. A simplified schematic diagram of the PFBC combined cycle is shown in Figure 4.

3.2.2 Overview of Process Development

Investigation of PFBC began in the late 1960's with the completion of a combustor rig at the National Coal Board (NCB) Coal Utilization Research Laboratory (CURL) in Leatherhead, England. Later expanded facilities, including a gas turbine blade cascade, were added at CURL. In the mid-70's to early 80's, a number of PFBC test facilities were built and tested. These were built by Exxon, Curtiss-Wright, General Electric, New York University, Argonne National Laboratory, NASA Lewis Laboratory, NCB (IEA Grimethorpe and CURL) and ASEA at its 15 MWt Component Test Facility (CTF). A summary of the major operating PFBC test facilities is shown in Table 3.2.

TABLE 3.2. Major Operating PFBC Test Facilities

Name	Rating, MWt (Maximum)	Pressure, atm (Maximum)	Bed Plan Area, ft2	Depth, ft (Maximum)	Temperature F (Maximum)	Fluidizing Velocity ft/s
New York University United States	7	7	4.95	11.81	1,742	7.9
IEA Grimethorpe United Kingdom	60	12	43.05	14.76	1,742	8.2
ASEA PFBC (CTF) Sweden	15	16	21.55	12.14	1,610	3.0

In late 1976, following theoretical studies and review of PFBC test results to date, AEP and ASEA PFBC (then STAL-LAVAL) signed an agreement to perform a joint feasibility study to evaluate the merits of PFBC technology and the technical hurdles to be overcome in proceeding with a development program. The primary effort in the hot test work was AEP and ASEA PFBC participation in the U.S. DOE sponsored 1,000 hour test program at CURL. Major objectives of this test program were to determine the operating life of gas turbine blades and in-bed tube erosion/corrosion potential.

Over 2,000 hours of tests were completed at CURL and, as a result, combustor and other component designs evolved. At that time, ASEA PFBC decided to erect

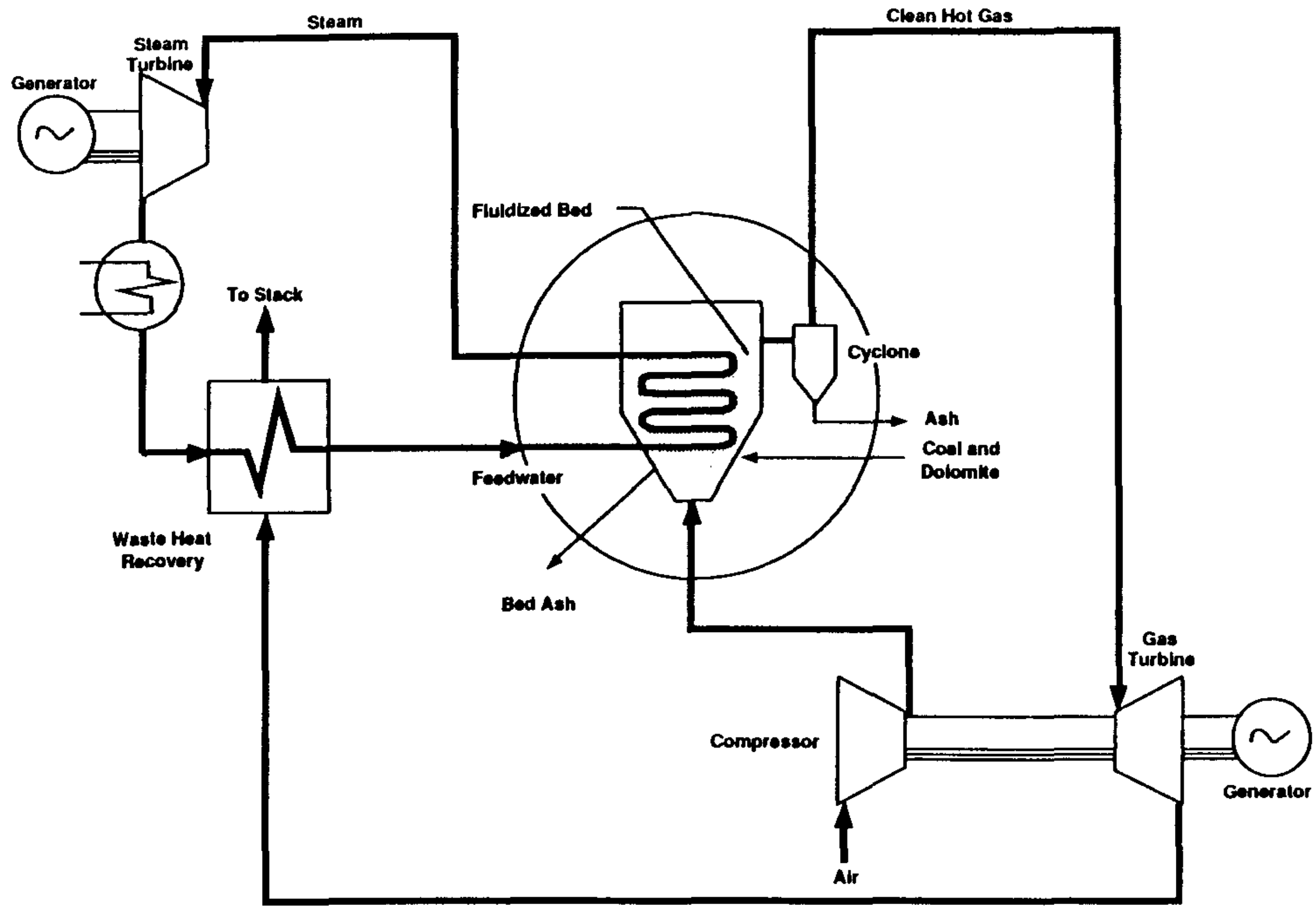

Figure 4. PFBC Combined Cycle

C87-399-C CC3

an integrated pilot plant to conduct more extensive tests on the PFBC process and PFBC-related systems. The CTF was designed in 1980 to incorporate all PFBC-related auxiliary systems and components required for operation in a commercial power plant.

In anticipation of possible commercial applications in the U.S., The Babcock and Wilcox Company (B&W) performed a careful review of the design and concept of PFBC. In October 1985, the partnership, ABP, was formed.

3.2.3 Application of Process in Proposed Project

The PFBC technology must be demonstrated in a moderate scale demonstration plant before the electric utility industry or the Government agencies that regulate it can gain the confidence to commit the investment dollars required for a large commercial plant.

The TPDP size corresponds to a commercial plant size in the 80 MWe range. The TPDP will use the same gas turbine, the GT-35P, that will be used for the 80 MWe plant. The output of the TPDP is less than 80 MWe due to the use of a lower pressure steam cycle (1,300 psi) and a lack of steam reheat. The gas turbine output for the TPDP is essentially identical to the commercial plant. Thus, there is a direct relationship between the scale of the PFBC equipment for the TPDP and the scale for a commercial 80 MWe plant. Use of the Tidd plant also will demonstrate the potential for PFBC in the repowering of existing facilities.

The TPDP will demonstrate a pressurized bubbling fluidized bed operating at a pressure of 12 atmospheres. The elevated pressure results in a compact design that requires a single pressure vessel. The fluidized bed combustor, the bed solid removal and reinjection system, cyclone dust collectors, and ash cooling hoppers are all contained in this single pressure vessel. The TPDP will allow testing and optimization of each plant component and subsystem in a utility operating environment. In addition to the components listed above, the TPDP will specifically assess the performance and reliability of the coal-water paste feed system, the sorbent feed system, the in-bed tube bundle, and the tapered bed design. Tests will provide for extended operating hours beyond that of previous pilot plant tests such that long-term reliability, availability, and serviceability data for the boiler and all boiler subsystems can be obtained. These long-term tests will serve as verification of component designs that were derived from pilot plant studies, notably the tests at the CTF. The TPDP is a fully appropriate and necessary step in the successful commercialization of this very promising technology.

The TPDP size of 70 MWe represents an economical and technically reasonable size to demonstrate PFBC combined cycle with reasonable future scale-up to a 320 MWe module for a commercial plant. The gas turbine that will be employed at the demonstration plant, is the result of an extensive effort by ASEA to develop a uniquely suitable gas turbine for PFBC. The TPDP is, thus, a necessary and vital link in the commercialization of PFBC.

3.3 GENERAL FEATURES OF PROJECT

3.3.1 Evaluation of Project Technical Risk

Developing a new technology, by definition, entails risk as the limits of knowledge are tested and ultimately expanded. During the fact finding process, DOE performed a detailed technical review. The technology and design approach to be used by AEP were found to be excellent.

The TPDP design utilizes information available from a number of previous pressurized fluidized tests from DOE/ASEA sponsored work at CURL and the CTF on which most of the subsystems of the TPDP have been tested. Based upon a review of proprietary information supplied by AEP and ABP, it has been concluded that all of the systems present acceptable technical risk, although the cyclone ash removal system has a moderate risk associated with unequal flows in parallel streams. This risk is mitigated by a report of proven work at the CTF.

Much of the related auxiliary equipment for the TPDP will be utilized from the existing Tidd No. 1 plant built in 1943. The plant was mothballed in 1976 using AEP's standard "lay away" procedure and a formalized equipment maintenance program. AEP's "lay away" procedures, ongoing maintenance program, and supporting documentation were reviewed. In general, the equipment "mothballing" and maintenance have been acceptable and no major problems should occur during refurbishing. Spare parts are available from the Tidd No. 2 plant which has also been mothballed.

3.3.1.1 Similarity of Project to Other Demonstration/Commercial Efforts

Significant research and development (R&D) has been conducted on PFBC over the past 10 years, and work has progressed to the point where sufficient data are available to design and construct a first-entry PFBC coal fired demonstration plant.

Although an active research concept for some time, interest in PFBC used in conjunction with a combined-cycle increased significantly in the early 1970's when major research efforts were sponsored by U.S. Government agencies. EPA initially sponsored research at the Exxon "Miniplant," Argonne National Laboratory, and at the Combustion Power Company. DOE involvement in the PFBC program progressed to pilot scale developmental work at the IEA Grimethorpe facility and at test rigs at General Electric (long-term materials test facility), New York University, and Curtiss-Wright (small gas turbine facility).

DOE's research activities are in support of private industry whose objective is the demonstration and commercialization of the first-entry PFBC systems by the early 1990's. This support includes a follow-on effort at Grimethorpe to develop pilot scale data on combustion efficiency using a coal slurry feed system, testing of advanced hot gas cleanup devices, and the collection of performance data from an updated U.S.-designed, in-bed heat exchanger. Other DOE sponsored activities include metal wastage studies to improve the understanding of erosion/corrosion phenomena and operation of the New York University test facility to test process components and evaluate operating parameters.

In support of the DOE sponsored PFBC developmental efforts, the Electric Power Research Institute (EPRI) has emphasized R&D on materials and hot gas cleanup. EPRI has also funded tests at two PFBC gas turbine simulators to provide the data needed to select turbine blade materials. Tests sponsored by DOE have shown that an electrostatic precipitator (ESP) could be expected to perform efficiently at the gas conditions of the turbocharged boiler.

At present, it appears that PFBC combined-cycle technology will be competing primarily with the following technologies for electric power generation in the 1990's:

a. Conventional PCF with flue gas desulfurization (FGD).

b. Atmospheric fluidized bed combustion (AFBC).

c. Turbocharged PFBC cycle.

d. Integrated coal gasification combined cycle (IGCC).

It is expected that a PFBC plant will have a higher thermal efficiency than either an AFBC plant or a PCF plant with FGD.

3.3.1.2 Technical Feasibility

One of the areas of technical concern in PFBC development has been in-bed tube erosion. Based on the successful operation of the CTF, it is fully anticipated that acceptable erosion rates of the tubes for commercial applications will be demonstrated at the TPDP. However, the TPDP plant will be designed for easy replacements of individual tube sections should this become necessary.

In PFBC applications, where a gas turbine is placed in the gas stream, it is necessary to take measures that will insure the integrity and operating life of the gas turbine. This involves two steps: firstly, gas cleanup to an extent that the solids in the gas stream are reduced to an acceptable size and concentration, and secondly, design enhancements of the gas turbine. These will be discussed in turn.

Based on the results of tests at CURL and the CTF and the experience of the cyclone manufacturer, a two cyclone train (i.e., two cyclones in series) was selected as the gas precleanup for the TPDP. In addition to sufficiently cleaning the gases for gas turbine protection, cyclones have no moving parts and have no cleaning and maintenance requirements. Testing was performed with two cyclone stages and resulted in a perfectly adequate collection efficiency as evidenced by the absence of any erosion of the blades in the test cascade. Particulates downstream of the cyclone typically have been between 80-200 ppm (weight) with a mean particle size of 1.5 to 2.5 microns.

Before and during the years of PFBC development, ASEA Stal has been conducting experimental and theoretical work in the field of turbine erosion, corrosion, and deposition. The early work included long-term operation of the GT-120 turbine with heavy residual oil. An erosion rig for testing of different materials in hot dust-laden gas has been installed and operated in the laboratories in Finspong, Sweden. The main experience, prior to the CTF, comes from CURL where ASEA Stal installed turbine cascades with actual turbine blade sections in one of the gas streams from the PFBC combustor for a series of tests conducted between 1977 to 1979. Stationary tests on erosion pins and dynamic tests on the test gas turbine have been run in the CTF. Inspections of the test gas turbine have revealed insignificant amounts of corrosion attack.

PFBC testing to date has not operated in a true combined-cycle mode (i.e., electrical production from the gas turbine). Based on extensive experience and test results, it is fully anticipated that the TPDP will prove the commercial viability of PFBC combined-cycle operation.

Other technical risks or previous problem areas have been essentially solved at the CTF and should pose minimal risk for the TPDP. These include the coal feed system with the successful testing of a coal-water paste feed system, the cyclone and bed ash depressuring systems, bed ash reinjection system, and control system. Use of these systems at the TPDP will provide long-term reliability and availability data that will be useful for designing a commercial plant.

All systems and components that will be used on the TPDP will be tested at the CTF or elsewhere to the maximum extent possible. This serves to greatly reduce the risk of proceeding from the CTF to the TPDP.

3.3.2 Resource Availability

3.3.2.1 Funds

The Ohio Coal Development Office has approved a request by the Participant to have the State of Ohio share in the proposed project in the amount of $10 million. OPCo will be responsible for financing the balance of project costs through rate recovery or issuance of debt in accordance with Public Utility Commission (PUC) of Ohio rate determination.

3.3.2.2 Site

The site of the TPDP project is the deactivated Tidd power plant located near Brilliant, Ohio (Figure 2). The site is owned by OPCo, a subsidiary of AEP. The cost of the TPDP project does not include the cost of land or any of the existing equipment and facilities which are being reused for this project.

3.3.2.3 Manpower

AEPSC is responsible to AEP and its subsidiary companies for the performance of all engineering, design, construction, financial, and other administrative and management functions required to execute all major projects. The resources, technical expertise, and top management of AEPSC are fully supportive of this PFBC project. AEPSC maintains and staffs its own support activities including laboratories, computer facilities, accounting, legal, engineering, project management, design, environmental, and construction departments. For the most part, these support functions are housed at AEP's headquarters in Columbus, Ohio. The laboratories are at other locations within the AEP system service area. AEPSC's years of experience and extensive background managing such projects will be fully utilized on this PFBC project.

3.3.3 Relationship Between Project Size and Projected Scale-up of Commercial Facility

The PFBC demonstration plant is a necessary step to the ultimate commercialization of PFBC technology. Therefore, scaling-up of critical parameters in their application to the commercial plant design has been carefully evaluated in the design of both the CTF and the TPDP. Comparisons have been made of critical design parameters between the CTF (15 MWt), the TPDP (200 MWt), and the commercial plant (800 MWt). Three major parameters in process performance must be evaluated in scale-up considerations: temperature, pressure, and residence time.

Bed temperature has a strong influence on process results. The CTF, TPDP, and commercial plant will all operate at a bed temperature of 1,580 degrees F. Operating pressure does not significantly influence process results in the 10 to 20 atmosphere range as indicated from tests at the CTF and other pilot plants. Residence time, a function of fluidizing velocity and bed depth has a strong influence on sulfur removal and combustion efficiency. The fluidizing velocity of 3 feet per second and bed height are similar for the plants; hence, scale-up is not expected to be a problem.

For sulfur capture, the calcium-to-sulfur molar ratio (Ca/S) is the controllable variable to compensate for variations of sulfur content in the coal. Due to the limited effect of this parameter with scale-up, a Ca/S ratio of 1.6 for 90 percent sulfur retention when burning 4 percent sulfur coal is anticipated to provide excellent sulfur removal.

Increasing the bed area is not anticipated to be a problem, especially since the larger bed area minimizes wall cooling effects. Experience at the CTF has shown that boiler tube geometry and proper air distribution are the most significant parameters with relation to bed temperature distribution.

The GT-35P and GT-120P gas turbines are of similar design, both with two shafts and intercooling. Both gas turbines can be used in commercial plants.

The TPDP will be the first PFBC plant to operate in a true combined-cycle mode, with the gas turbine driving a generator and the steam generated in the PFBC combustor driving a steam turbine. Essential gas conditions to the gas turbine, including gas velocity and temperature, will be the same for the TPDP and commercial plants.

The cyclones will be the same size in the TPDP and the larger commercial plants, with seven parallel strings in the former and 20 parallel strings in the latter. Both the original 3 stage cyclones and the modified 2 stage cyclones have design efficiencies in excess of 99 percent.

3.3.4 Role of Project in Achieving Commercial Feasibility of Technology

The TPDP is scheduled to be commissioned in late 1989 with the three year test program to begin in early 1990. The TPDP should provide an excellent source of data and operating experience for subsequent PFBC plants.

3.3.4.1 Comparative Merits of Project and Projection of Future Commercial Economics and Market Acceptability

If a utility were to build a new large size, coal fired power plant today, with over 200 MWe capacity which utilized commercially available technology to meet current NSPS emission standards, the only option would be a PCF plant with a wet lime/limestone flue gas desulfurization (FGD) system. However, it is not certain whether such a plant can be operated at high availability and reasonable reliability using high-sulfur (over 4 percent) coal. Furthermore, the cost of operating such a system is directly related to the sulfur content; i.e. the higher the sulfur, the higher the variable operating cost and, hence, the higher cost of electricity.

Admittedly, PFBC technology may require more engineering development than some other competing technologies but the expected benefits and potential may also be considerably greater for PFBC. It is important to note that no breakthroughs are required to demonstrate PFBC combined cycle technology. A successful demonstration project will prove the technical viability of the PFBC concept at commercial scale.

3.3.4.2 Availability and Application of Technology on Commercial Scale

The TPDP, during the test and demonstration period, will provide the confidence in design and the necessary data and experience to utilize PFBC technology for commercial power plants and will have the possibility to operate as a test base to develop further refinements and test new technologies.

AEP desires to see PFBC technology commercialized for use in future electric generation with competition among suppliers of PFBC-related equipment. Therefore, AEP expects to share the operational information gained from the TPDP with other electric utilities and industries. The successful operation of the TPDP may result in the interest of many U.S. manufacturers in providing equipment applicable to PFBC technology, including fuel preparation and feeding, ash removal, and hot gas cleanup. AEP intends to disseminate information to as wide an audience as is interested in PFBC combined-cycle technology.

The TPDP will have a sophisticated digital data acquisition system, which will have the capability of collecting and storing process data, performance data, and emission data. In addition, special tests will be conducted to measure performance, goals and environmental data. Such tests include combustion efficiency, sulfur retention, gas turbine heat rate, cyclone performance, stack emissions, and steam cycle conditions.

4.0 ENVIRONMENTAL CONSIDERATIONS

The PON requires that, upon award of financial assistance, the Participant will be required to submit the environmental information specified in Appendix J of the PON. This detailed site- and project- specific information will be used as the basis for site-specific NEPA documents to be prepared by DOE for the selected project. Such NEPA documents shall be prepared, considered, and published in full compliance with the requirements of 40 CFR 1500-1508 and in advance of a go/no-go decision to proceed beyond preliminary design. Federal funds from the CCT Program will not be provided for detailed design, construction, operation and/or dismantlement until the NEPA process has been successfully completed.

5.0 PROJECT MANAGEMENT

5.1 OVERVIEW OF MANAGEMENT ORGANIZATION

OPCo will utilize the services of AEPSC, its service company, in the performance of the Cooperative Agreement. AEPSC, acting on behalf of OPCo, will be responsible for the performance of all engineering, design, construction, operation, financial, legal, public affairs and other administrative and management functions required to execute the project. The project management responsibilities will be absorbed into the existing AEPSC internal structure and will be managed through and by the administrative organization of the corporation. The support functions such as legal, accounting, public affairs, finance, etc. will be maintained and provided by the respective speciality departments of AEPSC. The AEPSC and Tidd Project Organizations are shown in Figures 5 and 6.

5.2 PROJECT PROCEDURES, CONTROL AND MONITORING

5.2.1 Project Responsibility

In accordance with AEPSC procedures, the TPDP program manager supported by his staff has responsibility and authority for all of the engineering, design, scheduling, licensing, construction, and demonstration period efforts within AEPSC for the TPDP. Figure 7 shows the project schedule for the three phases.

5.2.2 Management Procedures, Controls and Monitoring

The procedure to be utilized on this project to achieve technical, cost, and schedule goals has been successfully used by AEPSC on past major power plant projects. These procedures have been established to meet a variety of project requirements.

5.3 KEY AGREEMENTS IMPACTING DATA RIGHTS AND PATENT WAIVERS

With respect to data rights, DOE has negotiated terms and conditions which will generally provide for rights of access by DOE to all data generated or utilized in the course of or under the Cooperative Agreement with OPCo and its subcontractors. DOE will have unlimited rights in data first produced in the performance of the Cooperative Agreement and the right to have access to proprietary data utilized in the course of the demonstration. DOE will have the further right to have some proprietary data delivered to it under suitable conditions of confidentiality. Finally, DOE has obtained, on behalf of responsible third parties and for itself, limited license rights in and to proprietary data utilized in the course of or under the demonstration program of this Cooperative Agreement.

As to patents, the OPCo has requested for itself and on behalf of its subcontractors who will participate in the demonstration program, a waiver of patent rights in any subject invention i.e., any invention or discovery by any of them which is actually reduced to practice in the course of or under the Cooperative Agreement. The patent waiver is expected to be granted. Any

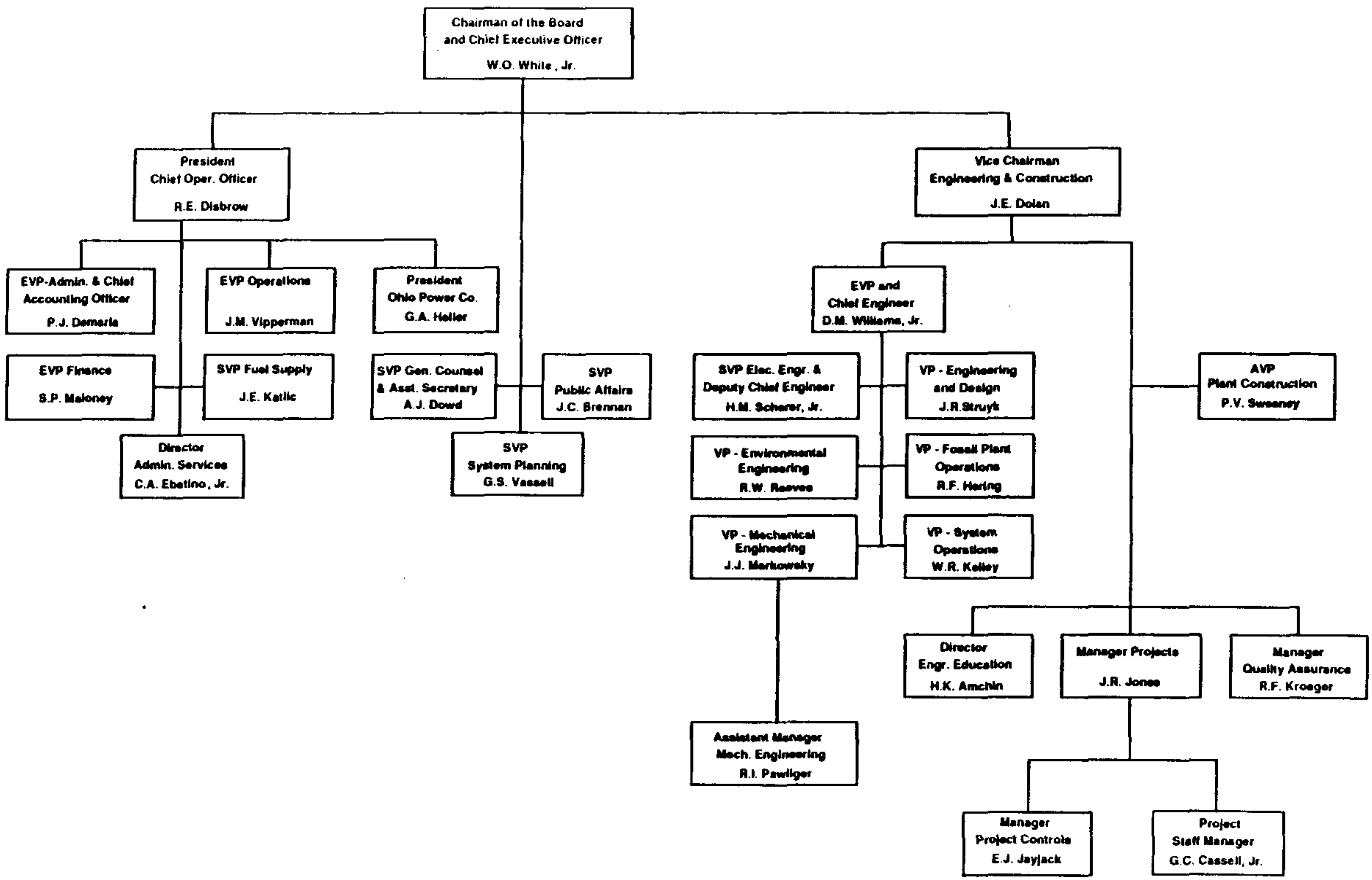

Figure 5. AEPSC Corporate Administrative Organization

C87-399-D CC3

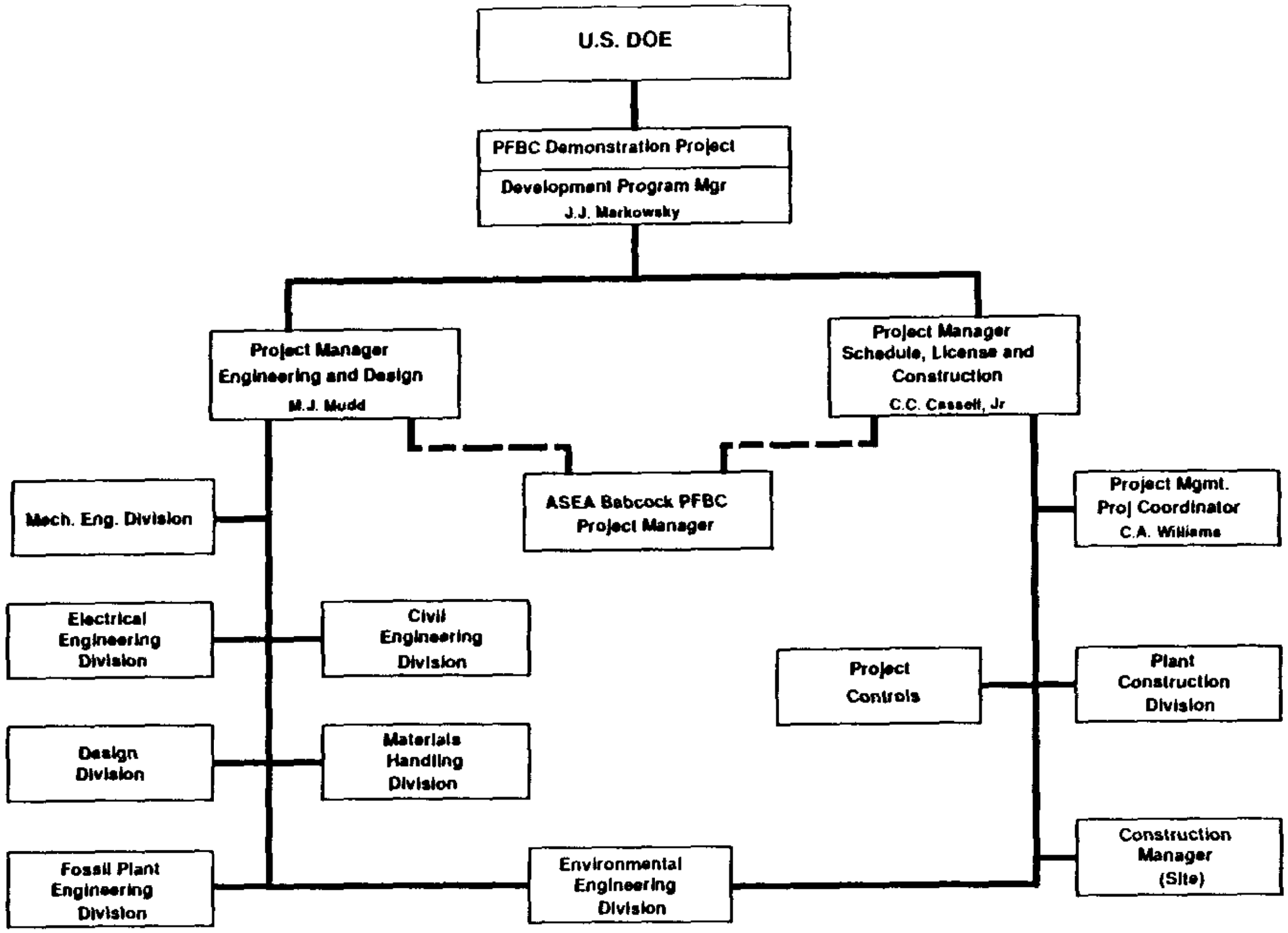

Figure 6. Tidd PFBC Demonstration Plant Project Organization

C87-399 B CC3

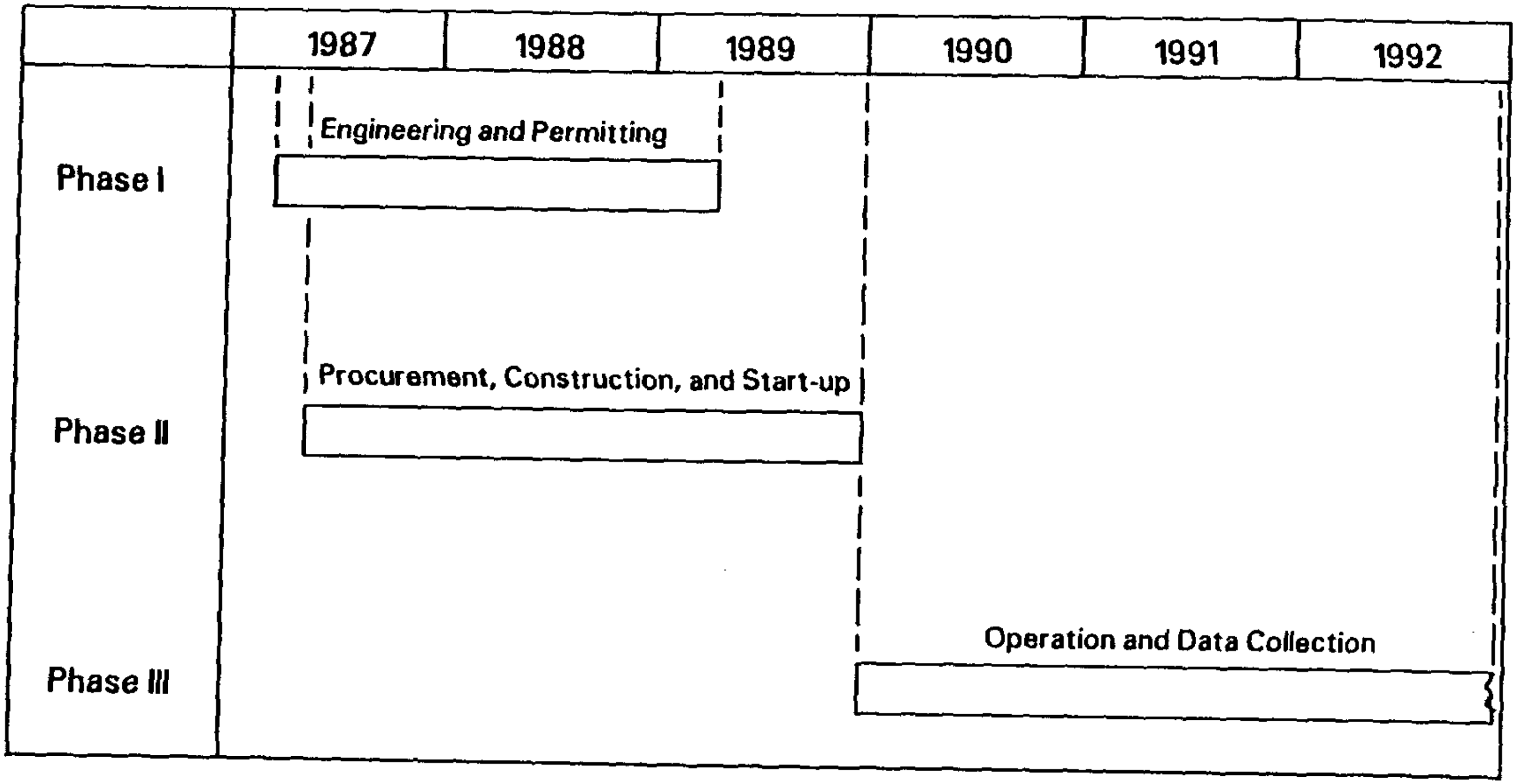

Figure 7. Tidd PFBC Demonstration Project

C87-620-A CC5

grant of a patent waiver will reserve to the Government a nonexclusive, nontransferrable, and irrevocable paid-up license to practice or to have practiced any waived subject invention for and on behalf of the United States.

5.4 COMMERCIALIZATION PLAN

5.4.1 Necessity of Demonstration

PFBC testing began in the late 1960's progressing to the point where several larger scale test facilities such as the National Coal Board (NCB), Coal Utilization and Research Laboratory (CURL), International Energy Agency (IEA), Grimethorpe, and the Component Test Facility have provided a solid background for the ultimate commercialization of PFBC technology.

These test facilities, while providing valuable process and hardware data, have not operated in a true combined-cycle mode (i.e., generation of electricity from both steam and gas turbines). Combined-cycle operation can only be technologically and economically demonstrated on a utility plant scale such as the TPDP.

5.4.2 Steps to Commercialization

The TPDP is a vital step in the commercialization of PFBC and is a link between past development and future commercialization plans.

5.4.3 Past and Current Development

AEPSC has been involved in the development of PFBC since 1976. At that time, AEPSC and ASEA PFBC of Sweden (then STAL-LAVAL) entered into an agreement to investigate the potential of the PFBC process using coal to generate electrical energy. During the ensuing years, PFBC has evolved in careful steps of feasibility studies, preliminary designs of demonstration plants, conceptual designs for commercial plants, cold model studies, hot model studies, extensive pilot plant testing, and final CTF testing.

AEP's participation in the pilot plant testing began in late 1977, utilizing Ohio coal and dolomite in a 6 atmosphere (90 psia) test rig at CURL for a 325 hour test program. Excellent combustion and sulfur retention performance data led to a 1,000 hour test program utilizing high-sulfur Ohio coal in late 1979 at CURL under the sponsorship of the DOE. This test series provided invaluable process data and successfully demonstrated the PFBC process in high SO_2 removal, low NO_x emission, the performance of cyclones for hot gas cleanup, and the survivability of the in-bed boiler tubes and gas turbine blades. The CTF has been in service since 1983, with over 4,500 hours of operation on worldwide coals, including 1,000 hours of operation on Pittsburgh No. 8 coal and Plum Run dolomite, both from Ohio, and 700 hours on coal and dolomite from Indiana. These tests have provided extensive data and confidence in the PFBC process for high SO_2 capture ($>$ 90 percent), low NO_x emissions ($<$ 0.3 pounds per million Btu), and high combustion efficiency ($>$ 99 percent carbon utilization). In addition, key developments have been made in the coal/dolomite feed and ash removal systems along with the controllability of the PFBC process for electric power generation.

5.4.4 TPDP to Complete Commercialization

The TPDP is scheduled to be commissioned in early 1990. The TPDP will be designed to operate for 10 years, providing an excellent source of data and operating experience for subsequent PFBC plants. Process data and hardware experience gained from the TPDP plus experience gained from the subsequent plants previously discussed, will provide a solid base for scale-up to a larger combined-cycle PFBC plant module with a nominal net capacity of 320 MWe (800 MWt). Engineering studies to further support the development of this larger PFBC plant (termed the PFBC 800) are in progress. After completion of this study, an assessment of manufacturing facilities for the pressure vessel parts will be made. Any changes required in the manufacturing infrastructure would be noted at that time.

Multiple PFBC 800 modules can be coupled to a common steam turbine to produce net plant capacities in 320 MWe increments. Commercialization of both the PFBC 200 and the PFBC 800 plant sizes will give utilities the ability to add small, moderate, or large increments of power to the grid in relatively short time intervals.

The PFBC 200 is expected to pass through an early commercialization phase in 1991 to 1994 and to be a completely commercial product in 1995. The PFBC 200 will be well suited for repowering and for small new capacity additions. An expanded version, the PFBC 800, is expected to be in the early commercialization phase in 1996 and be a completely commercial product before the turn of the century. The design philosophy of the PFBC 800 will involve multiples of hardware equipment that have already been proven on the PFBC 200. Early commercialization as used here refers to that phase in the commercialization process where PFBC is actively marketed with most of the guarantees and warranties normally associated with a mature technology.

5.4.5 Development Timetable

A commercialization schedule showing an orderly progression of future development plans based on past development achievements is shown in Figure 8.

5.4.6 Participant's Role

As a public utility, AEP will participate in the commercialization of the technology by engineering, designing, and operating new PFBC coal fired power plants.

The anticipated economic, efficiency, and environmental advantages of PFBC combined-cycle technology will be motivation for AEP to utilize this technology, once demonstrated, for its future plants.

5.4.7 Role of Others

OPCo's major subcontractor, ABP, will be responsible for the engineering, design, manufacturing, and erection of the PFBC equipment including combustor and gas turbine. ABP, through its partners, offers an excellent blend of technological expertise, design capabilities, and manufacturing experience.

The Babcock and Wilcox Company (B&W), one of the partners in ABP, designed and erected the first fluidized-bed boiler to operate under utility conditions. &W has been involved with fluidized-bed technology for over 30 years and is

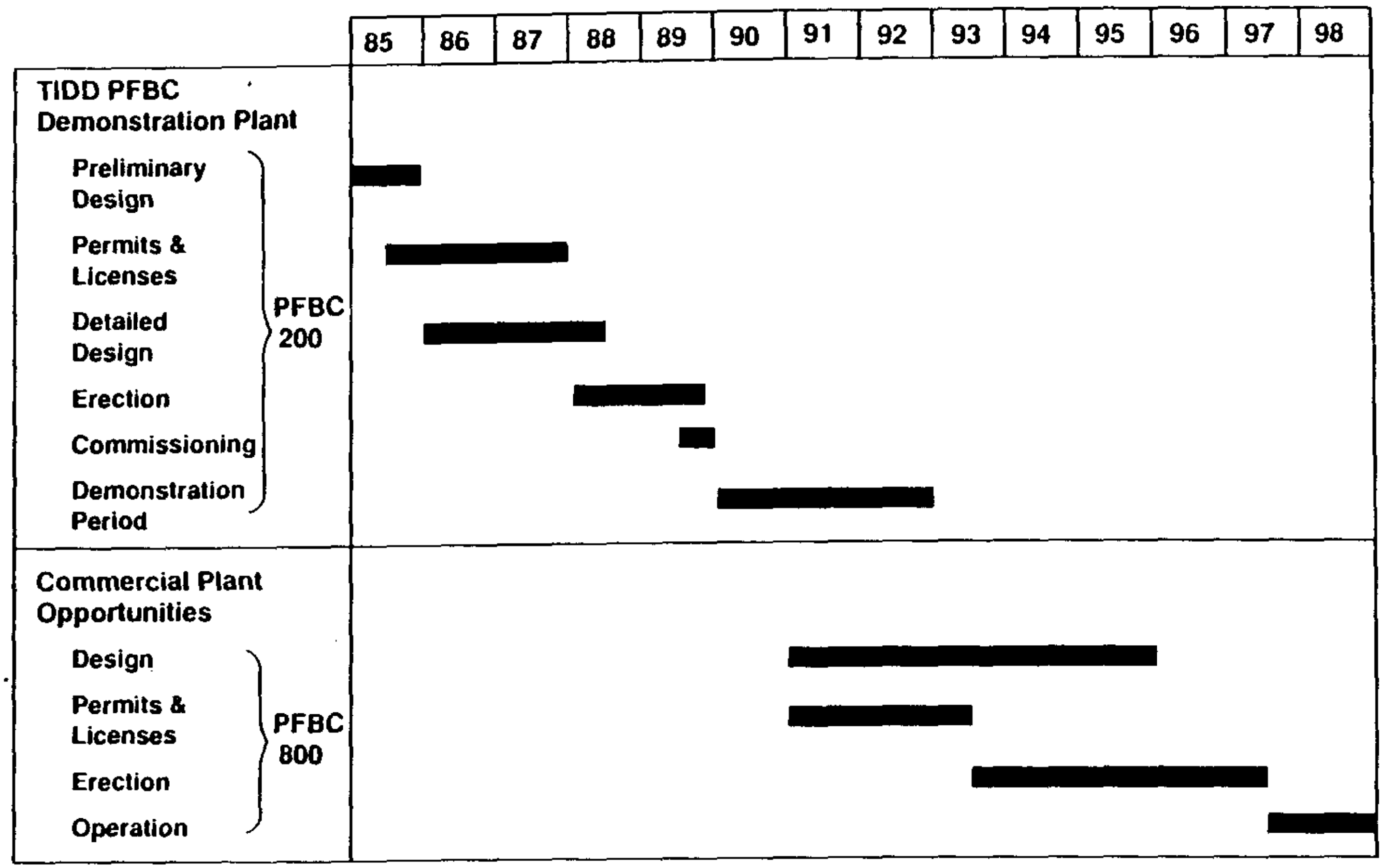

Figure 8. PFBC Commercialization Schedule

C87 399 A CC3

currently involved with numerous contracts including the largest retrofit of a stoker fired boiler to date.

The other partners in ABP, ASEA PFBC, and ASEA Stal signed, constructed, and tested the largest PFBC test facility financed solely from private funds. ASEA is also actively involved in AFBC.

6.0 PROJECT COST AND RECOUPMENT/REPAYMENT PLAN

6.1 PROJECT COSTS

The DOE and the Participant will share in the total estimated project costs during performance of the Cooperative Agreement as follows:

Phase I

	Amount	
DOE Share	$ 7,000,000	40.1%
Participant Share	$ 10,466,000	59.9%
Total	$ 17,466,000	100%

Phase II

	Amount	
DOE Share	$ 47,000,000	40.4%
Participant Share	$ 69,121,000	59.6%
Total	$116,121,000	100%

Phase III

	Amount	
DOE Share	$ 6,200,000	18.3%
Participant Share	$ 27,733,000	81.7%
Total	$ 33,933,000	100%

Total Estimated Project Cost

	Amount	
Total DOE share of Estimated Project Costs	$ 60,200,000	35.9% *
Total Participant share of Estimated Project Costs	$107,300,000	64.1%
Estimated cost for the entire project.	$167,500,000	100%

* The PON stated that the Government's contribution would be no more than 50% in each Phase of the project. The overall Government contribution for the project was originally reported to Congress as 34%. The increase to 35.9% is due to a decrease in the total estimated project cost to be funded under the Cooperative Agreement. The amount of the Government's contribution, as originally proposed by the Participant, has not changed and is capped at no more than $60,200,000. OPCo will be responsible for all other costs including those in excess of the Total estimated Project Cost. The Government contribution will decrease if the total project cost is less than estimated.

6.2 RECOUPMENT/REPAYMENT PLAN

In response to the stated policy of the DOE to recover an amount up to the Government's contribution to the project, the Participant has agreed to repay the Government in accordance with the Recoupment/Repayment Plan included in the Cooperative Agreement.