DOE/FE-0294P
DISTRIBUTION CATEGORY UC-101

# Supplemental Comprehensive Report to Congress Clean Coal Technology Program

## Tidd Pressurized Fluidized Bed Combustion (PFBC) Project

**A Project Proposed By:**
**American Electric Power Service Corporation**
**on Behalf of**
**The Ohio Power Company**

**U.S. Department of Energy**
*Assistant Secretary for Fossil Energy*
Office of Clean Coal Technology
Washington, D.C. 20585

**March 1994**

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## 1.0 EXECUTIVE SUMMARY

Public Law 99-190, enacted on December 19, 1985, directed the Department of Energy (DOE) to issue a general request for proposals for Clean Coal Technology (CCT) projects and made available approximately $387 million in financial assistance for projects ultimately selected. As a result of the ensuing proposal solicitation and selection of projects for funding, DOE in February 1987 submitted a Comprehensive Report to Congress for a CCT project entitled "Tidd PFBC (Pressurized Fluidized Bed Combustion) Demonstration Project," Report No. DOE/FE-0078. In that document, DOE reported to Congress that the Government share of project costs would be $60,200,000 and that the Participant agreed to absorb any cost overruns, even though the public law contained provisions which would allow DOE to share in project cost growths up to 25 percent of the original financial assistance. This Supplemental Report is being submitted because DOE now intends to increase its contribution to the project by approximately 11 percent to facilitate extension of the original 3-year operating period by one additional year. DOE's overall percentage cost share resulting from this extension will not exceed DOE's overall percentage cost share in the original agreement.

On March 20, 1987, DOE entered into a Cooperative Agreement with the Ohio Power Company (OPCo), a wholly-owned subsidiary of American Electric Power Company, Inc. (AEP), to construct and operate a 70 megawatt (MWe) PFBC combined-cycle demonstration plant at OPCo's Tidd Plant at Brilliant, Ohio (Figure 1). The facility is located on the Ohio River approximately 76 miles downstream from Pittsburgh, Pennsylvania (Figure 2). The purpose of the project is to demonstrate PFBC in a combined-cycle repowering application at a utility site in order to verify expectations of the technology's economic, environmental, and technical performance.

The work to be performed under the Cooperative Agreement included the design, construction, and operation of the demonstration plant. At the time of award, the project was estimated to cost $167,500,000 with the Government share being $60,200,000. OPCo agreed to absorb any cost overruns and agreed to a plan to repay the Government's contribution. Construction of the demonstration facility began in December 1987 and the original 3-year operating phase commenced in February 1991.

When the project began, it was envisioned that more than 13,000 hours (50 percent on-line factor) of coal-fueled operation would be accumulated during the planned 3-year operating phase. However, only about half of the expected operating time has actually been achieved, primarily because of a variety of

mechanical problems, the most serious of which can be attributed to gas turbine blade cracks or breakages. For instance, in 1992 and 1993, cracked or broken turbine blades forced separate outages of 4 and 5 months, respectively.

Consequently, AEP, on behalf of OPCo, and DOE have negotiated a modification to the original Cooperative Agreement which allows for a fourth year of plant operation to obtain additional data critical to the commercialization of the PFBC technology in the United States. Important information which will become available under this additional year of operation is associated with long-term gas turbine survivability, enhanced sulfur capture, and development of an advanced hot particle filtration technology.

## 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

Under the original Cooperative Agreement, OPCo repowered Unit 1 of the Tidd power plant in Brilliant, Ohio, with a combustor, gas turbine, and related auxiliary equipment, providing for plant operation using high sulfur U.S. coal. Construction began in December 1987 and the originally planned three-year operation period was initiated in February 1991. By February 1994, approximately 6000 hours of plant operation had been logged. While a substantial amount of operating data and experience has been attained, this represents only about half of the operating hours originally planned for the demonstration. Additional data are needed in two important areas before industry confidence in the technology can be established. These areas are (1) long-term survivability of the gas turbine, either in the current Tidd configuration or with the inclusion of hot particle filtration technology, and (2) enhanced sulfur capture efficiency due to changing market requirements. A one-year extension of the operating period has been proposed to address these needs. It is expected that this extension would provide approximately 4,350 additional hours of plant operation. The 12-month extension would begin on March 1, 1994 and end on February 28, 1995. However, no DOE Clean Coal Technology (CCT) funds will be expended unless and until the modification is executed. Hot gas cleanup research and development funds are being used to operate the plant so as to insure continuity of the hot gas cleanup project during the 30-day Congressional review period. Upon successful completion of the review period and execution of the

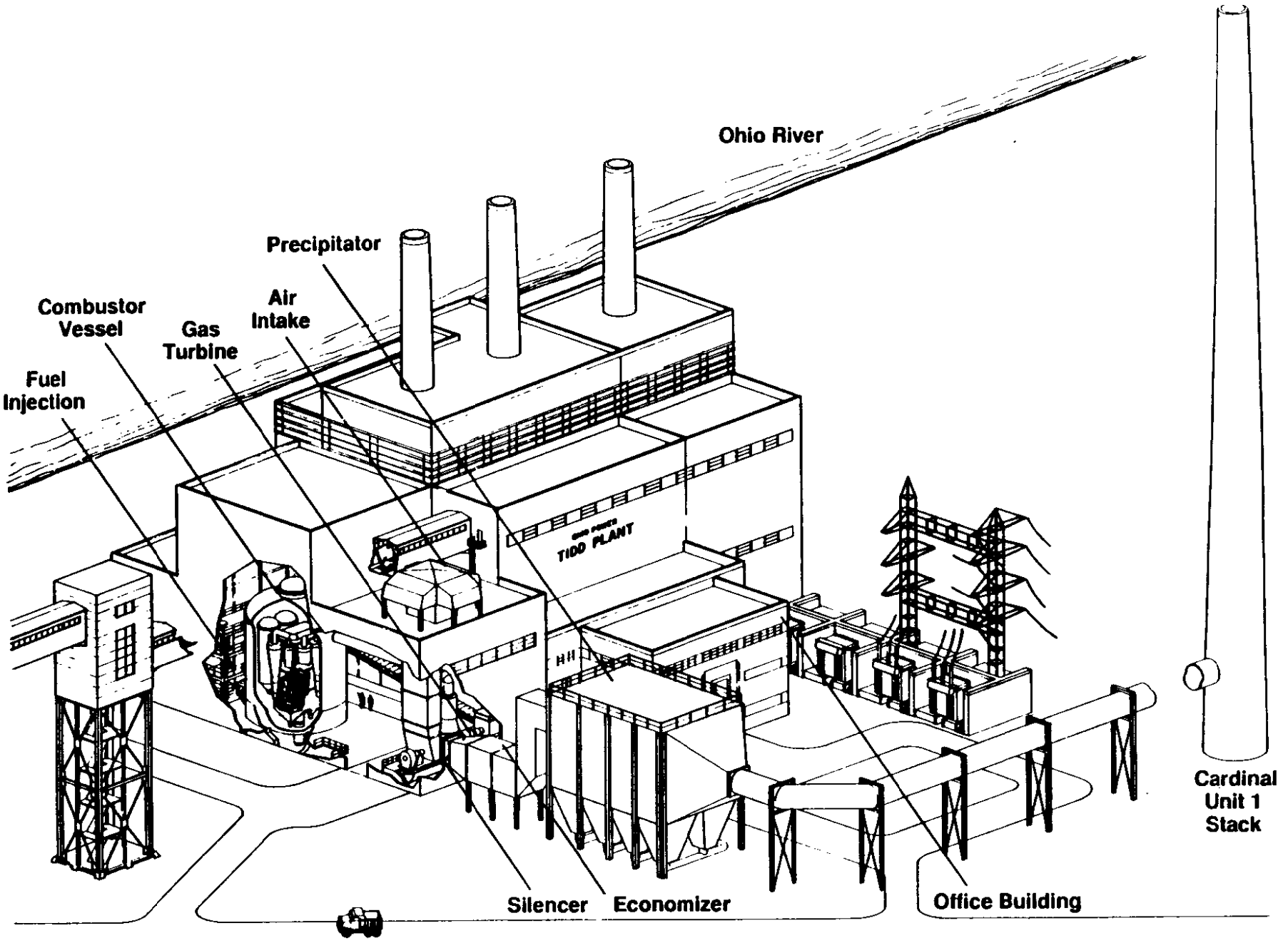


Figure 1. Tidd PFBC Demonstration Plant

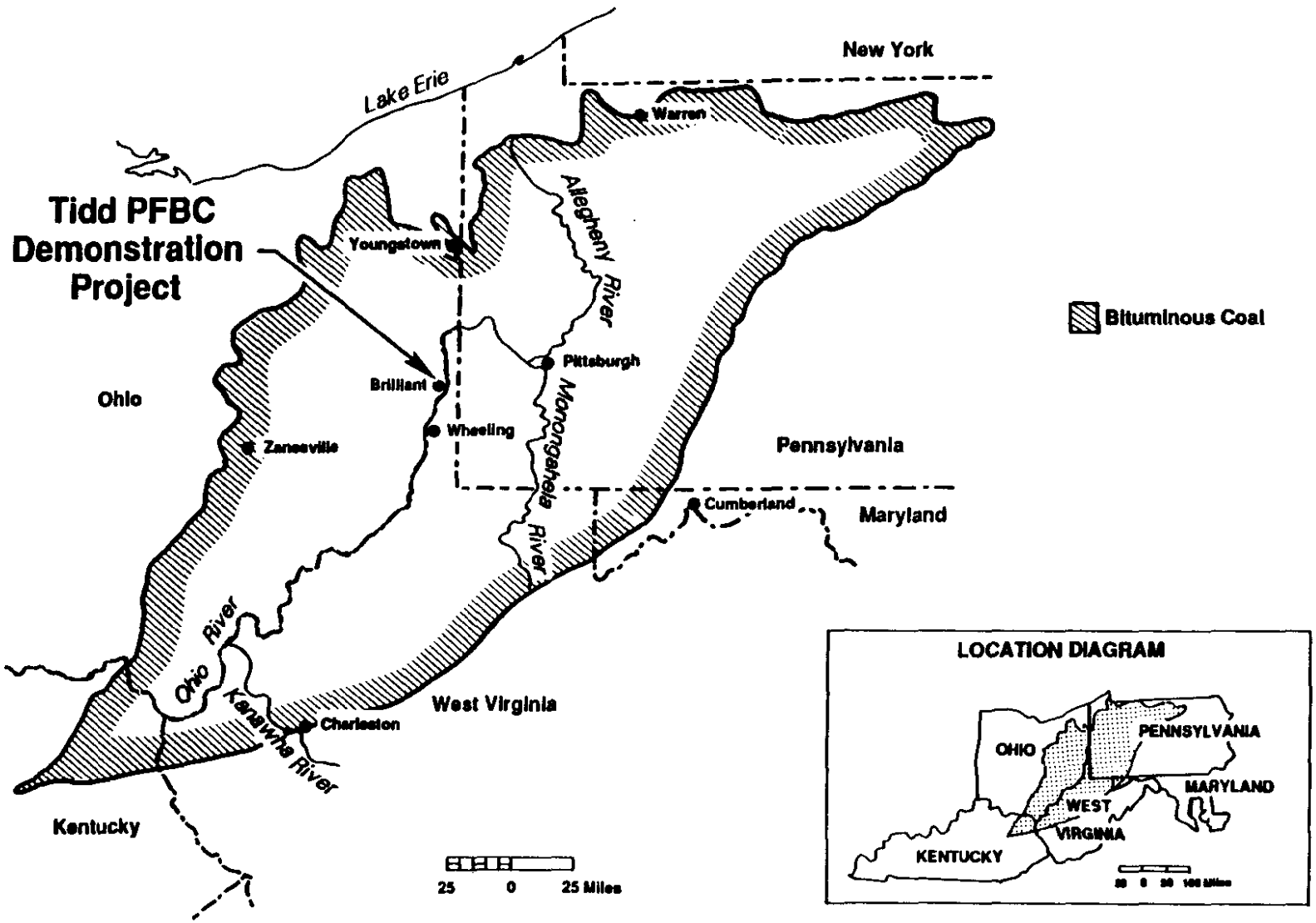


Figure 2. Tidd PFBC Demonstration Project Location

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cooperative agreement modification, the participant will use CCT funding provided as DOE's cost share of Phase I and Phase II overruns to fund CCT project costs from March 1, 1994.

## 1.3 PROJECT PARTICIPANTS

a. OPCo -- OPCo owns and operates the Tidd PFBC Demonstration Project and would continue to do so under the proposed additional year of operation. OPCo will contribute up to $2,300,007 in feed coal for the additional year of operation.

b. American Electric Power Service Corporation (AEPSC) -- AEPSC is the agent for OPCo and acts as project manager. AEPSC designed, engineered, and provided the construction management for the demonstration plant and will provide technical services to OPCo throughout the operating life of the plant.

c. ASEA Babcock AB -- ASEA Babcock is the subcontractor to OPCo for the PFBC-related equipment.

d. The Babcock & Wilcox Company (B&W), a McDermott company of New Orleans, Louisiana -- B&W is the U.S. licensee of the technology and has fully assumed the commercialization rights and responsibilities of ASEA Babcock. B&W will also provide $200,000 in cash and $200,000 in-kind contributions to the project for the proposed additional year of operation.

e. ABB Carbon AB -- ABB Carbon is the owner of the PFBC technology licensed to B&W and has assumed ASEA Babcock's repayment responsibilities. ABB Carbon will also provide $200,000 in cash and $200,000 in-kind contributions to the project for the proposed additional year of operation.

f. Ohio Coal Development Office (OCDO) -- The State of Ohio initially provided $10,000,000 for the project through OCDO; it has made available an additional $2,600,000 for the proposed fourth year of operation.

g. DOE -- DOE will provide funding and technical advice, monitor the project, and disseminate information which will lead to future commercialization.

## 1.4 PROJECTED COSTS

The projected cost for the project under the original Cooperative Agreement was $167,500,000. The total DOE share of this cost was $60,200,000 or 35.9 percent. If the actual amount for cost

sharing of this project became less than $167,500,000, the Government's contribution was to be proportionately reduced, in accordance with DOE's 35.9 percent cost share ratio. If the actual amount for cost sharing of this project exceeded $167,500,000, OPCo was to absorb any cost overruns. In other words, the U.S. Government's contribution was capped at $60,200,000.

Through design and construction of the project, actual costs did in fact exceed the total estimated project cost. In accordance with provisions of the Cooperative Agreement, OPCo funded the full amount of these overrruns, which amounted to $9,929,339. DOE did not share in any overruns. However, because of the importance to commercializing the technology of a fourth year of operation, DOE has agreed to modify the Cooperative Agreement to provide $3,564,633, or 35.9 percent (DOE's original overall project cost share ratio) of the Participant's Phase I and II cost overruns, subject to the condition that the Participant must utilize these funds to offset the cost of the additional year of operation. Details of cost and funding are provided in Section 2.1.2c, Project Cost and Participant Cost Share.

The estimated cost for the fourth year of operation is $12,457,000. Coupled with the overruns incurred in Phases I and II, the revised total estimated project cost as negotiated by the Participant and DOE is $189,886,339. DOE's share will be $66,956,993 or 35.26 percent, a slightly lower cost share percentage than was negotiated in the original Cooperative Agreement. The revised DOE contribution is $6,756,993 higher than was provided under the initial agreement. This is well within the legislated limit of 25 percent for the DOE share of any cost growths associated with Clean Coal Technology projects.

## 1.5 PROJECT SITE

The Tidd demonstration 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 Tidd facility utilizes 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 the project is a demonstration that PFBC can operate in a combined cycle mode, these conventional components have been a necessary part of the demonstration project.

## 2.0 TECHNICAL FEATURES

### 2.1 PROJECT DESCRIPTION

This project utilizes PFBC technology owned by ABB Carbon AB and marketed in the U.S. by The Babcock & Wilcox Company. The combined-cycle plant operates at less than 1,600 degrees Fahrenheit (°F) and a pressure of 12 atmospheres with off gases expanding through an ASEA Brown Boveri GT-35P gas turbine with a steam turbine bottoming cycle. The demonstration technology was used to repower a mothballed coal fired power plant, utilizing the existing steam turbine and site utilities.

#### 2.1.1 Project Summary

a. Title: Tidd PFBC Demonstration Project (TPDP)

b. Location: Brilliant, Jefferson County, Ohio

c. Technology Utilized: Pressurized Fluidized Bed Combustion

d. Application: Electric Utility Repowering

e. Product: Electricity

f. Type of Coal: Ohio High Sulfur Bituminous

g. Size: 70 MWe

h. Starting Date: February 11, 1987

i. Period: 106 months

#### 2.1.2 Project Participants and Cost

a. Project Participant:

Ohio Power Company

b. Co-Funders:

Ohio Power Company
State of Ohio, Ohio Coal Development Office
The Babcock & Wilcox Company
ABB Carbon AB
U.S. DOE

c. Project Cost and Participant Cost Share

The total estimated cost of the original project was $167,500,000, of which the DOE share was capped at $60,200,000. This equated to a DOE project share ratio of 35.9 percent. Actual project costs for design and construction activities exceeded the estimated amount by $9,929,339. DOE did not share in this cost growth.

The estimated cost for the fourth year of operation is $12,457,000. Coupled with the overruns incurred in Phases I and II, the revised total estimated project cost as negotiated by the Participant and DOE is $189,886,339.

Under the negotiated Cooperative Agreement modification to provide for the additional year, DOE has agreed to provide $3,564,633, or 35.9 percent (DOE's overall project cost share ratio) of the Participant's Phase I and II cost overruns, subject to the condition that the Participant must utilize these funds to offset the estimated cost for the fourth year of operation. This unmatched contribution would be expended prior to any other funds being used for plant operation beyond the original 3-year effort.

The remaining $8,892,367 in estimated cost would be shared by the Participant and DOE at the original DOE cost share ratio of 35.9 percent. Therefore, the cost for the proposed additional year of operation would be funded as follows:

| | |
|---|---|
| Participant Contribution from DOE recognition of Phase 1 and 2 cost overruns | $3,564,633 |
| New Contribution to be provided by the Participant (64.1%): | |
| Ohio Coal Development Office (cash) | 2,600,000 |
| The Babcock & Wilcox Company (cash) | 200,000 |
| ABB Carbon AB (cash) | 200,000 |
| Ohio Power Company (in-kind) | 2,300,007 |
| The Babcock & Wilcox Company (in-kind) | 200,000 |
| ABB Carbon AB (in-kind) | 200,000 |
| New Contribution to be provided by DOE (35.9%) | 3,192,360 |
| GRAND TOTAL | $12,457,000 |

The Cooperative Agreement will specify that DOE's $3,192,360 share of the funding will be used on a real-time basis, that is, the DOE funds expended will at no instant exceed DOE's cost share ratio of 35.9 percent of the total funds expended. Even were some unforeseen event to cause premature termination of the additional year of operation, the DOE contribution for the additional year would not exceed 35.9 percent, regardless of when that termination occurred.

## 2.2 PROCESS DESCRIPTION

The Tidd facility is the first large-scale demonstration of PFBC in the United States and one of only five worldwide. The boiler, cyclones, bed reinjection vessels, and associated hardware are encapsulated in a pressure vessel 45 feet in diameter and 70 feet high. The facility was designed so that one-seventh of the hot gases produced could be routed to a slipstream to test advanced filtration devices.

The Tidd facility is a bubbling fluidized bed combustion process which operates at a pressure of 12 atmospheres (Figure 3). Pressurized combustion air is supplied by the turbine compressor to fluidize the bed material which consists of a coal-water fuel paste, coal ash, and dolomite or limestone sorbent. Dolomite or limestone in the bed reacts with sulfur to form calcium sulfate, a dry, granular bed-ash material which is easily disposed of or is usable as a by-product. A low bed-temperature of less than 1,600 °F limits nitrogen oxide ($NO_x$) formation.

The hot combustion gases exit the bed vessel with entrained ash particles, 98 percent of which are removed when the gases pass through cyclones. The cleaned gases are then expanded through a 15-MWe gas turbine. The gases exiting the turbine are cooled via a waste heat economizer and further cleaned in an electrostatic precipitator.

The Tidd steam turbine operates at a pressure of 1,305 pounds per square inch ($lb/in^2$) and a temperature of 925 °F to produce approximately 55 MWe. Superheated steam is produced from pressurized boiler feed water in the in-bed combustor tubes. Steam generated within the combustor and the heat recovery system downstream of the gas turbine is used to generate power in a previously existing steam turbine. Due to repowering, plant efficiency was improved by 10 percent to a heat rate of 9,750 British thermal units per kilowatt-hour (Btu/kWh). This represents an efficiency of 35.1 percent based on higher heating value, HHV.

Ohio bituminous coals having sulfur contents of 2-4 percent are being used in the demonstration.

In 1992 a demonstration-scale hot gas cleanup system, funded separately under DOE's Fossil Energy Research and Development (R&D) Program, was installed at the Tidd Plant. A slipstream comprising one seventh of the total PFBC gas flow can be diverted to this system for testing advanced, ceramic barrier filter particulate removal devices. Cleaned gases exiting the hot gas cleanup system are remixed with the primary, conventionally-cleaned gas stream prior to expansion through the gas turbine. The slipstream testing conducted at Tidd has been an important component of DOE's efforts to develop and demonstrate hot gas cleanup systems for a number of advanced power generation technologies.

### 2.3 COMMERCIAL APPLICATION

Combined-cycle PFBC permits use of a wide range of coals, including high-sulfur coals. Bubbling PFBC technology, along with other advanced technologies, will compete with circulating PFBC systems to repower or replace conventional power plants. PFBC technology appears to be best suited for applications of 50 MWe or larger. Capable of being constructed modularly, PFBC generating plants permit utilities to add increments of capacity economically to match load growth. Plant life can be extended by repowering with PFBC using the existing plant area, coal-and waste-handling equipment, and steam turbine equipment. Another advantage for repowering applications is the compactness of the process due to pressurized operation, which reduces space requirements per unit of energy generated.

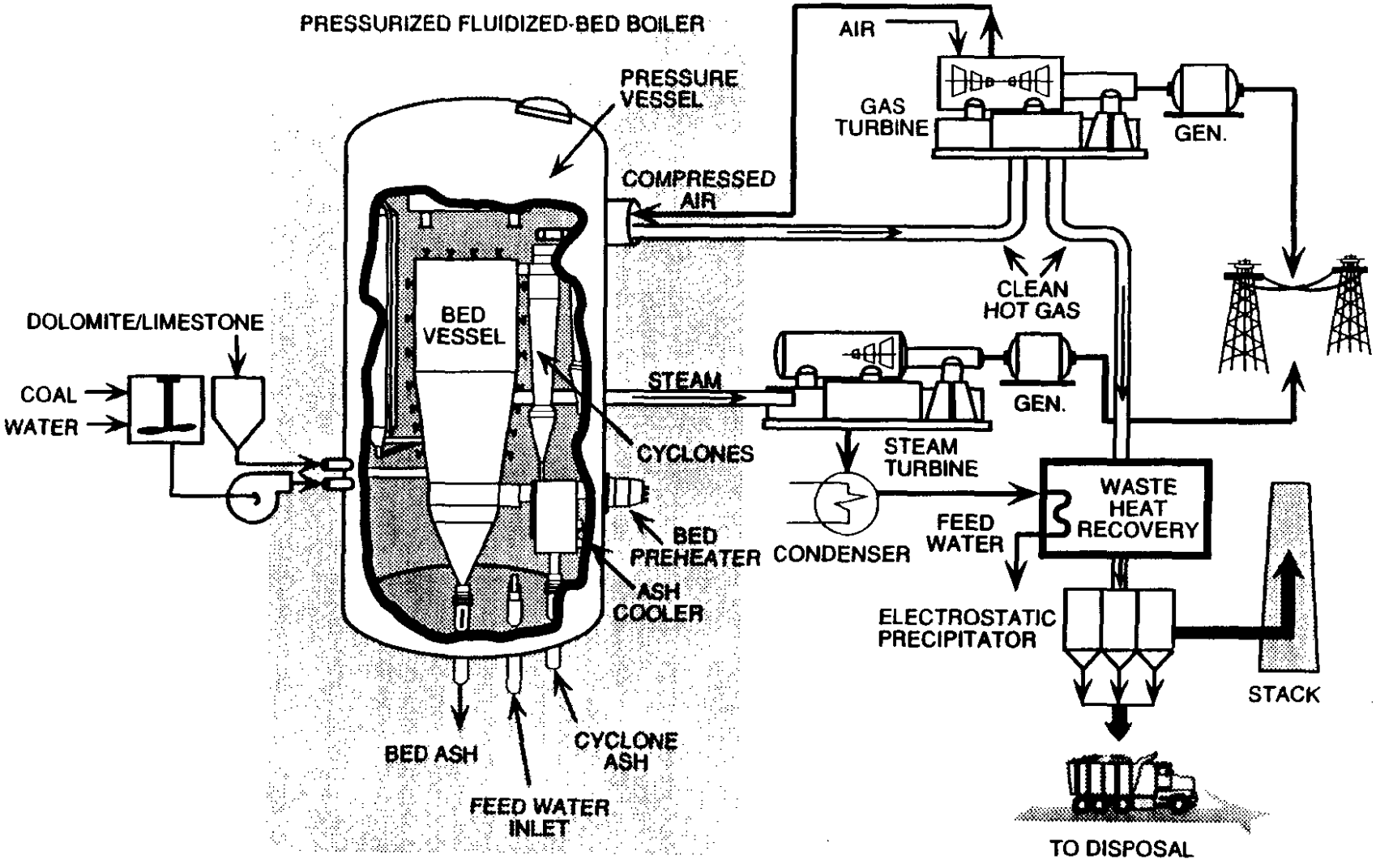
In a fully mature system, the projected net heat rate is 8,500 Btu/kWh (based on HHV) which equates to 40.2 percent efficiency. An advanced cycle that integrates a small gasifier to generate fuel gas for use in a topping combustor could yield heat rates approaching 7,500 Btu/kWh (45 percent efficiency).

The environmental attributes of a mature system include in-situ sulfur removal of 95 percent and $NO_x$ emissions levels of less than 0.1 pound/million Btu. Although the system generates a slight increase in solid waste as compared to conventional systems, the dry material is easily disposable and potentially usable.

## 3.0 PROPOSED EXTENSION OF OPERATING PERIOD

### 3.1 NEED FOR ADDITIONAL DEMONSTRATION DATA

Many of the original goals of the test program have been accomplished, and the operation of Tidd has provided significant insights into the design basis of a commercial unit. However, unresolved issues remain. Significant technical and commercial benefits could be realized at a relatively modest incremental cost by extending the operating period by an additional year.

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TIDD PFBC DEMONSTRATION PROJECT
OHIO POWER COMPANY
1/8/93

Figure 3. Tidd PFBC Schematic

While the viability of PFBC has been demonstrated by the operation of Tidd, efforts to date have focused primarily on identifying and resolving system and equipment problems which have prevented the unit from operating reliably. A variety of equipment problems coupled with two serious gas turbine failures have limited test time such that only minimal effort has been possible in the area of optimizing and enhancing the commercial attractiveness of the process.

### 3.1.1 Gas Turbine Survivability

One important issue that should be resolved before the Tidd Plant is shut down is determination that a gas turbine will survive under normal operations. At this time, gas turbine survivability over an extended period of operation is not fully known. The first year of demonstration was plagued with several start-up and off-normal (plugged cyclones) operations which apparently caused small, but measurable, amounts of erosion on the turbine blades. During this time cracks were discovered in the roots of some turbine blades, a problem which required a unit outage to reblade the turbine. A more significant problem occurred during the second year of operation when the turbine suffered major component failure after gas turbine blades broke during an operational test. These problems were determined to be turbine design issues that were not directly related to the PFBC technology. The turbine unit has since been rebuilt and testing has resumed.

Because of these problems, the gas turbine has not been exposed to long-term testing at normal, relatively steady operating conditions. Although the unit has operated for nearly 6,000 hours to date, the existing turbine (with new blades) has been exposed to approximately 2,500 hours of testing over the last 6-month period. It needs to be shown that earlier problems (i.e., erosion and blade failure) are not typical. Because increased operating experience and monitoring have resulted in recent operating successes and high on-line factors, further demonstration should be without the earlier problems; an additional year of operation should provide industry with the confidence needed to deploy the technology on a wide scale.

### 3.1.2 Sulfur Capture Enhancement

In addition, for the successful commercialization of the PFBC technology, it is important to demonstrate the technical and economic viability of 95 percent sulfur capture. Improvements in competing technologies and increases in regulatory pressures are placing more stringent emission control demands on PFBC systems. Although data to date have clearly demonstrated that 95 percent sulfur capture is achievable, it is important to demonstrate the economic viability of the technology at this higher removal level. Additional testing is needed to fully assess in-bed

sorbent distribution, sorbent particle size, sorbent reactivity, sorbent injection method, and required calcium-to-sulfur molar ratios so as to understand the minimum amount of sorbent material required to achieve a sulfur removal level of 95 percent. The original 3-year demonstration period did not provide sufficient operating time to address these issues.

### 3.1.3 Hot Gas Filtration

The proposed additional year of operation is important for another reason. Continuation of large-scale ceramic filter tests on the one-seventh flow slipstream at Tidd would provide critical information on high-temperature and high-pressure particulate removal technology from a domestic facility. Specifically, additional testing afforded by the continued operation of Tidd would provide data on the degradation of ceramic candle filters, operability and durability of the hot-metal filter structure, reliability of ancillary equipment, and the overall filtration process in order to formulate the direction and detailed designs for a number of CCT and R&D projects. For instance the DMEC-1 project, awarded in the third round of the Clean Coal Technology Program, has delayed initiation of detailed design twice in anticipation of specific hot gas cleanup design information. Sponsors of the Four Rivers Energy Modernization Project (a Round 5 project to be located at Calvert City, Kentucky) are also awaiting specific operational information. Additionally, large scale demonstrations of PFBC technology, such as the 330-MWe Mountaineer Project being conducted under Round 2 could benefit from the type of filter scale-up information which would be developed at Tidd. All of these projects will need additional data before 1995 to avoid further schedule slippage or abandonment of plans for large-scale demonstrations.

The ability of the Tidd tests to support filtration systems for integrated gasification combined cycle (IGCC) cannot be over-estimated. While specific IGCC filtration conditions are not being tested at Tidd, the performance of the filter support and enclosure design, along with the development of ancillary equipment, will provide direct information for these systems. IGCC projects in the CCT Program which would benefit from additional hot gas filtration data include those being conducted by Tampa Electric, Sierra Pacific, and TAMCO Power Partners.

## 3.2 EFFECT ON COMMERCIALIZATION

Although the original goals of the Tidd test program have been generally achieved, two important items remain before industry confidence in the technology can be established. These are (1) long-term survivability of the gas turbine and (2) increased sulfur capture efficiency due to changing market requirements.

The ability of a ruggedized gas turbine to operate in a PFBC flue gas environment has been demonstrated. However, the Tidd gas turbine has experienced measurable erosion and has suffered two major mechanical failures in the form of cracked and broken blades. Much of the erosion is likely due to the many restarts, upsets, and off-specification operating conditions encountered during the first two years of operation. While the original goal of operating the gas turbine for upwards of 13,000 hours cannot be realized, another year of operation would yield a total in excess of 10,000 hours, including approximately 6,800 hours on the same turbine assembly. With most of the operating problems resolved, fourth-year operation is expected to be at steady, long-term design conditions.

Additionally, because of the amendment of the Clean Air Act, sulfur capture must approach 95 percent for PFBC to achieve widespread viability in the commercial marketplace. Testing to date has clearly demonstrated that 95 percent is achievable. However, sufficient operating time has not yet been achieved to address key issues such as calcium-to-sulfur molar ratio and in-bed sorbent distribution. Additional time is needed to conduct parametric tests to more fully prove that higher sulfur capture efficiencies are economically viable.

Thus, the fourth year will provide upwards of 4,300 hours of additional operation to expose the gas turbine to additional duration testing and to gather additional data on sulfur capture parameters. This information will help to solidify domestic confidence in PFBC systems as clean, efficient, reliable, and economic alternatives in the commercial marketplace.

In addition, U.S. competitiveness in the world market should not be overlooked. Today, a total of five commercial PFBC units are operating in the world (two in Sweden, one in Spain, one in Japan, and the Tidd demonstration facility). These units have accumulated over 25,000 hours of operation and are providing key design data to other PFBC units on the drawing boards (e.g., in Poland and Turkey). Tidd is the only domestic version of PFBC that is operating and is needed to help generate domestic industrial confidence and to maintain U.S. expertise in an advanced technology that is seeing increased application around the world.

## 4.0 ENVIRONMENTAL CONSIDERATIONS

National Environmental Policy Act (NEPA) compliance for the original project was accomplished through a 1987 memorandum-to-file (MTF). The MTF fully accounted for the design, construction, and operation of the facility. After review of the MTF, it is determined that the proposed fourth year of operation does not affect the findings of the MTF.

Although the compliance documentation did not specify a precise operational test period, the additional testing is within the scope of the original test plan. It was originally conceived that the plant would operate during half of the available time and would accumulate more than 12,000 hours of operation during the three years of testing. However, because of unplanned outages, the facility was not available to operate as originally anticipated.

To date, the unit has accumulated approximately 6,000 hours of coal-fueled operation. During the additional year of testing, it is expected that the unit will accumulate upwards of 4,300 hours. Total operation, including the fourth year, is expected to approach, but not exceed, the original objective.

Thus, the fourth year of testing does not represent an increase in the total operation time or emissions from what was originally envisioned. The one year extension does not have an impact on the MTF conclusions.

## 5.0 PROJECT MANAGEMENT

### 5.1 OVERVIEW OF MANAGEMENT ORGANIZATION

OPCo will continue to 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 overall project organization structure is shown in Figure 4.

### 5.2 PROJECT PROCEDURES, CONTROL AND MONITORING

#### 5.2.1 Project Responsibility

In accordance with AEPSC procedures, the Tidd program manager supported by his staff has responsibility and authority for all of the project activities of AEPSC for the demonstration project.

#### 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 the construction and operation of Tidd and other 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 has 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 has 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, OPCo has been granted for itself and on behalf of its subcontractors who have participated 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 reserves to the Government a non-exclusive, nontransferable, 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

The necessity of demonstration, steps to commercialization, and past and current development activities remain essentially unchanged from when the original Cooperative Agreement for the Tidd Project was awarded. Changes which have occurred are with respect to the developmental timetable and the role of others.

In 1987, it was envisioned that a larger, utility-scale commercial version of the Tidd technology would be designed during the early 1990's with construction and operation to be completed by the end of the decade. The design of a domestic, utility-scale version of the technology was initiated in 1990 under the CCT Program via a Round 2 project with AEP, *viz.*, the PFBC Utility Demonstration Project.

After design of that plant was initiated it was determined, in 1992, that value engineering activities would be required to reduce the cost of the first commercial version such that it would be clearly a least-cost option for the host utility. Those activities have been successful. With the exception of the need for the additional technical data to be obtained from the fourth year of operation at Tidd, the only obstacle preventing

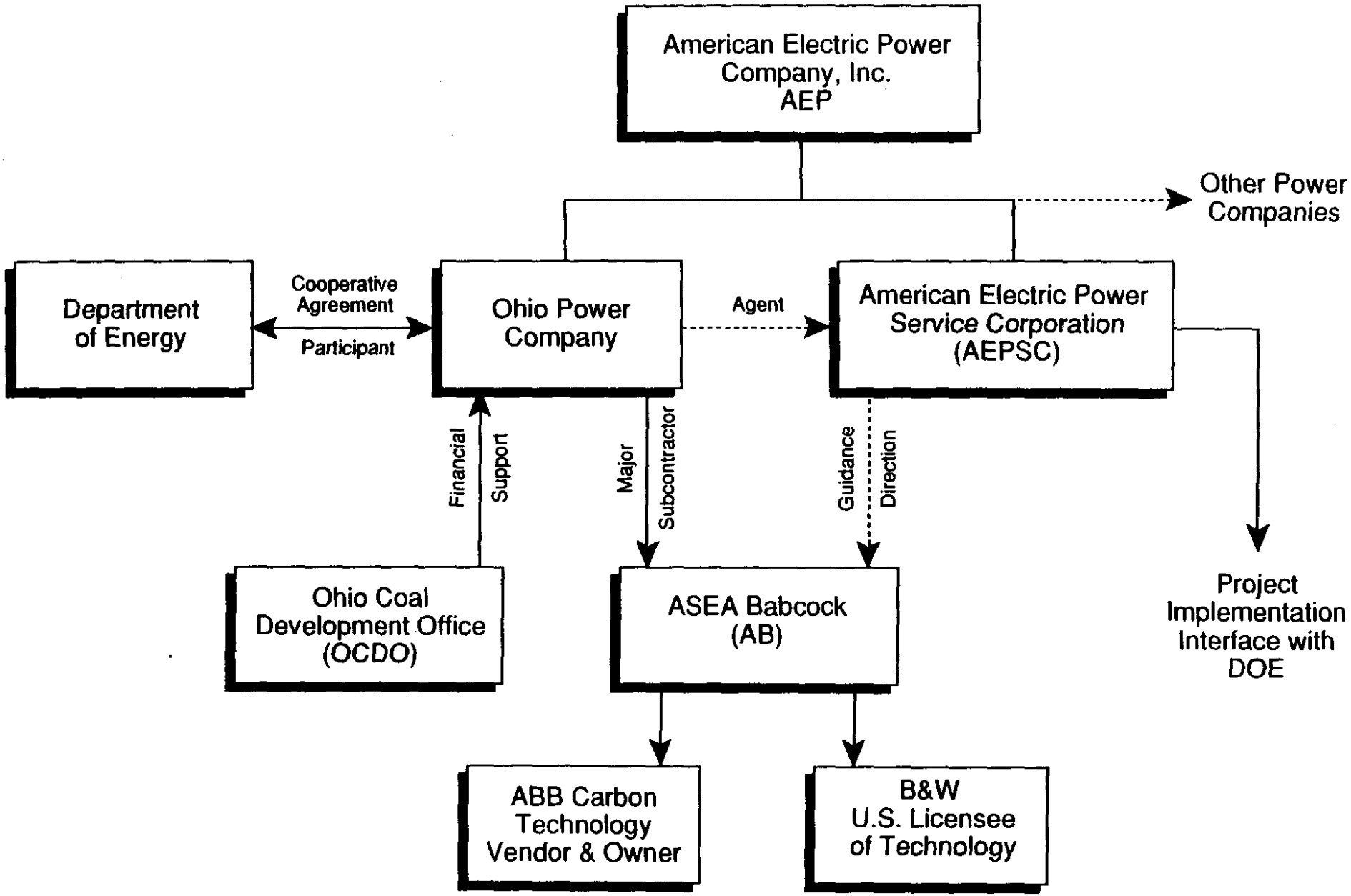


Figure 4. Project Organization



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commercialization would be a low projected capacity need for a host utility. Utility-scale commercialization is close to becoming a reality.

The second change to have occurred since this project was awarded is with respect to the roles of key organizations. Within the past two years, B&W has come to the forefront as the U.S. licensee of the technology. Originally, B&W and ABB Carbon were partners and jointly supported ASEA Babcock in the engineering, design, manufacturing, erection and subsequent commercialization of the technology.

B&W, a major U.S. boiler manufacturer, has acquired domestic rights to the technology and is vigorously pursuing its commercialization within the U.S. This commitment by B&W, when coupled with the additional data to be derived from Tidd, will establish a strong U.S. industry capability to meeting market requirements for the advanced and highly efficient PFBC technology. Additional test data will help this domestic manufacturer establish PFBC technology as a viable option in the U.S. market.

## 6.0 PROJECT COST AND RECOUPMENT/REPAYMENT PLAN

### 6.1 PROJECT COSTS

With incorporation of the proposed additional year of operation, DOE and the Participant will have shared in the total estimated project costs during performance of the Cooperative Agreement as follows:

| Phase I (as awarded) | Amount | |
|---|---|---|
| DOE Share | $ 7,000,000 | 40.1% |
| Participant Share (cash) | 10,446,000 | 59.9% |
| Total | $ 17,446,000 | 100.0% |

| Phase II (as awarded) | Amount | |
|---|---|---|
| DOE Share | $ 47,000,000 | 40.4% |
| Participant Share (cash) | 69,121,000 | 59.6% |
| Total | $116,121,000 | 100.0% |

| Phase III (as awarded) | Amount | |
|---|---|---|
| DOE Share | $ 6,200,000 | 18.3% |
| Participant Share (cash) | 27,733,000 | 81.7% |
| Total | $ 33,933,000 | 100.0% |

| Total Agreement (as awarded) | Amount | |
|---|---|---|
| DOE Share | $ 60,200,000 | 35.9% |
| Participant Share (cash) | 107,300,000 | 64.1% |
| Participant Share (in-kind) | 0 | |
| Total | $167,500,000 | 100.0% |

| Phase I and II Cost Growth [1] | Amount | |
|---|---|---|
| DOE Share | $ 3,564,633 | 35.9% |
| Participant Share (cash) | 6,364,706 | 64.1% |
| Total | $ 9,929,339 | 100.0% |

| Additional Fourth Year of Operation [1] | Amount | |
|---|---|---|
| Participant Contribution from DOE's Sharing in Phase I & II Cost Growth | $ 3,564,633 | |
| New Contributions: | | |
| DOE Share | 3,192,360 | 35.9% |
| Participant Share (cash) | 3,000,000 | 33.7% |
| Participant Share (in-kind) | 2,700,007 | 30.4% |
| Total | $ 12,457,000 | 100.0% |

| Total Agreement (as modified) | Amount | |
|---|---|---|
| DOE Share | $ 66,956,993 | 35.3% |
| Participant Share (cash) | 120,229,339 | 63.3%2 |
| Participant Share (in-kind) | 2,700,007 | 1.4% |
| Total | $189,886,339 | 100.0% |

[1] See Section 2.1.2

## 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.