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Comprehensive Report To Congress Clean Coal Technology Program

Advanced Cyclone Combustor With Integral Sulfur, Nitrogen And Ash Control

A Project Proposed By
Coal Tech Corporation
Merion, Pennsylvania

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U.S. Department of Energy
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1.0 EXECUTIVE SUMMARY

The FY86 Appropriations Act, P.L. 99 – 190, included approximately $400 million to support the construction and operation of demonstration facilities using Clean Coal Technologies. These Clean Coal Projects cover a broad spectrum of technologies having the following things in common: 1) All are intended to increase the use of coal in an environmentally acceptable manner; and 2) all are ready to be proven at the demonstration level.

In response to the resulting Program Opportunity Notice (PON), fifty – one proposals were received in April 1986. After evaluation, nine projects, representing seven different technologies, were selected in July 1986 for funding under the Clean Coal Technology (CCT) Program.

One of the nine projects selected was the Coal Tech Corporation proposal for the demonstration of an advanced horizontal cyclone combustor with integral sulfur, nitrogen, and ash control systems. Standard burners or combustors which are attached to the outside walls of boilers, mix air with fuel, provide an ignition source and discharge the burning mixture into the boiler, heating water in the tubes to produce steam. The Coal Tech combustor, which will replace a standard burner, also mounts on the outside wall of the boiler, mixes coal, sorbent (limestone) and air, provides ignition, and removes ash before discharging the hot combustion products to the boiler. The 30 million Btu/hour combustor is approximately five feet in diameter by eight feet long.

Sulfur oxides (SO_x) control is achieved by means of limestone injection into the burner. Nitrogen oxides (NO_x) formation is limited by operating the first combustion stage with an oxygen deficiency. Additional oxygen is added to complete combustion after the combustion products leave the combustor. The system is also designed to obtain very high ash removal by cyclonic action in the combustor, resulting in a unit that is easily retro – fittable to gas – and oil – fired units. It is the simultaneous reduction of three different pollutants that makes the performance of this combustor unique.

The demonstration of the 30 million Btu/hour combustor on a small industrial boiler will make this technology ready for commercialization on industrial (30 – 70 million Btu/hour) boilers. It will also provide an excellent basis for scale – up to the larger, 100 million Btu/hour utility size combustor. The total potential retrofit market for this technology is estimated at 60,000 combustors, including coal, gas, and oil fired boilers.

The expected performance capabilities are as follows:

- up to 90% SO_x removal

- NO_x reduction to 100 parts per million by volume in the flue gas
- 90% to 95% ash removal in the combustor

The duration of the Coal Tech Demonstration Project is to be 25 months and it will be conducted at Williamsport, Pa. (Figure 1). Other co – funders and their contributions are the State of Pennsylvania Energy Authority ($200,000), Pennsylvania Power and Light (test coals), and Keeler Boiler Manufacturing Company (use of site and boiler). The total cost of the Project is estimated to be $785,984, of which 50% will be paid by DOE.

The Project will be managed by Coal Tech's Project Manager. As a small business, background patent and background data rights will remain with Coal Tech. New inventions made by Coal Tech will be owned by Coal Tech, and the Government will have unlimited rights in any technical data first produced under this Cooperative Agreement.

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.

Award of a Cooperative Agreement and start of the project are expected early in the second quarter of FY87. Environmental permitting for Phase I is scheduled to be finished in the third

LOCATION OF COAL TECH PROJECT

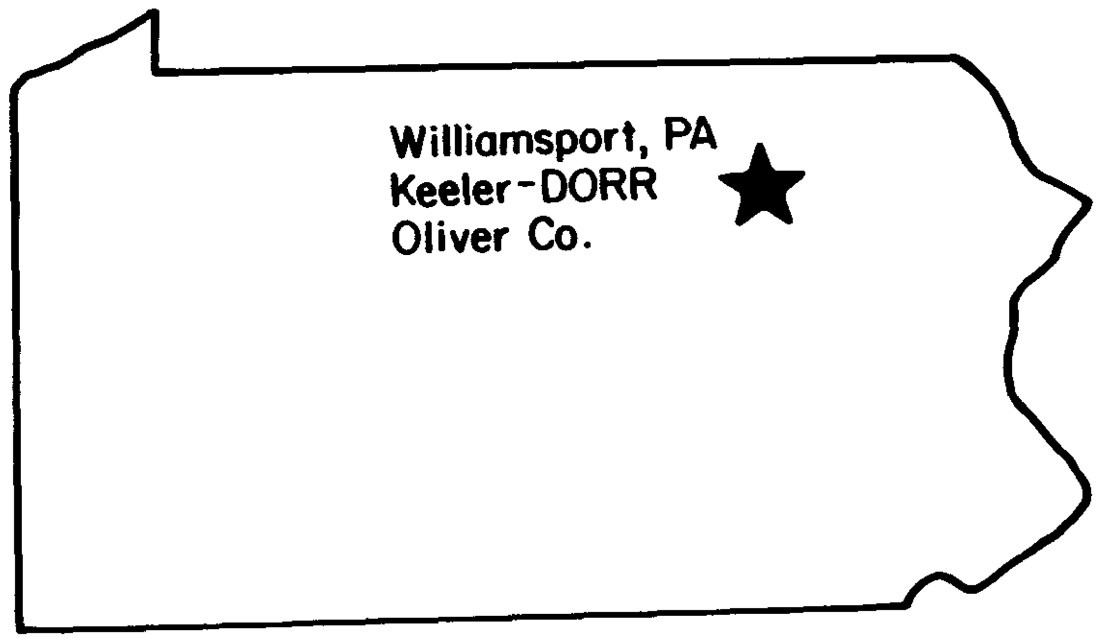


FIGURE 1.

quarter of FY87. Phase II is the procurement and installation of ancilliary equipment and shakedown testing and is scheduled to begin two months after Phase I begins. Phase III, testing and data analysis, will start in the fourth quarter of FY87. Testing and data analysis will end in late FY88, followed by dismantling of equipment and issue of a final report in the second quarter of FY89.

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, 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 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 Coal Tech Corporation's Advanced Cyclone Combustor Project.

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 that 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, "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; and
c) The desirability of selecting for support a group of projects that represent 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 on 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 Coal Tech Corporation, was one of the proposals selected for award.

3.0 PROJECT AND PROCESS DESCRIPTION

3.1 Project Summary

Project Description:	The Demonstration of an Advanced Cyclone Combustor with Internal Sulfur, Nitrogen, and Ash Control for the Conversion of a 23 million Btu/hour Boiler to Coal
Project Title:	Advanced Cyclone Combustor Demonstration
Proposer:	Coal Tech Corporation
Project Location:	Williamsport, Pennsylvania - Lycoming County
Technology:	Advanced Air-Cooled Slagging Cyclone Combustor with Limestone Addition for SO_2 Control
Application:	Industrial and Utility Boilers; New or Retrofit; Coal, Oil, or Gas Designed
Type of Coal Used:	Pennsylvania Bituminous - Freeport Seam (2-4% S)
Product:	Steam and/or Electricity
Project Size:	1 ton/hour Coal Feed to Combustor
Project Starting Date:	02/09/87
Project End Date:	02/28/89
Project Sponsor:	Coal Tech Corporation
Proposed Co-Funders:	State of Pennsylvania Energy Development Authority Pennsylvania Power and Light Keeler Boiler Manufacturing Company
Proposed Project Cost:	$785,984

Proposed Cost Distribution:	Participant Share (%)	DOE Share (%)
	50	50

3.2 Process Development

Standard burners, which are attached to the outside walls of boilers, mix air with fuel, provide an ignition source, and discharge the burning mixture into the boiler. In the boiler, the hot combustion gases pass through bundles of tubes containing water to produce steam. The Coal Tech combustor, which will replace a standard burner, also mounts on the outside wall of the boiler, mixes coal, sorbent (limestone), and air, provides ignition, and removes ash before discharging the hot combustion products to the boiler. The 30 million Btu/hour combustor is approximately five feet in diameter by eight feet long.

The cyclone combustor is an elevated temperature (3000 + ^{o}F) device in which a high velocity, swirling gas is used to burn crushed or pulverized coal. The ash is separated from the coal in liquid form (slag) on the cyclone walls and flows toward a port located at the downstream end of the device. The cyclone combustor has a long commercial history as an ash – removal device in the U.S. and Germany. These early cyclones were of similar design, and very coarse coal particles were burned under excess air combustion conditions that produced very high NO_x emissions. This adverse environmental impact, which has since been corrected, was one of the major factors in the greatly reduced use of these cyclones in the late 1960's.

The present advanced cyclone coal combustors, under development by Coal Tech Corporation and others in the U.S., are derived largely from R&D on their applications to magnetohydrodynamic (MHD) power generation. These early MHD combustors are similar to the current cyclone and slagging combustors under development for oil – and coal – fired boiler applications.

3.3 Process Description

Coal Tech's combustor concept was tested extensively from 1975 – 1981 at the 1 million Btu/hour pilot scale, as part of a DOE – and utility – sponsored program. Since 1981, the development of the combustor has continued at Coal Tech Corporation, which was formed for this purpose. To date, almost $1 million of Federal, State of Pennsylvania, utility, industrial, and private sector funding has been expended and committed for the continuing development of this combustor at Coal Tech.

Coal Tech's horizontal cyclone combustor is internally lined with a ceramic cylinder, backed by an air – cooled, metal – tube assembly. A gas or oil burner, located at the center of the closed end of the unit, will be used to preheat the ceramic – lined combustor wall and to start coal combustion. Pulverized coal, air, and sorbent are injected toward the wall through tubes in the annular region enclosing the gas or oil burner. In this manner, the coal particle combustion takes place in a region favorable to particle retention in the combustor. Figure 2 depicts Coal Tech's combustor.

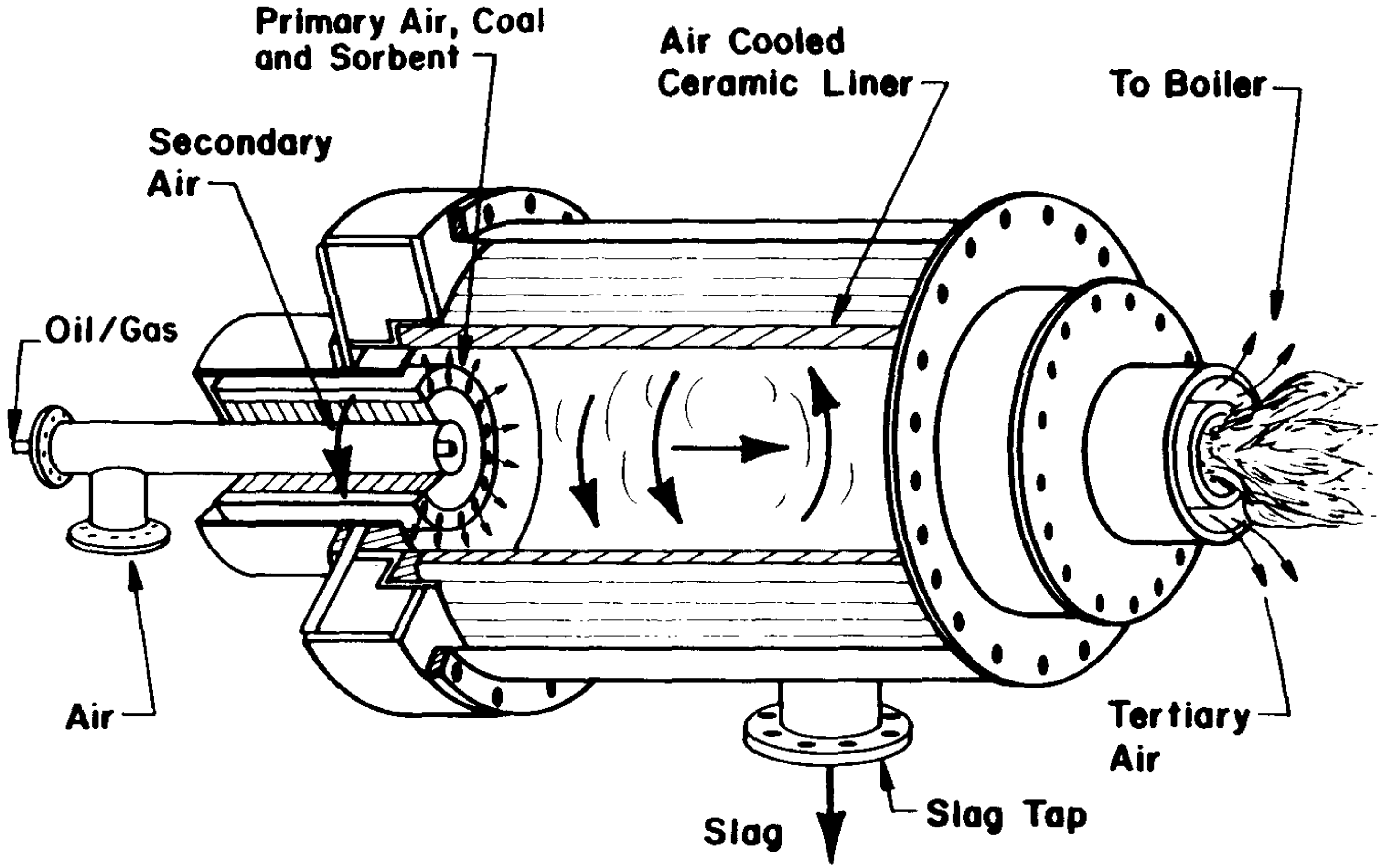


Figure 2

AIR COOLED CYCLONE COAL COMBUSTOR

(Coal Tech Corp, Merion, PA)

Secondary air (SA) is used to adjust the overall combustor stiochiometry. The ceramic liner is cooled by the SA and maintained at a temperature high enough, 2200 – 2500^{O}F, to keep the slag in a liquid, free – flowing state. The SA is preheated by the combustor walls to the 1000^{O}F range which helps attain efficient combustion of the coal particles in the fuel – rich combustor. The SA tangential injection velocity is in the range of several 100 ft/sec. The fine coal pulverization allows combustion of approximately 2/3 of the coal particles which are in suspension near the cyclone wall, with the balance being burned on or near the wall following re – entrainment by the high velocity gas flow. This improves combustion in the fuel – rich chamber, as well as slag retention. This slag contains over 90% of the ash and sorbent fed to the combustor. The combustor is operated fuel – rich, with final combustion taking place in the boiler furnace, to which the combustor is attached.

There are two sources of NO_x in coal combustion, thermal and fuel bound. It is well known that thermal NO_x is controlled by maintaining the combustion gas temperature at 3000^{O}F, or less. The main source of NO_x in coal combustion is fuel bound nitrogen in the coal. This is released as NH_3, NO, and HCN in the fuel – rich combustion zone. By maintaining the combustion gases in a fuel – rich zone, it is possible to convert these three species to N_2 prior to the introduction of final combustion air to a furnace. This conversion process can take from several milliseconds to 0.5 seconds, depending on the gas conditions.

Therefore, in the application of this combustor to boiler conversions, one must place the final combustion air inlets to the furnace region of the boiler at a location far enough away from the combustor gas exhaust to allow this conversion to take place. A series of experiments in the 1 million Btu/hour combustor lead to the discovery that under fuel – rich operation, NO_x emission reductions below 100 ppm could be achieved.

Due to the 3000^{o}F temperature in the combustor, sulfur capture proceeds via two separate non – equilibrium mechanisms. The first one occurs primarily in the coal/air injection zone of the cyclone in time periods of less that 100 milliseconds, during the period when the limestone particles rapidly calcine and react with the SO_x. The other sulfur capture mechanism occurs during re – entrainment by the swirling gas, of the larger limestone particles from the slag covered wall. It is estimated, that each of the two mechanisms could capture 50 % of the sulfur and since the mechanisms act sequentially, they can together remove most of the sulfur in coal.

In addition to sulfur capture and retention inside the cyclone, sulfur can also be captured by limestone injection in the cooler excess air region of the boiler. This process requires gas temperatures in the 2000^{o}F range, which means that the sorbent must be injected near the convective passages in the boiler. The advantage of this approach with the cyclone is that since most of the slag is removed in the combustor, there are no ash catalytic effects which can desulfurize the $CaSO_4$ particles.

The use of air cooling of the cyclone combustor walls allows accurate control of the slag layer thickness for a wide range of coals. This is important for the following reasons: it allows rapid slag removal to prevent sulfur re-evolution, and it allows recovery of the combustor's heat loss, which results in more efficient fuel-rich operation. Air cooling also simplifies the integration of a combustor with an existing boiler since water cooling requirements of water-cooled combustors are not always compatible with the feed water requirements of the boilers on which they are to be installed.

The proposed project is to demonstrate the performance, reliability, and suitability of the advanced, air-cooled, slagging cyclone combustor, developed by Coal Tech Corporation, in retrofit applications. The size of the combustor used in this project is directly suitable for some industrial boilers. However, additional scale-up to 100 million Btu/hour is necessary for use in larger boilers. This project will also confirm scale-up parameters; and, thus, the design for larger combustors, making the need for a separate demonstration of the 100 million Btu/hour unit unlikely.

3.4 Unique Features of Project

One difference between the Coal Tech unit and other combustors is the air cooling that promotes a higher wall temperature in the Coal Tech unit and affects the slag properties and sulfur emissions capture by the injected limestone. Another difference is the direction of coal injection that contributes to cyclonic action to enhance particle retention. Other combustors use water cooling and axial injection. Air cooling considerably simplifies the problem of combustor heat loss by also using the cooling air as combustion air.

Unlike the Coal Tech unit, some slagging combustors allow the ash and reacted limestone to exit with the combustion gases. The use of this latter type of combustor in oil – fired boiler applications requires a large vessel for particle capture at the combustor exit. This doubles the length of the combustor, a feature that is undesirable, particularly in boiler retrofit applications where there is limited space.

Finely pulverized coals, injected either dry or in slurries, may be an alternative concept for oil – fired boilers. However, unless the inherent ash in the coal is reduced to a very low level, about 1%, the boiler will have to be extensively derated. In either case, the cost of beneficiation or derating adds significantly to the cost of this approach to all boilers. The combustion of coal – water slurries in a cyclone combustor is considered to be a very attractive option. The cyclone provides one method of overcoming the problem of coal particle agglomeration, which is common to slurries.

3.5 Development of Demonstration Project

Early development work was performed on a 1 million Btu/hour air-cooled unit. It was operated in a series of eighteen tests from 1978 – 1981 for about one hundred hours on coal and up to 90% slag retention was obtained. A two-stage, ceramic-lined, water-cooled, cyclone combustor was then tested for about thirty hours with pulverized coal at 7 million Btu/hour. These experiments, conducted at Argonne National Laboratory, have shown that the fuel/air ratio is a critical parameter to controlling sulfur capture. Over 90% sulfur emission reduction was obtained, which provides the verification that the cyclone combustor can meet NSPS standards. A common feature of these two small combustors is the use of end-wall injection of coal and air. Therefore, the use of end-wall injection has been demonstrated at smaller sizes, and its use for the 30 million Btu/hour combustor should be successful.

The Keeler site was proposed by Coal Tech because of the technical knowledge of the staff and the existence of a 23 million Btu/hour boiler within the manufacturing complex in Williamsport, Pa. The boiler is currently equipped for oil- or gas-firing. The Coal Tech combustor has already been installed on the existing Keeler boiler as part of a previous test effort. It is planned to operate the test boiler with a four man crew. Two persons will be provided by Keeler, and the other two by Coal Tech.

The only external consumable raw materials will be coal and limestone. The former will be delivered and stored in a 20 ton truck, with pneumatic unloading, which will also serve as the coal feed hopper. This truck will be replaced approximately every 1.5 days at a combustion rate of 1 ton/hour, 16 hours/day. The limestone will be stored in a small storage bin. All power, water, gas, and oil requirements are available at the site.

The current 30 million Btu/hour combustor demonstration is the next logical step in the commercialization of this system.. It has been successfully tested at the 1 million Btu/hour and 7 million Btu/hour sizes. This successful long – term demonstration of the 30 million Btu combustor, a scale – up of 4.3, is intended to be the final step in the commercialization of the system for industrial size boilers. It will also be used to confirm the parameters for the conservative 3.3 scale – up used for the already completed design of a 100 million Btu/hour combustor that is sized for utility boilers. Multiple burners will be required for utility boilers that are typically 100 MW and larger.

It is expected that the information obtained in this project will confirm the design and permit the construction of these larger combustors, without the need for additional demonstration since the conservative scale – up to 100 million Btu/hour size will be a low – risk scale – up.

3.6 Commercial Feasibility of the Technology

Objectives of the proposed 900 – hour test program are to demonstrate reliable operation of the combustor, with representative medium and high sulfur U.S. coals. During the test, the various streams will be sampled and analyzed to prove the following:

a) Up to 90% reduction of sulfur dioxide emissions;
b) 70% – 80% reduction of nitrogen oxides (to less than 100 parts/million);
c) Reduction of particulate matter by retaining 90% of the ash in the combustor;
d) Applicability to retrofit an oil – designed boiler;
e) Operation over an output factor of 3 to 1; and
f) Demonstration of safe disposal of the coal ash.

In addition to the above performance parameters, there are other important facts to be learned in these tests. The critical issue with a ceramic – lined unit is materials durability; and the critical issue with converting an oil – fired boiler to coal is the impact of the combustion gas exhaust on the boiler internal surfaces.

The only method of satisfying market acceptability is to perform long – duration tests on a commercial – scale boiler. The selection of a boiler manufacturing concern, Keeler, as the boiler test site, assures that the project will be implemented in a manner that will satisfy power equipment purchasers, and that a successful conclusion to the project will lead to commercial acceptance. The economic assessment of the technology will be performed by Coal Tech. Coal Tech may also use the test effort for marketing purposes by inviting potential boiler users to visit the test site. A successful test effort will allow Coal Tech to rapidly commercialize the technology.

Successful demonstration of this technology will result in a device that, due to its compactness, can be easily retrofitted to a significant number of oil – and gas – fired boilers to meet present environmental regulations for SO_x and NO_x, and would also be equally applicable to new installations to meet proposed emission standards. This device would be attachable directly to an existing boiler, and exhausts a hot, relatively clean, combustion gas into the boiler.

It is this combination of performance capabilities that are expected to provide the major impetus for commercialization of this combustor. The SO_x and NO_x emissions are expected to meet or exceed NSPS requirements. The exceptionally good ash removal capability enhances its retrofittability to oil and gas units with little or no derating, since problems with slagging and fouling of boiler tubes are less likely. The cost of this combustor will be about the same as the burner/combustor replaced. The economic advantage will be attained by avoiding the cost of post – combustion flue gas cleanup, which is needed to meet the environmental requirements.

Another merit of this technology is that, although vastly improved, it is in some ways similar to other and earlier cyclonic combustors. This factor will aid in acceptance by both utility and industrial boiler operators. It is expected that successful demonstration of the 30 million Btu/hour combustor will completely prove its applicability for the smaller (industrial) boiler applications. The successful conclusion of this project will also provide a foundation for acceptance by the utilities. Acceptance by the utilities is further enhanced by the fact that a utility is also a participant in this program.

The installation and fabrication of these combustors may be done through licensing agreements with established firms. Acceptance of this technology by potential customers, following a successful demonstration program, is very likely, since this technology offers an economical approach to emission reductions that will have been proven reliable and flexible by the demonstration program. This combustor will be available for commercial application following the first successful test.

An important application of this technology is retrofit of pre-NSPS coal-fired boilers. It is also applicable to new boilers and retrofit to oil- and gas-fired units. The total potential retrofit market for gas- and oil-fired boilers is estimated at about 33,000 and 25,000 combustors in the utility and industrial sectors, respectively. For new boilers, it is estimated that there is a total potential market of 2,500 combustors per year in the industrial and utility sectors combined. Many factors such as unsuitability for retrofit on some boilers, remote coal sources, competing technologies, relative fuel costs, and the inconvenience/cost of coal handling equipment (especially on small units), will influence the actual amount of market penetration that will be achievable by the Participant's technology.

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 Roles and Responsibilities

The administrative and technical control of the project will be accomplished by the Coal Tech Project Manager. He will be responsible for all aspects of project performance, as set forth in the Statement of Work.

His contact in DOE for technical and administrative matters is the Contracting Officer's Technical Representative (COTR), who will provide technical advice, including such items as:

1) Suggest redirection of the Cooperative Agreement effort, recommend a shifting of work emphasis between work areas or tasks, and suggest pursuit of certain lines of inquiry, which assist in accomplishing the Statement of Work.
2) Approve those technical reports and technical information required to be delivered by the Participant to the DOE under this Cooperative Agreement.

Technical advice from the COTR must not change the scope of work, cost, or terms and conditions of the Cooperative Agreement, nor can it interfere with the Participant's right to perform the work. Such changes may be recommended by the COTR, but must be agreed to, in writing, by the Participant and the DOE Contracting Officer.

5.2 Implementation and Control Procedures

All work will be divided into three phases. Those phases and their expected durations are:

Phase I	Design and Permitting (4 months)
Phase II	Construction and Start-Up (5 months)
Phase III	Operation, Data Collection, Reporting, Dismantlement, and Disposition (18 months)

Overall program length is 25 months; there will be a two-month overlap between Phases I and II.

Budget periods will be established to coincide with the project phases. Consistent with Public Law No. 99-190, DOE will obligate sufficient funds to cover its share of the cost for each budget period. To continue work beyond the current project phase, the Participant shall submit a Project Evaluation Report and a continuation application to the DOE Contracting Officer at least sixty days prior to the end of the current budget period. The continuation application shall contain, as a minimum, the following:

- a detailed report of technical progress
- a detailed description of the Participant's plans for the conduct of the subsequent phase
- the detailed budget for the subsequent phase

DOE will approve or disapprove the continuation application thirty days prior to the end of the current budget period. DOE will approve the continuation application, provided the criteria in the approved Project Evaluation Plan (see Article XIII of the PON) are met and appropriated funds are available for the project. In determining whether the criteria have been met, DOE will consider the Participant's Project Evaluation Report and other available information. In the event DOE does not approve the continuation application, DOE will bear no costs of the project in excess of the maximum DOE obligation through the current budget period.

Throughout the course of this project, reports dealing with the technical, management, cost, and environmental monitoring aspects of this project will be prepared by the proposer and provided to DOE. Federal Assistance reporting guidelines will be used.

5.3 Key Agreements on Patents and Data Rights

Since Coal Tech Corporation is a small business, background patent and background data rights will remain with the Participant. Standard patent and data clauses for a small business will apply. New inventions made by Coal Tech will be owned by Coal Tech, and the Government will have unlimited rights in technical data first produced under this Cooperative Agreement.

5.4 Commercialization of Technology

As described in Section 3.6, this technology is intended to be commercialized through licensing agreement(s) with burner manufacturers and/or engineering firms. The manufacturing will be done by the licensee chosen by Coal Tech. Initial combustors will, most probably, be manufactured under subcontract to Coal Tech.

Upon successful completion of the demonstration program (perhaps earlier) it is anticipated that marketing can begin. Inquiries on the Coal Tech combustor have already been received. It is, therefore, expected that the first orders for industrial sized burners will be received after demonstration. Their use in the utility industry can be expected to follow, after they are already in use in the industrial sector. Their use in industrial applications before utility acceptance is due to two factors. The first is that this project will demonstrate a burner size that is suitable for use in industrial boilers, while the utility size will require scale – up. The second is that the utility sector tends to be more conservative. Assuming the goals of the project are met, this combustor's performance, characteristics, compact size, and cost will allow it to be competitive with other technologies when used on new boilers and in retrofit applications.

6.0 PROJECT COST AND SCHEDULING

6.1 Project Baseline Costs

The total project cost is $785,984. The cost for each individual phase of the project is:

Phase I – Permits, Plans, Design: $38,472

Phase II – Procurement, Installation, Shakedown: $123,072

Phase III – Demonstration Tests, Test Reports, Dismantling: $624,440

DOE's share is 50% of the cost of each phase.

DOE funds will be obligated by phase. The Participant will be responsible for the private cost share of the funding on a monthly basis.

In addition to Coal Tech Corporation, the other co – funders and their contributions are the State of Pennsylvania Energy Authority ($200,000), Pennsylvania Power and Light (test coals), and Keeler Boiler Manufacturer Company (use of site and boiler).

6.2 Milestone Schedule

The milestones are identified in Table 1 along with their occurrence in the project timetable. After a break – in period of 30 hours the intial 470 – hour test period will be run on a 2%

FORM EIA-459B

U.S. DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE MILESTONE PLAN

FORM APPROVED OMB No. 1900-0127

1 Program/Project Identification No.: DE-FC22-87PC79799

2 Program/Project Title: Demonstration of an Advanced Cyclone Coal Combustor

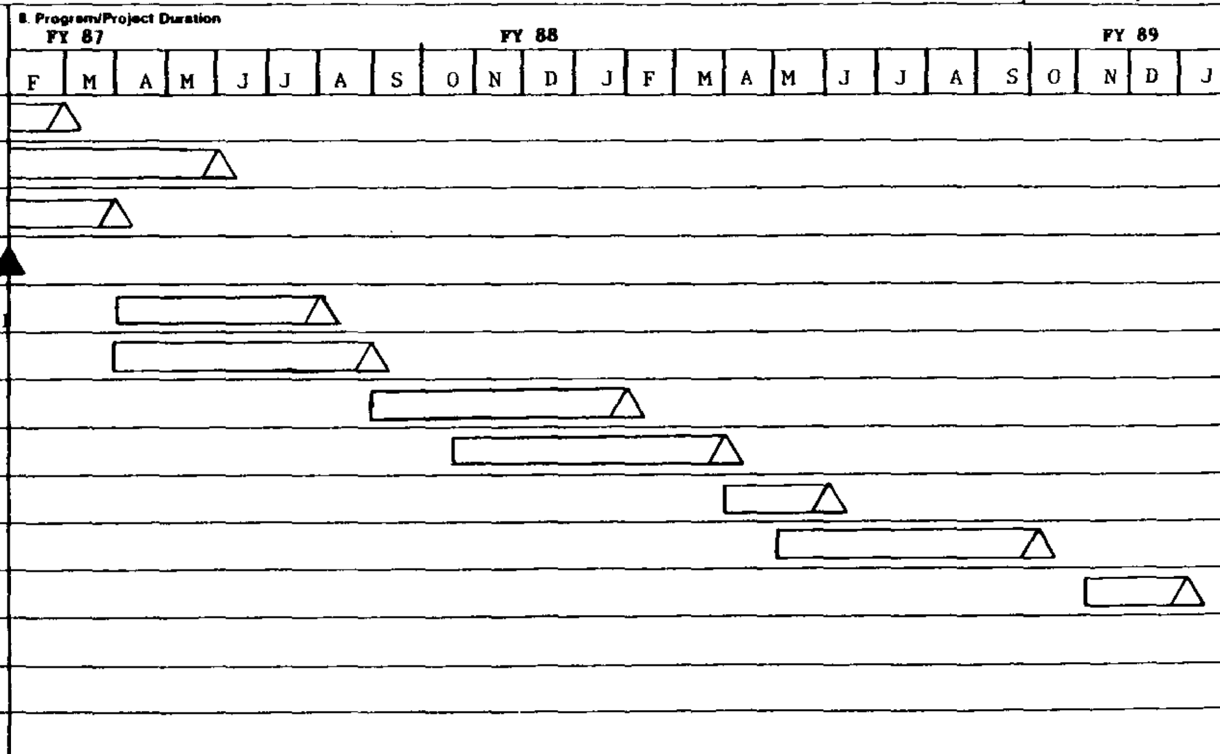
3 Performer (Name, Address):
Coal Tech, Inc.
P.O. Box 154
Merion Station, PA 19066-0154

4 Program/Project Start Date: February 2, 1987

5 Program/Project Completion Date: February 28, 1989

8 Program/Project Duration: FY 87 (F M A M J J A S), FY 88 (O N D J F M A M J J A S), FY 89 (O N D J)

6 Identification Number	7 Planning Category (Work Breakdown Structure Tasks)	9 Comments (Notes, Name of Performer)
1.1.1.1	Environmental Information	
1.1.2.1	Permit Applications & Awards	
1.1.3.1	Project Work Plan	
1.1.4.0	Design	
1.2.1.1	Procurement and Installation of Supporting Systems (Coal Handling, Particulate Removal etc.)	
1.2.2	Shakedown Testing	
1.3.1.1	470 Hour Test	
1.3.1.2	470 Hour Test Analysis	
1.3.1.3	400 Hour Test	
1.3.1.4	400 Hour Test Analysis	
1.3.2	Test Facility Dismantling	
1.3.3	Project Completion	2/28/89



10 Remarks: 1-15-87

11 Signature of Recipient and Date

12 Signature of DOE Reviewing Representative and Date

sulfur Pennsylvania coal. The subsequent 400 – hour test will consist of 300 hours on 2% sulfur coal and 100 hours on 3 – 4% sulfur coal.

6.3 Recoupment 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.