DOE/FE-0256P
Distribution Category UC-101

Comprehensive Report to Congress Clean Coal Technology Program

Micronized Coal Reburning Demonstration for NOx Control on a 175-MWe Wall-Fired Unit

A Project Proposed By:
Tennessee River Valley Authority

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

June 1992

TABLE OF CONTENTS

	Page
1.0 EXECUTIVE SUMMARY	1
2.0 INTRODUCTION AND BACKGROUND	4
2.1 Requirement for Report to Congress	4
2.2 Evaluation and Selection Process	4
2.2.1 PON Objective	5
2.2.2 Qualification Review	5
2.2.3 Preliminary Evaluation	6
2.2.4 Comprehensive Evaluation	6
2.2.5 Program Policy Factors	7
2.2.6 Other Considerations	8
2.2.7 National Environmental Policy Act (NEPA) Compliance	8
2.2.8 Selection	8
3.0 TECHNICAL FEATURES	9
3.1 Project Description	9
3.1.1 Project Summary	11
3.1.2 Project Sponsorship and Cost	12
3.2 Micronized Coal Reburning Technology	12
3.2.1 Overview of Technology Development	12
3.2.2 Process Description	15
3.2.3 Application of Technology in Proposed Project	16
3.3 General Features of the Project	18
3.3.1 Evaluation of Developmental Risk	18
3.3.1.1 Similarity of Project to Other Demonstration/Commercial Efforts	19
3.3.1.2 Technical Feasibility	19
3.3.1.3 Resource Availability	20
3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility	20
3.3.3 Role of the Project in Achieving Commercial Feasibility of the Technology	21

Preceding page blank

TABLE OF CONTENTS

Page

3.3.3.1 Applicability of the Data to be Generated 21
3.3.3.2 Identification of Features that Increase Potential for Commercialization 21
3.3.3.3 Comparative Merits of the Project and Projection of Future Commercial Economics and Market Acceptability 23

4.0 ENVIRONMENTAL CONSIDERATIONS 24

5.0 PROJECT MANAGEMENT 26

5.1 Overview of Management Organization 26
5.2 Identification of Respective Roles and Responsibilities 26
5.3 Summary of Project Implementation and Control Procedures .. 28
5.4 Key Agreements Impacting Data Rights, Patent Waivers, and Information Reporting 30
5.5 Procedures for Commercialization of the Technology 32

6.0 PROJECT COST AND EVENT SCHEDULING 33

6.1 Project Baseline Costs 33
6.2 Milestone Schedule 34
6.3 Repayment Plan 34

1.0 EXECUTIVE SUMMARY

Public Law No. 101-121 provided $600 million to conduct cost-shared Clean Coal Technology (CCT) projects to demonstrate technologies that are capable of replacing, retrofitting or repowering existing facilities. To that end, a Program Opportunity Notice (PON) was issued by the Department of Energy (DOE) in January 1991, soliciting proposals to demonstrate innovative, energy efficient technologies that were capable of being commercialized in the 1990s. These technologies were to be capable of (1) achieving significant reductions in the emissions of sulfur dioxide (SO_2) and/or nitrogen oxides (NO_x) from existing facilities to minimize environmental impacts such as transboundary and interstate pollution, and/or (2) providing for future energy needs in an environmentally acceptable manner.

In response to the PON, 33 proposals were received by DOE in May 1991. After evaluation, nine projects were selected for award. These projects involved both advanced pollution control technologies that can be "retrofitted" to existing facilities and "repowering" technologies that not only reduce air pollution but also increase generating plant capacity and extend the operating life of the facility.

One of the nine projects selected for funding is a project proposed by the Tennessee Valley Authority (TVA) called the Micronized Coal Reburning Demonstration (MCRD) project. This project will provide a full-scale demonstration of Micronized Coal Reburn (MCR) technology for the control of NO_x on a wall-fired steam generator. This demonstration is expected to reduce NO_x emissions by 50 to 60%.

Micronized coal is coal that has been very finely pulverized (80% less than 325 mesh). This micronized coal, which may comprise up to 30% of the total fuel fired in the furnace, is fired high in the furnace in a fuel-rich reburn zone at a stoichiometry of 0.8. Above the reburn zone, overfire air is injected into the burnout zone at high velocity for good mixing to ensure complete combustion. Overall excess air is 15%. MCR technology reduces NO_x emissions with minimal furnace modifications, and the improved burning characteristics of micronized coal enhance boiler performance.

In addition to NO_x reduction, several additional problems are solved concurrently by the availability of the reburn micronized fuel, as an additional fuel to the furnace:

- The mill capacity added to produce the micronized coal allows units that are mill limited because of fuel switching to reach their maximum continuous rating; and this becomes a very economical source of additional generation capacity.

- Reburn burners can also serve as low load burners, and units can achieve a turndown of 8:1 on nights and weekends without consuming expensive auxiliary fuel.

- Existing pulverizers can be adjusted to operate on a variety of coals with improved performance, since they no longer need to provide the entire fuel supply. This may allow use of low-sulfur coals with high moisture and low heating values, allowing reduction in sulfur emissions with minimal impact on unit output.

- Better carbon burnout at lower excess air and improved efficiency are obtained by the combination of micronized coal reburn fuel and better pulverizer performance.

MCR technology can be applied to cyclone-fired, wall-fired and tangentially-fired pulverized coal units. The overfire air system can also be easily adapted to incorporate in-furnace sorbent injection for SO_2 control with minimal capital expenditures.

The demonstration project will be conducted at TVA's Shawnee Fossil Plant, located near Paducah, Kentucky. The Shawnee Fossil Plant is a 10-unit power plant, built in the mid-1950s. Nine of the units are wall-fired, with nameplate ratings of 175 MWe, and the other unit is a 160 MWe atmospheric fluidized-bed combustion unit. The MCR technology will be demonstrated on one of the nine wall-fired units.

This demonstration project will be performed over 48 months. Project activities will include: design and engineering, construction, start-up, operations, and reporting.

The total project cost is $7,330,041. The DOE's share is $3,514,755. The co-funder is TVA, whose share is $3,815,286. Operation is scheduled to begin in August 1993. Overall project completion is scheduled for August 1996.

2.0 INTRODUCTION AND BACKGROUND

2.1 Requirement for a Report to Congress

On October 23, 1989, Congress made available funds for the fourth Clean Coal Demonstration Program (CCT-IV) in Public Law 101-121, "An Act Making Appropriations for the Department of the Interior and Related Agencies for the Fiscal Year Ending September 30, 1990, and for Other Purposes" (the "Act"). Among other things, this Act appropriates funds for the design, construction, and operation of cost-shared, clean coal projects to demonstrate the feasibility of future commercial applications of such "... technologies capable of retrofitting or repowering existing facilities ...." On November 5, 1990, Public Law 101-512 was signed into effect, requiring "a general request for proposals for CCT-IV by no later than February 1, 1991, and to make selections of projects for negotiations no later than eight months after the date of the general request for proposals."

Public Law 101-121 appropriates a total of $600 million for executing CCT-IV. Of this total, $7.2 million are required to be reprogrammed for the Small Business Innovation Research Program (SBIR), and $25.0 million are designated for Program Direction Funds for costs incurred by DOE in implementing the CCT-IV program. The remaining $567.8 million was available for award under the PON.

The purpose of this Comprehensive Report is to comply with Public Law 101-512, which directs the Department to prepare a full and comprehensive report to Congress on each project selected for award under the CCT-IV program.

2.2 Evaluation and Selection Process

DOE issued a draft PON for public comment on November 20, 1990, receiving a total of 19 responses from the public. The final PON was issued on January 15, 1991, and took into consideration the public comments received on the draft PON. DOE received 33 proposals in response to the CCT-IV solicitation by the May 17, 1991, deadline.

2.2.1 PON Objective

As stated in PON Section 1.2, the objective of the CCT-IV solicitation was to obtain "proposals to conduct cost-shared Clean Coal Technology projects to demonstrate innovative, energy-efficient technologies that are capable of being commercialized in the 1990s. These technologies must be capable of (1) achieving significant reductions in the emissions of sulfur dioxide and/or the oxides of nitrogen from existing facilities to minimize environmental impacts such as transboundary and interstate pollution, and/or (2) providing for future energy needs in an environmentally acceptable manner."

2.2.2 Qualification Review

The PON established seven Qualification Criteria and provided that, "in order to be considered in the Preliminary Evaluation Phase, a proposal must successfully pass Qualification." The Qualification Criteria were as follows:

(a) The proposed demonstration project or facility must be located in the United States.

(b) The proposed demonstration project must be designed for and operated with coal(s) from mines located in the United States.

(c) The proposer must agree to provide a cost-share of at least 50% of total allowable project costs, with at least 50% in each of the three project phases.

(d) The proposer must have access to, and use of, the proposed site and any proposed alternate site(s) for the duration of the project.

(e) The proposed project team must be identified and firmly committed to fulfilling its proposed role in the project.

(f) The proposer agrees that, if selected, it will submit a "Repayment Plan" consistent with PON Section 7.7.

(g) The proposal must be signed by a responsible official of the proposing organization, authorized to contractually bind the organization to the performance of the Cooperative Agreement in its entirety.

2.2.3 Preliminary Evaluation

The PON provided that a Preliminary Evaluation would be performed on all proposals that successfully passed the Qualification Review. In order to be considered in the Comprehensive Evaluation phase, a proposal must be consistent with the stated objectives of the PON and must contain sufficient information on finance, management, technical, cost, and other areas to permit the Comprehensive Evaluation described in the solicitation to be performed.

2.2.4 Comprehensive Evaluation

The Technical Evaluation Criteria were divided into two major categories: (1) the Demonstration Project Factors were used to assess the technical feasibility and likelihood of success of the project, and (2) the Commercialization Factors were used to assess the potential of the proposed technology to reduce emissions from existing facilities, as well as to meet future energy needs through the environmentally acceptable use of coal, and the cost effectiveness of the proposed technology in comparison to existing technologies.

The Cost and Finance Evaluation criteria were used to determine the business performance potential and commitment of the proposer.

The PON provided that the Cost Estimate would be evaluated to determine the reasonableness of the proposed cost. Proposers were advised that this determination "...will be of minimal importance to the selection..." and that a detailed cost estimate would be requested after selection. Proposers were cautioned that if the total project cost estimated after selection is greater than the amount specified in the proposal, DOE would be under no obligation to provide more funding than had been requested in the proposer's original Cost Sharing Plan.

2.2.5 Program Policy Factors

The PON advised proposers that the following program policy factors could be used by the Source Selection Official to select a range of projects that would best serve program objectives:

(a) The desirability of selecting projects that collectively represent a diversity of methods, technical approaches, and applications.

(b) The desirability of selecting projects in this solicitation that contribute to near-term reductions in transboundary transport of pollutants by producing an aggregate net reduction in emissions of sulfur dioxide and/or nitrogen oxides.

(c) The desirability of selecting projects that collectively utilize a broad range of U.S. coals and are in locations which represent a diversity of EHSS, regulatory, and climatic conditions.

(d) The desirability of selecting projects in this solicitation that achieve a balance between (1) reducing emissions and transboundary pollution and (2) providing for future energy needs by the environmentally acceptable use of coal or coal-based fuels.

(e) The desirability of selecting projects that provide strategic and energy security benefits for remote, import-dependent sites, or that provide multiple fuel resource options for regions which are considerably dependent on one fuel form for total energy requirements.

The word "collectively," as used in the foregoing program policy factors, was defined to include projects selected in this solicitation and prior clean coal solicitations, as well as other ongoing demonstrations in the United States.

2.2.6 Other Considerations

The PON stated that, in making selections, DOE would consider giving preference to projects located in states for which the rate-making bodies of those states treat the Clean Coal Technologies the same as pollution control projects or technologies. This consideration could be used as a tie breaker if, after application of the evaluation criteria and the program policy factors, two projects received identical evaluation scores and remained essentially equal in value. This consideration would not be applied if, by so doing, the regional geographic distribution of the projects selected would be significantly altered.

2.2.7 National Environmental Policy Act (NEPA) Compliance

As part of the evaluation and selection process, the Clean Coal Technology Program developed a procedure for compliance with the National Environmental Policy Act of 1969 (NEPA), the Council on Environmental Quality NEPA regulations (40 CFR 1500-1508) and the DOE guidelines for compliance with NEPA (52 FR 47662, December 15, 1987). DOE final NEPA regulations replacing the DOE guidelines were published in the Federal Register on April 24, 1992. This procedure included the publication and consideration of a publicly available Final Programmatic Environmental Impact Statement (DOE/EIS-0146), issued in November 1989, and the preparation of confidential preselection project-specific environmental reviews for internal DOE use. DOE also prepares publicly available site-specific documents for each selected demonstration project as appropriate under NEPA.

2.2.8 Selection

After considering the evaluation criteria, the program policy factors, and the NEPA strategy as stated in the PON, the Source Selection Official selected nine projects as best furthering the objectives of the CCT-IV PON. These selections were announced on September 12, 1991, during a press conference.

3.0 TECHNICAL FEATURES

3.1 Project Description

MCR technology for NO_x control operates in the same manner as natural gas reburning on coal-fired boilers. The entire furnace operates as a low-NO_x burner with the existing burners being operated in a slightly oxidizing mode with accurate fuel/air control. A reburn zone is established above the top row of existing burners, and the micronized fuel (microfine coal with a particle size of 80% less than 325 mesh) fired substoichiometrically in the reburn zone consumes oxygen very rapidly and, with a residence time of 0.5 to 0.6 seconds, converts NO_x to molecular nitrogen. Above the reburn zone, high velocity overfire air uniformly mixes with the substoichiometric furnace gas to complete combustion, giving a total excess air ratio of 1.15. This technology reduces NO_x emissions by 50 to 60% to a NO_x level of 0.35 to 0.47 lb/million Btu.

This demonstration will be conducted at TVA's Shawnee Fossil Plant, located on the Ohio River 10 miles northwest of Paducah, Kentucky, as shown in Figure 1. This 10-unit power plant was built in the mid-1950s with an original total nameplate rating of 1750 MWe. In the late 1980s, Unit 10 with a rating of 175 MWe was decommissioned, and a 160 MWe atmospheric fluidized-bed combustion unit was added.

Unit 6 has been selected as the demonstration unit for the MCRD project. Four MicroFuel Systems will be located on the operating floor of this unit. Reburn burners will be installed above the top row of existing burners with an extended windbox, and overfire air nozzles will be installed in a row above the reburn burners. With MCR, the combustion efficiency of the existing burners and the reburn burners is expected to improve due to lower unburned carbon in the fly ash. The ability to feed additional fuel to the boiler, combined with improvements in combustion efficiency and the lowering of excess air, will increase steam generator capacity. Thus, MCR technology not only reduces NO_x emissions but also improves boiler efficiency and increases boiler capacity. Also, MCR will result in a smaller average particle size for the fly ash passing through the convection sections, economizer, and air heater. This, together with

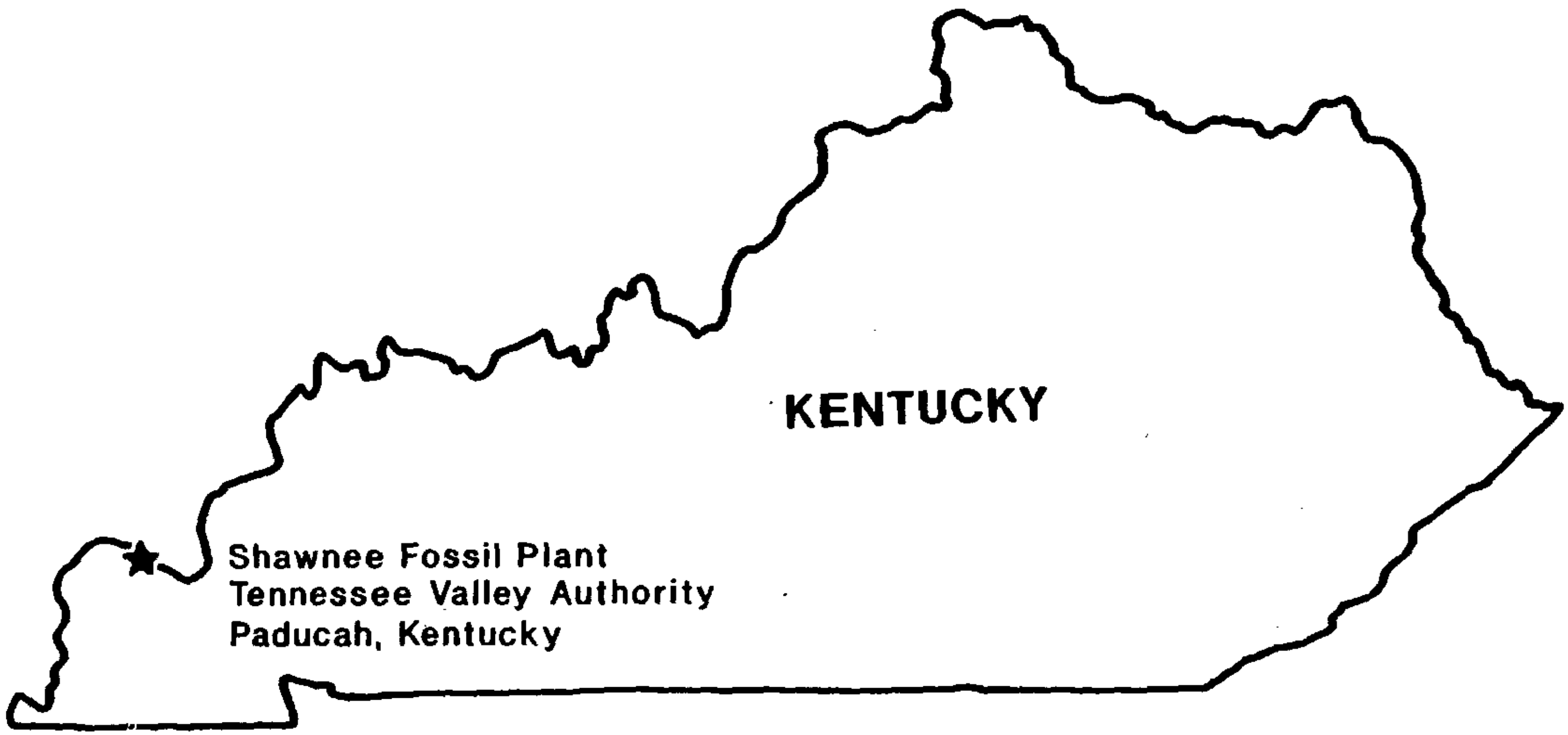

FIGURE 1. TVA MCRD PROJECT SITE LOCATION

more uniform temperatures and better gas mixing, should reduce fouling. The fly ash entering the baghouse will be collected with the same degree of efficiency, because baghouses are relatively insensitive to particle size.

The objective of this project is a full-scale demonstration of the MCR technology in a commercial power plant. If successful, the technology will reduce NO_x emissions by 50-60%, while increasing plant efficiency and capacity. This technology should be applicable to a large number of existing generating units, thus allowing them to reduce emissions and increase capacity with a minimum capital investment.

3.1.1 Project Summary

Project Title:	Micronized Coal Reburning Demonstration Project
Proposer:	Tennessee Valley Authority
Project Location:	Shawnee Fossil Plant McCracken County Paducah, Kentucky
Technology:	Reburning of a microfine coal (80% less than 325 mesh) in coal-fired power plants to reduce NO_x emissions
Application:	New and retrofit utility and industrial furnaces for NO_x emissions reductions
Type of Coal Used:	Mainly low-sulfur eastern Kentucky and West Virginia coal with some tests on Powder River Basin coal
Product:	Pollution Control Technology
Project Size:	20 Tons/Hr of Micronized Coal
Project Start Date:	August 1992
Project End Date:	August 1996

3.1.2 Project Sponsorship and Cost

Project Sponsor: Tennessee Valley Authority

Proposed Project Cost: $7,330,041

Proposed Cost Distribution:

Participant Cost Share (52%)	DOE Cost Share (48%)
$3,815,286	$3,514,755

3.2 Micronized Coal Reburning Technology

3.2.1 Overview of Technology Development

Reburning technology refers to a process in which a fraction of the fuel is injected into a zone downstream of the main combustion zone to form a fuel-rich zone. Additional air is added further downstream to complete combustion. Thus, reburning is a combustion modification technology which removes NO_x from combustion products by using reburn fuel as the reducing agent. This technology, which is alternatively referred to as "in-furnace NO_x reduction" or "staged fuel injection," involves kinetic processes similar to those in staged combustion, based on the principle that hydrocarbon (CH) fragments can react with NO_x.

Combustion in a furnace employing reburning technology can be divided into three zones, as illustrated schematically in Figure 2.

- Primary Zone - This is the main heat release zone, where 70 to 80% of the total heat input to the system is released under slightly oxidizing conditions.

- Reburning Zone - This is the zone where the reburning fuel (normally 10 to 30% of the total fuel) is injected downstream of the primary zone to create a fuel-rich NO_x reduction zone. Reactive nitrogen species react with hydrocarbon fragments from the reburning fuel to produce intermediate species, such as ammonia (NH_3), hydrogen cyanide (HCN), and nitrogen (N_2).

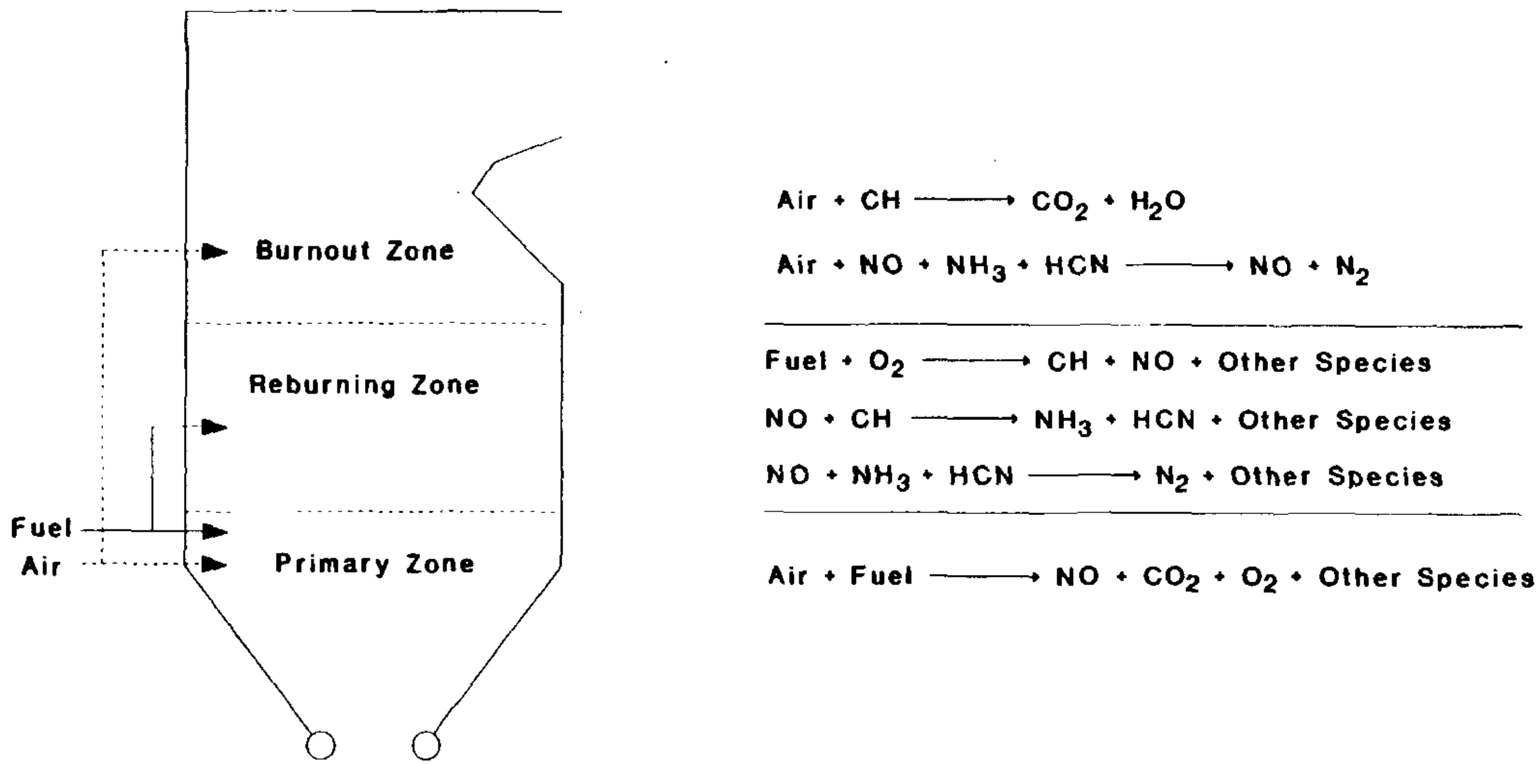

Figure 2. SCHEMATIC OF THE REBURNING PROCESS

Burnout Zone - In this zone, air is added to produce overall fuel-lean conditions and oxidize all remaining fuel. All of the nitrogen species will either be oxidized to NO_x or reduced to N_2.

MCR is an outgrowth of other types of reburning which use natural gas and conventional pulverized coal, but MCR results in improved boiler efficiency and performance. Micronized coal pulverizers have already been demonstrated as ignition burners on coal-fired utility-sized boilers at the same capacity as planned for this reburn demonstration. DOE is presently sponsoring gas reburning on wall-, cyclone-, and tangentially-fired boilers and conventional pulverized coal reburning on a cyclone-fired boiler.

There has been only one coal reburn fuel staging project for NO_x control conducted in the United States. There are, however, a substantial number of natural gas reburning projects in U.S. coal-fired power plants. Pilot projects have also been conducted using coal as a reburn fuel, and a full-scale CCT-II demonstration project is in the design stage at the Nelson Dewey Station of Wisconsin Power & Light Company. This project is using pulverized coal as reburn fuel on a cyclone-fired boiler.

The development of micronized coal technology has been advanced primarily in the United States, where the standard for micronized coal is 80% below 43 microns (325 mesh). Most of the operating history of micronized coal-fired combustion systems is on industrial-sized process furnaces.

Development of the centrifugal-pneumatic mill, used to produce micronized coal, began in the fall of 1983; and, during an 18-month development period, several prototype mills were designed, built, and tested. MicroFuel Corporation (MFC) is the developer of this technology.

In 1984, when oil prices were escalating very rapidly, there developed significant interest in micronized coal firing as a replacement for gas or oil firing for industrial applications, including aggregate dryers, cement plants, packaged boilers, and other process furnaces. Since a 5 ton/hr mill was required to meet the firing rates of most furnace applications, a 30-inch mill was developed with a classifier, based upon a horizontal cyclone design and a solid steel cast impeller.

Several 30-inch mill systems were built in the mid-to-late 1980s, most of which were installed on aggregate dryers. However, by 1988 the focus was on utility applications, and a more reliable impeller was required. Therefore, a replaceable-blade impeller was designed. This unit was thoroughly tested at full scale at MicroFuel's R&D facility and at Duke Power's Cliffside Power Station.

The MicroFuel System installed in 1988 at Duke Power's Cliffside Station was installed on a 600 MWe Combustion Engineering tangentially-fired furnace. The main oil guns were removed from corners 2 and 4, and micronized coal-fired burners were installed for the purpose of start-up ignition. This MicroFuel System has processed approximately 4,000 tons of coal at this installation. This project will use the same type of system as used at Cliffside, except that it will be run continuously.

Over the past two years, the MicroFuel System at the Cliffside Station has gone through approximately 100 starts and has been involved in many of the cold starts of the power plant. MicroFire burners have been operated in a cold furnace without oil support and have been fired at 60 million Btu/hr on a continuous basis over the full-load range of the tangential furnace (60 to 600 MWe).

3.2.2 Process Description

MCR technology is a combination of fuel reburning for NO_x control with a technology that produces micronized coal reliably and economically. Micronized coal is defined as coal ground to a particle size of 43 microns or smaller. Micronized coal has the surface area and combustion characteristics of atomized oil. The extended surface area of micronized coal allows carbon conversion within milliseconds, and volatiles are released at a more even rate over a given temperature range. This uniform, compact combustion envelope permits complete combustion of the coal/air mixture in a smaller furnace volume than is possible with conventional pulverized coal. Heat rate, carbon loss, boiler efficiency, and NO_x formation are also impacted by coal particle size. When micronized coal is fired at a stoichiometry of 0.8 to 1.0, devolatilization and carbon conversion occur rapidly. Accurate control of the combustion process is enhanced by the extensive surface area of micronized coal.

Feed coal (2" X 0 size range) is fed to a MicroFuel System mill, where it is micronized to a particle size of 80% less than 43 microns. The micronized coal is then pneumatically conveyed to the furnace reburn zone, which is above the regular firing zone. The micronized coal is fired at fuel-rich (reducing) conditions to provide hydrocarbon fragments that can react with NO_x. Overfire air is injected above the reburn zone to produce fuel-lean conditions where complete fuel burnout can occur. This is illustrated schematically in Figure 3.

The MicroFuel System, used to produce the micronized coal, consists of two major elements - the MicroMill™ and the external classifier. The heart of the system is a patented centrifugal-pneumatic MicroMill™. The mill is capable of grinding coal and other minerals with varying degrees of hardness into a fine powder, without the use of mechanical attrition or roll crushing normally associated with coal mills. With a single rotating impeller, the MicroMill™ creates mechanically induced high-speed air streams in a conical chamber which makes small high-speed particles bombard larger particles until the desired particle size is achieved. The ability to create large surface area at a low energy cost per ton is the principle advantage of this device.

The coal being fed to the MicroFuel System is the same coal that is fed to the regular pulverizers. This means that the same coal handling system can be used to provide feed to both the MicroFuel System and the regular pulverizers with significant cost savings.

3.2.3 <u>Application of Technology in Proposed Project</u>

The MCRD project will be installed on Unit 6 at TVA's Shawnee Fossil Plant. This is a 10-unit power plant, built in the early 1950s to burn high-sulfur coal. Nine of the units are 175 MWe nameplate capacity, wall-fired units. In the

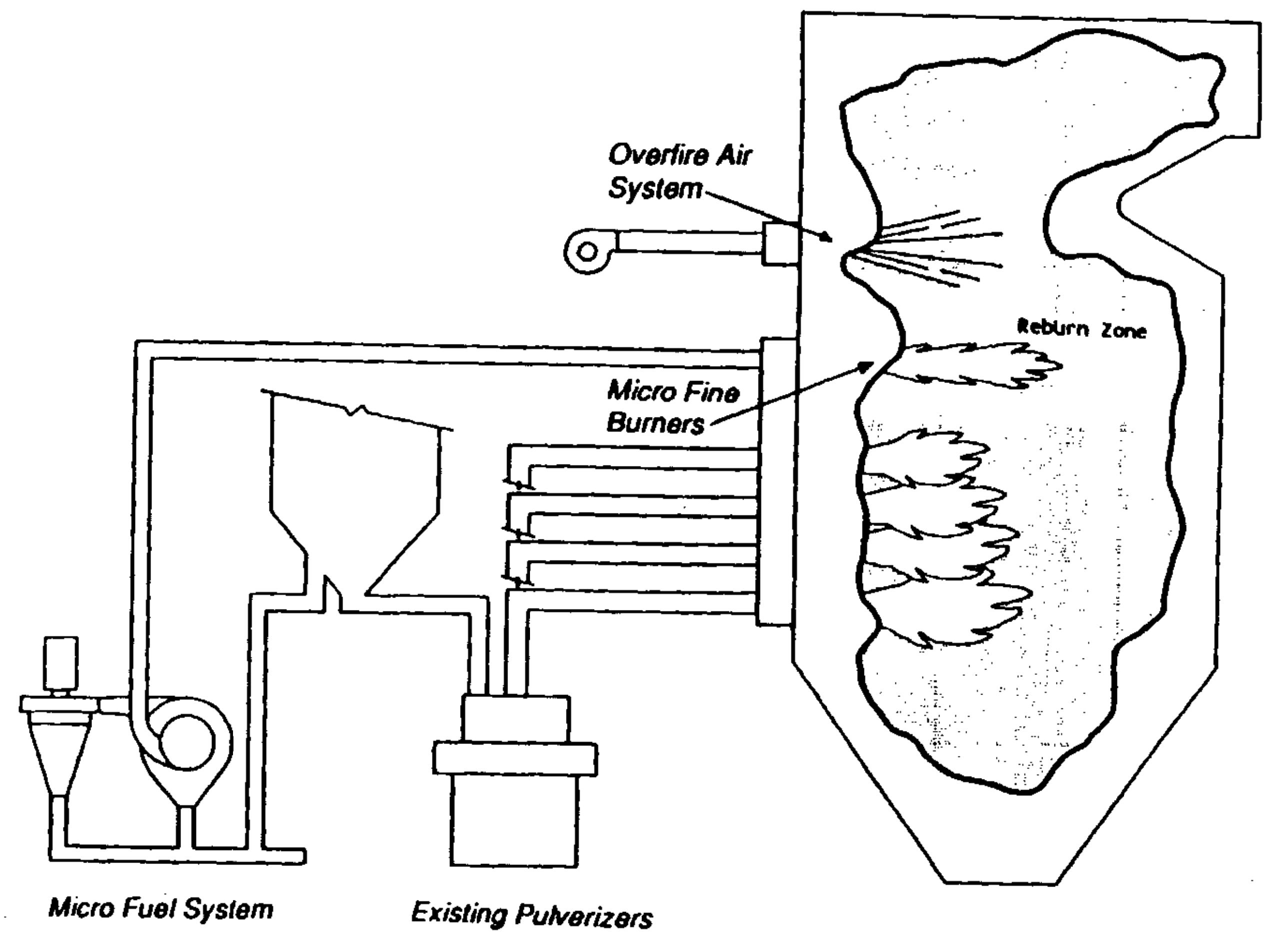

Figure 3. MICRONIZED COAL REBURNING SCHEMATIC

1970s, the plant was modified to burn low-sulfur coal in order to meet SO_2 emission limits, which resulted in mill limiting each unit to 154 MWe. Each unit is equipped with a baghouse to control particulate emissions. Although any of the nine wall-fired units could be used to demonstrate the MCR technology, Unit 6 was chosen, because the original secondary air registers have been replaced, thus allowing for better control of air/fuel staging.

The specific objectives of the demonstration are:

- To demonstrate NO_x emissions reduction of 50 to 60% without use of oil or gas for reburning and without the decrease in boiler efficiency that accompanies use of these fuels (especially gas).

- To show reduced energy replacement costs due to improved ability to operate at rated load even with wet coals and/or equipment problems.

- To show increased generation capacity at very low investment costs.

- To achieve increased fuel flexibility by allowing use of high-moisture, low-Btu, western low-sulfur coals, while mitigating deratings caused by fuel handling limitations.

- To demonstrate improved turndown and stability at low loads without firing supplemental fuels.

- To demonstrate the ability to operate existing pulverizers at reduced throughput without unit deratings.

3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

As described earlier, much work has already been performed to develop this technology. There are two parts to the technology: coal micronization and reburning. Reburning for NO_x control has been practiced, mainly using natural gas or oil as the reburn fuel. Although successful, use of these fuels for this purpose suffers from one or more of the following disadvantages: reliability of supply, especially in winter; higher fuel costs; problems in firing dual fuels; and reduced efficiency because the higher hydrogen content results in an increase in moisture in the flue gas. Burning of micronized coal has been demonstrated, and these operations have shown the advantage of burning ultrafine coal.

The MicroMill™, which will be used to produce the micronized coal, has been thoroughly tested, both in pilot-scale and in commercial-scale operations. Therefore, no problems are anticipated with this part of the technology. Thus, all the pieces of the technology have been demonstrated, although not in the configuration to be demonstrated in this project.

3.3.1.1 Similarity of the Project to Other Demonstration/Commercial Efforts

As far as is known, there are no other operations demonstrating the exact combination of technologies being demonstrated in this project. DOE is sponsoring gas reburning on wall-, cyclone-, and tangentially-fired boilers and conventional pulverized coal reburning on a cyclone-fired boiler. The MCRD project provides a greater degree of NO_x reduction and results in improved boiler efficiency and performance.

3.3.1.2 Technical Feasibility

The novel portions of the system are the advanced micronized coal reburning system and the MicroFuel MicroMill™. All of the other equipment is standard equipment and is commercially available. In fact, in retrofit applications, all of the other equipment will be existing equipment. The only additional equipment will be ducts and fans, as required, for combustion air for the reburn burners and the overfire air system. The source of this air is the secondary air duct, where preheated air is taken from the air heater to the windbox.

While this reburn system is in a state of technical readiness for full-scale demonstration, there are some supporting activities that will ensure that the demonstration achieves a high degree of success. These activities include cold-flow and computer modeling, customizing the reburn burners, and the various field testing programs. These activities will be conducted in Phase I and will provide further evidence of the adequacy, availability, suitability, and quality of the data and data analysis to support the decision to advance to the demonstration stage.

3.3.1.3 Resource Availability

Adequate resources are available for this project over the 48-month demonstration period. TVA has committed funds, as discussed in Section 6.1, adequate to cover the proposed project cost. They have also dedicated the necessary personnel to conduct this demonstration program.

Sufficient space is available at the Shawnee Fossil Plant site for installation of the new equipment required for the demonstration. The project will use existing coal handling equipment.

TVA has contracts in place to supply Shawnee with low-sulfur bituminous coals from Kentucky and West Virginia. These coals will be used as the primary fuels for the project. Since the late 1970s, TVA has test-burned western coals at a number of sites, including Shawnee, and Powder River Basin coal will be purchased on short-term contracts for this demonstration. Other resources, such as electricity, can be supplied in the required quantities by the existing systems.

3.3.2 Relationships Between Project Size and Projected Scale of Commercial Facility

As mentioned previously, the test boiler is a 175 MWe wall-fired utility unit, firing low-sulfur pulverized coal. This unit is typical of a large portion of the nation's utility operating base. Thus, there is the potential for wide application of the technology after successful completion of this demonstration. Although demonstrated on a wall-fired unit, the technology should be equally applicable to cyclone-fired and tangentially-fired pulverized coal units. Once a larger MicroMill™ is developed, this technology should be applicable to large central station units.

3.3.3 Role of the Project in Achieving Commercial Feasibility of the Technology

This project will demonstrate, at commercial scale, a novel technology for meeting the expected NO_x limits on existing coal-fired units as a result of the 1990 Clean Air Act Amendment. The technology can use virtually any coal and can be easily retrofitted to many types of coal-fired furnaces. Success of the demonstration project will provide a great impetus to commercialization.

Should the MCRD project for NO_x control prove successful, TVA will consider retrofit of MCR technology at the remaining 8 wall-fired units at Shawnee Fossil Plant (175 MW each, 1400 MW total), 3 units at Allen Fossil Plant (cyclone-fired, 330 MW each, 990 MW total), and other TVA plants.

3.3.3.1 Applicability of the Data to be Generated

The demonstration project will test all aspects of the MCR technology at commercial scale on a commercial coal-fired unit. Data collection, analysis, and reporting will be performed during the operations phase and will include on-stream factors, material balances, equipment performance, comparisons with previous results, efficiencies, and NO_x emission levels. The data that will be generated on the MicroMill™ and on firing micronized coal for electric power production and NO_x reduction will be directly applicable to other commercial applications and will provide valuable information to permit scaleup to larger units.

3.3.3.2 Identification of Features that Increase Potential for Commercialization

Although primarily developed as a means for decreasing NO_x emissions from coal-fired furnaces, the MCR technology has several other potential benefits which will make it attractive for many operators of coal-fired units. Among the possible benefits are:

- Increased capacity on mill-limited units.

- Providing back-up for existing pulverizers, while having no negative impact on furnace performance.

- Improved efficiency due to lower excess air and decreased loss on ignition.

- Competitive capital, operating, and maintenance costs.

- Ease of retrofit, since the reburn burners and overfire air ports are the only furnace wall penetrations required. MicroMill™ Systems are compact and lightweight and can typically be mounted on the operating floor adjacent to bunker outlets, and existing burners and registers can be modified at minimal expense for fuel/air staging.

- Ability to fire low-sulfur, low-cost subbituminous coals as a reburn fuel.

- Up to 30% reduction in existing pulverizer throughput, thus permitting classifiers to be adjusted for a significant improvement in coal fineness.

- Improved steam and superheat temperature at low load, as a result of firing micronized coal in the upper furnace and rapid devolatilization and char burnout of the reburn fuel.

The combination of micronized coal and reburning for NO_x control are a natural fit for existing older fossil units. Together, they provide flexibility and economies of scale that are unattainable with other NO_x control technologies. With MCR providing NO_x reductions of 50 to 60%, most tangential- and wall-fired furnaces should be able to meet the Clean Air Act Amendments NO_x compliance limits without expensive back-end control methods.

3.3.3.3 Comparative Merits of the Project and Projection of Future Commercial Economics and Market Acceptability

The primary competing technology for NO_x control is low-NO_x burners. Although low-NO_x burners will meet the current emission requirements, the benefits of MCR technology will allow it to compete effectively with low-NO_x burners. These benefits include the use of the micronized coal system for start-up and low-load operation, and restoring mill-limited units to rated capacity. Installing MCR technology will reduce the load on existing mill systems, improve carbon burnout, reduce excess air, and increase unit efficiency. The technology is expected to be competitive from a capital and operating standpoint with low-NO_x burner applications.

Despite slow growth of electric power demand and a corresponding decrease in generating plant construction during the 1980s, demand for electricity is expected to continue to increase at a rate that will not only require new generating capacity but will put additional demands on the existing coal-fired generating base. Recently, the Electric Power Research Institute (EPRI) compiled a listing of 75 MW to 300 MW coal-fired units that were built in the U.S. between 1945 and 1965. This list totals 389 units with nearly 60 GW of capacity. Although they will reach their 40-year life spans between 1985 and 2005, these units are candidates for retrofitting and continued operation, either as baseload or peaking units. As new generating capacity is added, this will further relegate the older installed base to cyclic duty. Benefits of the MCR technology will best be realized on this boiler population. The technology will not only meet the NO_x emission requirements but will allow the operation of these units on low load while firing only coal, thereby reducing operating costs and ultimately the cost of electricity delivered to the end user.

It is expected that, if the MCRD project proves to be successful, this technology could capture up to 15% of the NO_x control market. This is based on the premise that this technology not only allows the utilities to meet NO_x emission requirements but also gives them operating benefits that low-NO_x burners and other competing technologies do not.

4.0 ENVIRONMENTAL CONSIDERATIONS

The NEPA compliance procedure, cited in Section 2.2, contains three major elements: a Programmatic Environmental Impact Statement (PEIS); a pre-selection, project-specific environmental analysis; and a post-selection, site-specific environmental analysis. DOE issued the final PEIS to the public in November 1989 (DOE/EIS-0146). In the PEIS, results derived from the Regional Emissions Database and Evaluation System (REDES) were used to estimate the environmental impacts expected to occur in 2010 if each technology were to reach full commercialization and capture 100% of its applicable market. These impacts were compared with the no-action alternative, which assumed continued use of conventional coal technologies through 2010 with new plants using conventional flue gas desulfurization to meet New Source Performance Standards.

The preselection, project-specific environmental review, focusing on environmental issues pertinent to decision-making, was completed for internal DOE use. The review summarized the strengths and weaknesses of each proposal in compliance with the environmental evaluation criteria in the PON. It included, to the extent possible, a discussion of alternative sites and processes reasonably available to the offeror, practical mitigating measures, and a list of required permits. This analysis was provided for consideration of the Source Selection Official in the selection of proposals.

As the final element of the NEPA strategy, the Participant (TVA) submitted to DOE the Environmental Information Volume specified in the PON. This detailed site- and project-specific information formed the basis for the NEPA documents prepared by DOE. These documents, prepared in compliance with the Council on Environmental Quality regulations for implementation of NEPA and the DOE regulations for NEPA compliance, must be approved before Federal funds can be provided for detailed design, construction, and operation activities.

In addition to the NEPA requirements outlined above, the Participant must prepare and submit an Environmental Monitoring Plan (EMP) for the project. The purpose of the EMP is to ensure that sufficient technology, project, and site environmental data are collected to provide health, safety, and environmental information for use in subsequent commercial applications of the technology.

This technology will significantly reduce NO_x emissions, without producing any adverse environmental impact. No new waste products (or emissions) will be generated, and no new permits or licenses will be required to implement the project.

5.0 PROJECT MANAGEMENT

5.1 Overview of Management Organization

The project will be managed by a TVA Project Manager. This individual will be the principal contact with DOE for matters regarding the administration of the Cooperative Agreement between TVA and DOE. The DOE Contracting Officer is responsible for all contract matters, and the DOE Contracting Officer's Technical Project Officer (TPO) is responsible for technical liaison and monitoring of the project.

5.2 Identification of Respective Roles and Responsibilities

DOE

The DOE shall be responsible for monitoring all aspects of the project and for granting or denying approvals required by the Cooperative Agreement. The DOE Contracting Officer is DOE's authorized representative for all matters related to the Cooperative Agreement.

The DOE Contracting Officer will appoint a TPO who will be the authorized representative for all technical matters and will have the authority to issue "Technical Advice" which may:

- Suggest redirection of the Cooperative Agreement effort, recommend a shifting of work emphasis between work areas or tasks, or suggest pursuit of certain lines of inquiry which assist in accomplishing the Statement of Work.

- Approve all technical reports, plans, and items of technical information required to be delivered by the Participant to the DOE under the Cooperative Agreement.

The DOE TPO does not have the authority to issue technical advice which:

- Constitutes an assignment of additional work outside the Statement of Work.

- In any manner causes an increase or decrease in the total estimated cost or the time required for performance of the Cooperative Agreement.

- Changes any of the terms, conditions, or specifications of the Cooperative Agreement.

- Interferes with the Participant's right to perform the terms and conditions of the Cooperative Agreement.

All Technical Advice shall be issued in writing by the DOE TPO.

<u>Participant</u>

The following organizations will interact effectively to meet the intent of the PON and to assure a timely and cost effective implementation plan from conceptual design to start-up and operation of the proposed MCRD facility:

- Tennessee Valley Authority
- MicroFuel Corporation (MFC)
- Research-Cottrell Research & Development (R-C R&D)
- Duke/Fluor Daniel (D/FD)

TVA will be primarily responsible for reporting to and interfacing with DOE and for subcontracting work to MFC. TVA will be responsible for all phases of the project.

The overall project approach of the above Participants will consist of, but not necessarily be limited to, the following:

- A single project manager will be responsible to DOE and all project Participants for all three project phases.

- MFC will serve as a subcontractor to TVA and will manage the design and construction phases of the MCRD project. MFC will utilize the assistance of R-C R&D and D/FD.

- Maximum use will be made of the competitive bidding process in the purchase of equipment, material, engineering, and construction services for the demonstration project. Bids will be evaluated on both technical and commercial criteria, and those bids providing the highest value to the program will be selected.

- MFC is the developer of Micronized Coal Technology and the MicroMill™ and has joined with R-C R&D to adapt micronized coal combustion to reburning. MFC will be responsible for the design and construction phases of the MCRD project.

- R-C R&D, a leader in developing advanced reburn technology, will provide engineering and R&D support, including computer and cold flow boiler modeling, emissions monitoring, and laboratory analysis. R-C R&D will be a subcontractor to MFC.

- D/FD will be the engineer constructor and will provide architectural and engineering services to facilitate construction and integration of the system to the boiler. D/FD will be a subcontractor to MFC.

TVA will be the primary liaison between the Government and all other organizations, as shown in Figure 4, Project Organization.

5.3 Summary of Project Implementation and Control Procedures

All work to be performed under the Cooperative Agreement is divided into three phases. These phases are:

Phase I: Design and Engineering (9 months)
Phase II: Construction (9 months)
Phase III: Operations (36 months)

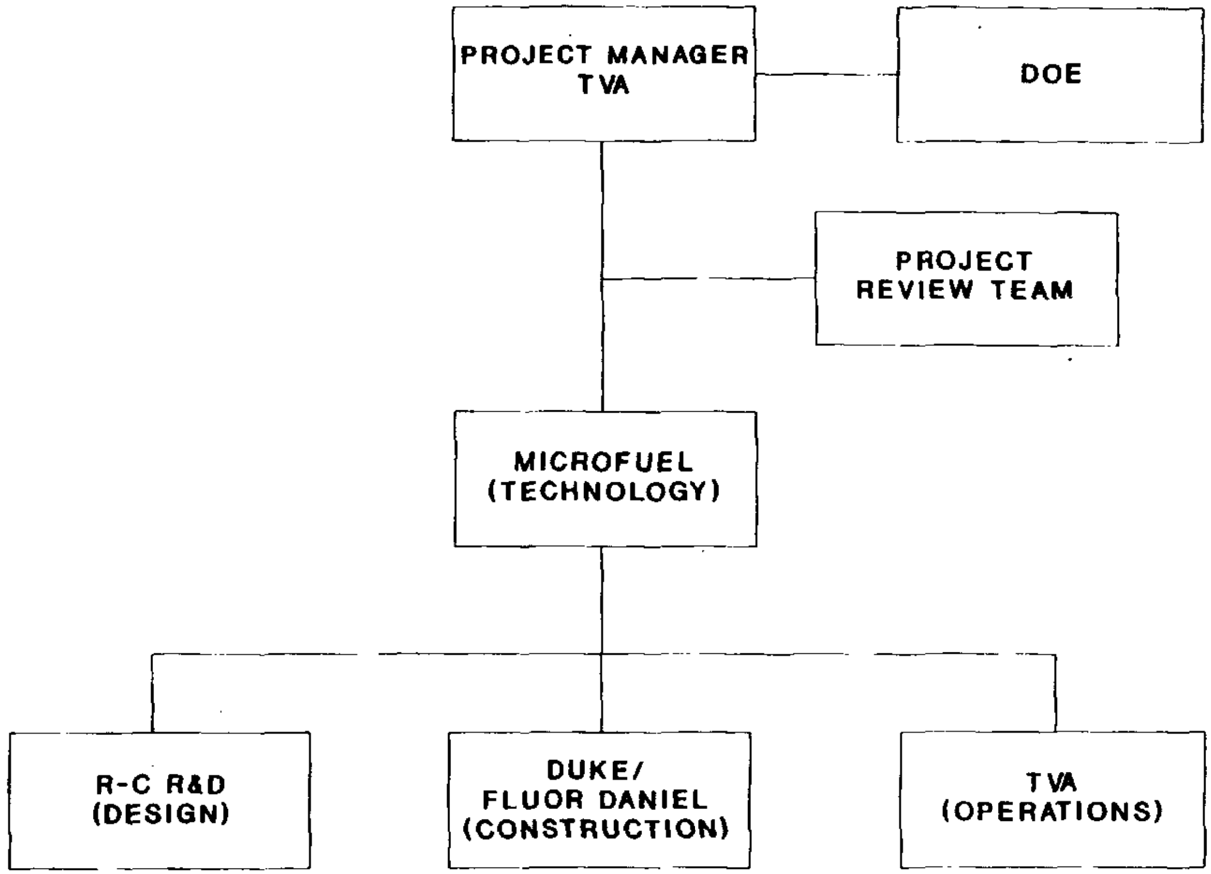

FIGURE 4. PROJECT ORGANIZATION FOR TVA MCRD PROJECT

As shown in Figure 5, the total project encompasses 48 months.

All three phases of this project will be included in one budget period. Due to the short duration of Phases I and II and the low cost of Phase III, there is little need for more than one budget period to adequately control the project. Consistent with P.L. 101-512, DOE will obligate funds sufficient to cover its share of the cost of the project. Throughout the course of this project, reports dealing with the technical, management, cost, and environmental monitoring aspects of the project will be prepared by TVA and provided to DOE.

5.4 Key Agreements Impacting Data Rights, Patent Waivers, and Information Reporting

The key agreements in respect to patents and data are:

- Standard data provisions are included, giving the Government the right to have delivered, and use, with unlimited rights, all technical data first produced in the performance of the Agreement.

- Proprietary data, with certain exclusions, may be required to be delivered to the Government. The Government has obtained rights to proprietary data and non-proprietary data sufficient to allow it to complete the project if the Participant withdraws.

- Rights in background patents and background data of MFC, TVA, and all of its subcontractors are included to assure commercialization of the technology.

TVA will make such data, as is applicable and non-proprietary, available to the DOE, EPA, other interested agencies, and the public.

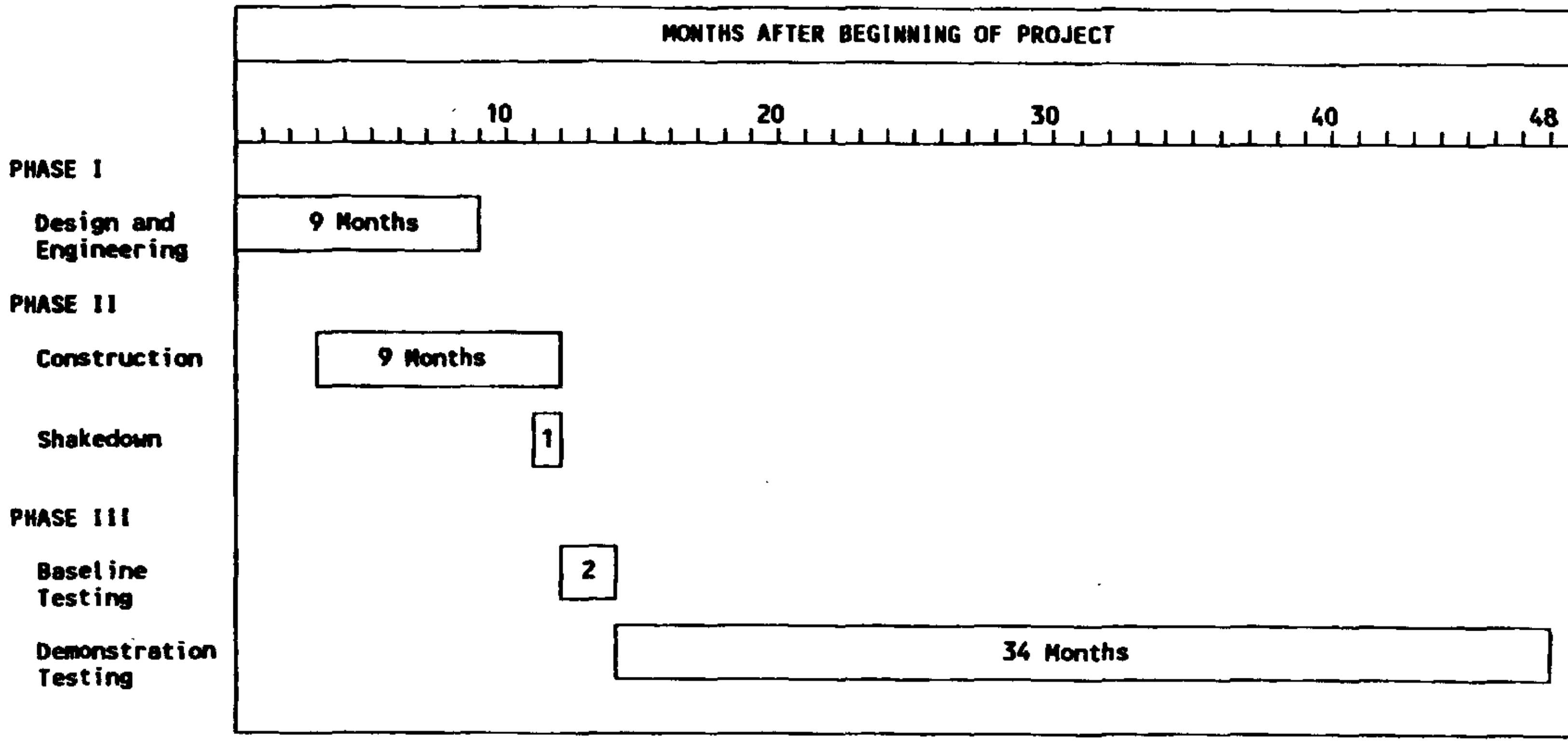

Figure 5. OVERALL PROJECT SCHEDULE FOR TVA MCRD PROJECT

5.5 Procedures for Commercialization of the Technology

The commercialization of MCR for NO_x control will be through the efforts of TVA's first tier subcontractor, MicroFuel (MFC). MFC will market the MCR technology for the coal preparation and delivery systems and for the reburn and furnace technology.

MFC and its investors have spent many years and several million dollars developing, patenting, and marketing the MicroFuel MicroMill™ System to serve the electric utility market for low-load and start-up applications. This investment includes research and development facilities, full-size demonstration units, and personnel to meet the company's strategic plan and goals.

The MicroFuel Corporation is an excellent fit for the commercialization of this demonstration technology. MFC serves the electric utility industry by supplying micronized coal systems to displace gas and oil as the start-up and low load stabilization fuel; MCR technology development and validation is a major component of their existing strategic plan. The demonstration project represents the final step in the development of MCR technology, and MFC's management is deeply committed to the MCR technology and to this market sector.

MFC plans to begin marketing the MCR technology as soon as the project demonstration testing provides the anticipated affirmation of the MCR process and documents the NO_x reduction goals. At that time, detailed marketing plans will be finalized, and a dedicated group to serve this market will be formed within MFC's existing marketing organization.

TVA's commitment towards the commercialization of MCR technology is evidenced by its written option with MFC for installation of this MCR technology on eight additional units at the Shawnee Station. TVA will have all of its future MCR purchases excluded from the requirements of the repayment agreement; and, therefore, the purchase price will be discounted accordingly.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 Project Baseline Costs

The total estimated cost for this project is $7,330,041. The Participant's share and the Government's share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
Pre-Award		
Government	-0-	-0-
Participant	106,251	100
Phase I		
Government	887,441	45
Participant	1,081,720	55
Phase II		
Government	1,862,030	50
Participant	1,862,031	50
Phase III		
Government	765,284	50
Participant	765,284	50
Total Project		
Government	3,514,755	48
Participant	3,815,286	52

The project will be co-funded by DOE and TVA.

DOE	$3,514,755
TVA	$3,815,286
TOTAL	$7,330,041

At the beginning of the project, DOE will obligate funds sufficient to pay its share of expenses.

6.2 Milestone Schedule

The overall project will be completed in 48 months. The project schedule, by phase and activity, is shown in Figure 5.

Phase I, which involves design and engineering, will continue for 9 months. Phase II, construction, will overlap Phase I by 6 months and last a total of 9 months. Phase III, operations, will last 36 months.

6.3 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 Repayment Agreement, which is consistent with the model repayment agreement in the CCT-IV PON.