DOE/PC/91162--T13

Project: " DEVELOPMENT & TESTING OF INDUSTRIAL SCALE, COAL FIRED COMBUSTION SYSTEM,PHASE 3"

Contract: DE-AC22-91PC91162

Contract Period of Performance: 9/30/91 to 9/30/95

Fourteenth Quarterly Technical Progress Report

Period Covered by Report: April 1,1995 to June 30,1995

Contractor: Coal Tech Corp.
P.O.Box 154, Merion Station, PA 19066

Principal Investigator: Dr.Bert Zauderer, Phone No.(215)667-0442

Date Submitted: July 7,1995

Prepared for

PETC Project Manager: Andrew Karash

Pittsburgh Energy Technology Center
U.S.Department of Energy
P.O.Box 10940
Pittsburgh,PA 15236

TABLE OF CONTENTS

LIST OF FIGURES

1. SUMMARY

The effort of the second quarter of calendar year 1995 continued the work on task 5, "Site Demonstration", with emphasis on installation of the 20 MMBtu/hr combustor and auxiliary equipment at the Philadelphia test site. The task 5 effort involves testing the combustor over extended periods under conditions that fully simulate commercial operation and that meet the combustion and environmental specifications for this project. To meet this project objective within the current work scope requires 500 hours of testing. Operation beyond this period is dependent on recovering the added costs by placing the steam production from the boiler to beneficial use. During the present quarterly reporting period, most of the major components needed to implement the initial 100 hours of testing under task 5 were installed at the test site. The only major remaining work at the end of this reporting period was the installation of power to the components and the installation of the controls and diagnostics. This work will be performed in the next quarter.

The previous quarterly report for the period ending March 31, 1995, was submitted in mid-April 1995. It contains the progress made to the end of March 1995. The present report is a summary of the activities to the end of June 1995. Details are given in Section 3.

The most important component in the new Philadelphia facility is the air cooled combustor and exit nozzle extension section which is added to the original air cooled combustor. It was delivered to the test site at the end of March. The refractory liner was installed in the original and new combustor sections at the site, and the two sections were installed on the support stand. A number of problems were encountered and corrected due to deviations in the combustor extension sections from the specifications. Due to improper specification by the supplier of the refractory that used for the combustor liner, it was necessary to fill voids formed in the rear of the liner refractory during the casting of the liner. This problem had not occurred in prior applications of the liner refractory with refractory of similar composition. Also, the insulation and high temperature refractory wall in the new transition section between the combustor exit nozzle and the boiler inlet was installed prior to attaching the combustor to the boiler.

A key feature in the new combustor installation is the capability to retract the combustor from the boiler in less than one day in order to perform internal maintenance. In the prior 20 MMBtu/hr combustor installation this required over one week's work. In the prior unit the combustor exit nozzle was an integral part of the boiler inlet and its refractory had to be removed to remove the combustor. Also, all the air and fuel feed pipes and cooling water pipes encompassed the combustor and they had to be removed to move the combustor. In the present installation, the air, water, oil, gas, coal, and sorbent feed pipes are modularized so that they do not interfere with the maintenance of the combustor. The water, oil, and gas modules were completed in the present reporting period, and they will be connected to the combustor in the next quarter.

To meet the Philadelphia particulate emission standard of 0.06 lb/MMBtu a baghouse was installed in a newly paved alley adjacent to the building. The stack ducting from the boiler to the baghouse, and from there to the induced draft fan, and exhaust stack were also installed.

During the installation of the critical combustion and cooling air ducting, a major improvement in the design was invented. This lowered the total power consumption by an additional 50% from about the 130 kW result obtained during the task 5 design effort to about 70 kW. The compares with almost 200 kW used in the Williamsport operation of the 20 MMBtu/hr combustor. The local utility's power rates under the planned operating conditions will be 23 cents/kW-hr, and this represents a substantial power cost saving. It also greatly simplifies the combustor's operation. Of even greater significance, this power reduction will reduce the internal power consumption in a commercial installation to economically attractive levels.

During this quarter, work on changing and simplifying the combustor controls from relay operation to programmable control logic circuits began.

During the present installation period substantial simplifications and improvements in the design of this plant have been made. To continue this effort and meet the project objective of a low capital and operating cost, coal fired plant in the power range of 1 to 20 MW, the installation schedule has been extended somewhat. This allows the incorporation of improvements by the engineering staff with a minimum of redesign. One example of this new approach is the new air ducting installation cited above. The air ducting at the Williamsport test site was installed by a power plant installation contractor using air flow specifications provided by Coal Tech. Despite the fact that the pressure in the air system are very small, the contractor used heavy piping which was costly and required more complex and costly installation. In the present installation, most of this piping has been replaced with light weight material that is compatible with the air flow conditions. This results in substantial material and installation cost savings.

During the next quarter, the power and controls will be installed, the remaining auxiliary component work will be connected to the combustor. Initial shakedown tests will begin early in the following quarter.

Figure 1 is a plot plan of the installation of all the planned equipment at the task 5 test site. As reported previously, the coal processing system will be installed after the initial shakedown tests. Figure 2 is a photograph of the combustor and boiler installation at the test site that was taken in May 1995, right after the combustor was installed on its support stand.

2. PROJECT DESCRIPTION

2.1. Objectives

The primary objective of the present Phase 3 effort is to perform the final testing, at a 20 Mmbtu/hr commercial scale, of an air cooled, slagging coal combustor for application to industrial steam boilers and power plants. The focus of the test effort is on combustor durability, automatic control of the combustor's operation, and optimum environmental control of emissions inside the combustor. In connection with the latter, the goal is to achieve 0.4 lb/ MMBtu of SO_2 emissions, 0.2 lb./MMBtu of NO_x emissions, and 0.02 lb. particulates/MMBtu. Meeting the particulate goal will require the use of a baghouse to augment the nominal slag retention in the combustor. The NOx emission goal will require a modest improvement over maximum reduction achieved to date in the combustor to a level of 0.26 lb./MMBtu. To reach the SO_2 emissions goal may require a combination of sorbent injection inside the combustor and sorbent injection inside the boiler, or stack.

The original plan was to meet the project objectives by a series of increasingly longer duration tests totaling up to 800 hours, with over 500 hours in the task 5 "Site Demonstration" effort. In the implementation of the first three project tasks, it was determined that this objective could met by daily cycling of the combustor in these three tasks, and by focusing the test effort on fuel flexibility and optimized combustion and environmental performance. Cycling without combustor refurbishment between cycles provides a more stringent test of combustor durability. In task 5, the steam output will be blown off. However, the option has been added to use the steam for process heat or steam turbine power generation if a means for generating revenue from this energy is developed during task 5. This last option will only be implemented after the completion of the required testing under the present project.

The final objective is to define suitable commercial power or steam generating systems to which the use of the air cooled combustor offers significant technical and economic benefits. In implementing this objective both simple steam generation and combined gas turbine-steam generation systems will be considered.

2.2. Technical Approach

2.2.1. Overview

The work of this Phase 3 project will be implemented on Coal Tech's patented, 20 MMBtu/hr, air cooled cyclone coal combustor that is installed on an oil designed, package boiler. The task 2 and task 3 testing were performed at a manufacturing plant in Williamsport, PA, where this combustor was installed in 1987. The task 5 tests will be implemented at a new site in Philadelphia, PA which was selected after the completion of the task 3 tests. The combustor has undergone development and demonstration testing since 1987. The primary fuel has been coal. Other tests, including combustion of refuse derived fuels and vitrification of fly ash, have been successfully performed.

The combustor's novel features are air cooling and internal control of SO_2, NO_x, and particulates. Air cooling, which regenerates the heat losses in the combustor, results in a higher efficiency and more compact combustor than similar water cooled combustors. Internal control of pollutants is accomplished by creating a high swirl in the combustor which traps most of the mineral matter injected in the combustor and converts it to a liquid slag that is removed from the floor of the combustor. SO_2 is controlled by injecting calcium oxide based sorbents into the combustor to react with sulfur emitted during combustion. The spent sorbent is dissolved in the slag and removed with it, thereby encapsulating the sulfur in slag. Part of the sorbent exits the combustor with the combustion products into the boiler where it can react with the sulfur. The spent sorbent either deposits in the boiler or it is removed in the stack particle scrubber. NO_x is controlled by staged, fuel rich combustion inside the combustor. Additional reductions are achievable by reburning in the boiler or by ammonia injection if the stack gases. Neither of the latter two procedures has been attempted in this project to date, but they may be required to meet the task 5 operating conditions at the site selected for this effort. Final combustion takes place in the boiler.

Excellent progress had been made prior to the start of the present project in meeting several of these combustor performance objectives. One of the most important objectives of this technology development effort is to demonstrate very high SO_2 reduction in the combustor. Prior to the start of the present Phase 3 project, the peak SO_2 reduction achieved with sorbent injection in the combustor had been 56%, (+/-) 5%. Of this amount a maximum of 11% of the total coal sulfur was trapped in the slag. On the other hand, up to 81% SO_2 reduction has been measured with sorbent injection in the boiler immediately downstream of the combustor. Tests in the past several years have revealed the critical role played by optimum operating conditions in the SO_2 reduction process. Specifically, combustor operation must be automatically controlled, and solids feed and air-solids mixing in the combustor must be optimized. Progress in both areas has been accomplished in the past 5 years by using a microcomputer to control the combustion process and by testing various methods of feeding and mixing the coal and sorbents. In the summer of 1992, tests performed in a prior project indicated that in excess of 90% SO_2 reduction could be achieved by sorbent injection in the combustor. However, to date this result has not been duplicated, in part due to focus on other areas of combustor testing. In general, 70% SO_2 reduction has consistently obtained in tasks 2 and 3 at Ca/S ratios between 3 and 4.

Combustor durability is an essential requirement for commercial utility of the combustor. Due to the aggressive nature of the combustion process and the need to utilize refractory materials inside the combustor to withstand the 3000F gas temperatures, durability has been one of the key challenges in the development process. Here also the use of computer control has been the means whereby this problem is being solved. Since introduction of computer control four years ago, the need for frequent refractory liner patching inside the combustor has been sharply reduced. The durability issue can be addressed by accumulating running time in daily cyclic operation without combustor refurbishment between runs. This approach has been used in the latter task 2 and task 3 effort. All tests between May 1 and December 2, 1993, consisting of 26 hours of operation in task 2 and 185 hours in task 3, have been performed without significant internal combustor refurbishment.

The final project objective of placing the combustor in a viable industrial steam or power generating system was accomplished by detailed engineering analysis on the use of the combustor in one or more steam generating cycles. This effort included an assessment of the requirements for commercializing the combustor for several industrial application. To assure commercialization of this technology, the final project task is being implemented in a system that duplicates a commercial prototype power plant utilizing the air cooled coal combustor technology.

2.2.2. Task Description

Task 1: Design, Fabricate, and Integrate Components

This task consists of components design, component fabrications, and components integration, and shakedown tests. The 20 MMBtu/hr combustor will be modified to allow safe and environmentally compliant operation for periods of up to 100 hours. This task is complete.

Task 2: Preliminary Systems Tests

The modified combustor system will undergo a series of one day parametric tests of total duration of up to 100 hours to validate the design changes introduced in task 1, and to accomplish the project objectives and goals. This task is complete.

Task 3. Proof of Concept Tests

The durability of the combustor will be determined in a series of tests of between 50 and 100 hours of accumulated operation with no combustor refurbishment between tests. The total test period will be up to 200 hours. This task is complete.

Task 4. Economic Evaluation & Commercialization Plan

The economics of one or at most two different industrial scale steam based cycles using the combustor will be evaluated. A commercialization plan will be developed for marketing the combustor in an industrial environment both in the US and overseas. This task is complete.

Task 5. Conduct Site Demonstration

This task will be the final test activity in the project. Its objective will be to demonstrate the durability and hence the commercial readiness of the combustor for its intended industrial application(s). The effort will consist of two sub-tasks. In the first one any changes required as a result of prior tests will be made to the combustor. In the second one, a series of tests, each of up to 100 hours of continuous coal fired operation will be performed, with a total test time of 500 hours. This task is in the installation phase.

Task 6. Decommissioning Test Facility

The test facility will be removed from the boiler installation and disposed in accordance with required regulations.

3. PROJECT STATUS.

3.1. Task 5. Site Demonstration

3.1.1. Installation of Test Equipment

Electric Power Usage: The previous quarterly report contained a discussion on how the power required to operate the combustor was reduced from the 200 kW used in Williamsport to about 130 kW at the new site. This was done by optimizing the operation of the various components used in the facility. Additional power was needed for the coal preparation system. Since the on site utility power circuits are only rated at 130 kW, it had been decided to acquire a diesel generator, and a permit for this purpose had been obtained from the City.

As each step of the installation proceeded in the present quarter, the power requirements were re evaluated. In the final installation design of the air ducting for the combustor cooling and combustion air, a procedure was initially developed in which the largest blower would be only turned on after the combustor reached about 3/4 of full combustor output. This would save about 50% of the operating power during the several hours of heatup and cooldown each day. The reason for this change was that this blower can only operate above 3/4 of rated output. On further evaluation of this matter, including a re-examination of all the Williamsport test data related to combustor thermal performance, it was determined that it might be possible to completely eliminate this blower by modifying the combustor cooling procedure. As a result, it is now planned to operate the combustor without the large blower. This lowers the power requirement to about 70 kW without coal processing and about 100 kW with coal pulverization. This is almost a factor of three power reduction from the mode of operation used in Williamsport. As a result, it is unlikely that a diesel generator will be acquired.

Boiler Installation: As previously reported, the boiler will be operated in a steam blowoff mode for the task 5 tests, and at a pressure of 15 psig. During the past quarter, the two refurbished 6 inch boiler valves, and the two boiler safety valves, and the appropriate piping for steam blowoff and safety blowoff, and the water inlet pipe, were installed on the boiler. Also, the boiler blowdown valves were refurbished. The only remaining work is to pipe the boiler blowdown, the soot blower, and to wire the boiler controls..

Water System: Most of the work on piping of the cooling water circuits was completed. The remaining work is to refurbish and connect the slag tank cooling circuits to the combustor.

Combustor Extension and Exit Nozzle: The combustor extension section was delivered to the site at the end of March. A number of fabricating defects were noted and those that would interfere with the operation of the combustor were corrected.

Combustor Refractory Liner Installation: The refractory liner in both the original and extension sections of the combustor was installed at the site. The refractory originally selected for this purpose was not available on a timely basis, and an alternate material with identical thermal chemical,. and mechanical properties was selected. The manufacturer's technical staff assured us that this material similar casting characteristics as the original material.

In preparation for the casting, a series of thermocouples were installed in both combustor sections. Insulating material was installed between the combustor cooling tubes and the outer combustor shell. On removing the outer covering of the liner substantial voids were discovered in the refractory between the tubes. This had not occurred in the previous castings of the refractory liner. On contacting the manufacturer on this matter, their in house staff disclaimed all responsibility for this problem which was due to the size distribution of the material and to its flow properties. To correct this problem, we removed the insulating material from the rear of the liner in both combustor sections. This also necessitated removing the thermocouples, some of which had to be replaced. The voids were them filled by hand with a castable cement.

Combustor-Boiler Interface Refractory Installation: A refractory assembly was installed in the boiler front section that interfaces between the combustor and the boiler. This section is a totally new design that is based on the years of testing various approaches in Williamsport. The purpose of this design is to allow removal of ash and slag flowing from the combustor outlet to the boiler without shutdown of the combustor and waiting several days for cooling of the boiler. To accomplish this a number of features were incorporated in the design. As part of the installation it was necessary to remove sections of the original boiler refractory brick work. During the installation several design changes were made. The divergence angle of the inner refractory liner was changed. Also, the inlet section of the combustor to the boiler was redesigned in such a manner as to allow rapid, within one day, removal of the combustor from the boiler. In Williamsport , combustor removal required almost complete removal of the combustor-boiler interface ceramic. This work is now almost complete. The only remaining items are the installation of a small portable section of combustor-boiler interface, which requires a few days of work.

Combustor Installation: After completion of the installation of the insulating ceramics in the boiler and the liner, the two combustor sections were installed on the combustor support stands. Since the combustor is placed on a stand that is 6 feet above the floor, a preliminary check assembly was conducted on the floor. The check assembly revealed that there was a slight misalignment in the two combustor section bolt circle, which was readily corrected. The two sections fitted perfectly, as had been previously verified before the refractory installation. The refractory liner sections matched within 1/4" in the axial direction. The combustor sections were then disconnected and each one was hoisted onto the 6 foot high stand and moved into position in front of the boiler. The combustor was then aligned with the boiler. The alignment procedure showed that the originally planned method for connecting the combustor to the boiler wall would not allow ready retraction of the combustor for servicing. A modified method for this attachment was designed which eliminates the connection problem.

The combustor was then retracted for installation of the boiler refractory, after which is was bolted to the boiler. The latter effort required less than 1 day. Figure 2 is photograph of the combustor installed on its support stand in front of the boiler. It was taken in May right after the combustor was placed on its support stand.

Baghouse: All the stack gas ducting including the induced draft fan have been installed and connected to the boiler and baghouse. The fan used in Williamsport for the wet particle scrubber was refurbished by replacing the corroded inlet section, and the fan wheel. While the original wheel appeared to be serviceable, it has several corrosion holes at its outer diameter and the wheel was replaced as a safety measure. Since the fan is belt driven, a simple change of the pulley system to the motor allowed modification of the fan for the anticipated conditions of the baghouse operation.

Controls: Work began on converting the manual relay controls to programmable logic controllers. The remaining reinstallation of the controls will begin in the next quarter.

Coal Processing System: A modified coal processing system consisting of a 16 ton raw coal storage bin, a raw coal conveyor, a refurbished coal mill, a small baghouse, and mill air ducting will be installed during the initial 100 hour test. This installation will cost about 1/3 of the one designed last year and it will meet the requirements for the added 400 hours of operation.

Figure 1 shows a plan view of the entire facility installation, including the coal processing system.

4. Effort of the Next Quarter

The installation of the balance of the equipment necessary for the first 100 hours of operation will take place in the next quarter. This involves a schedule slippage of several months. The reason for this is due in part to the need to optimize the available resources. However, the primary reason is that a key project objective is to develop a low capital cost power system. Therefore, as new lower cost options are uncovered in the installation task they are being introduced, even if it requires removal of some components used in Williamsport or planned in the task 5 design phase. Examples include the drastic reduction in power requirements, the simplification of the air ducting, coal and sorbent feed, the installation of the combustor in a manner that allows its rapid removal. As a result of this work, we conclude that the present combustor boiler technology will be a low cost solid fuel fired system that will compete on capital cost with clean fuel power systems.

The remaining work consists of installing the power lines to the major components, reinstalling the controls and diagnostic wiring, installing a small oil tank, and completion of the various piping connections. It is estimated that as of the end of June over 90% of the equipment has been installed and about 70% of the connection work has been completed.

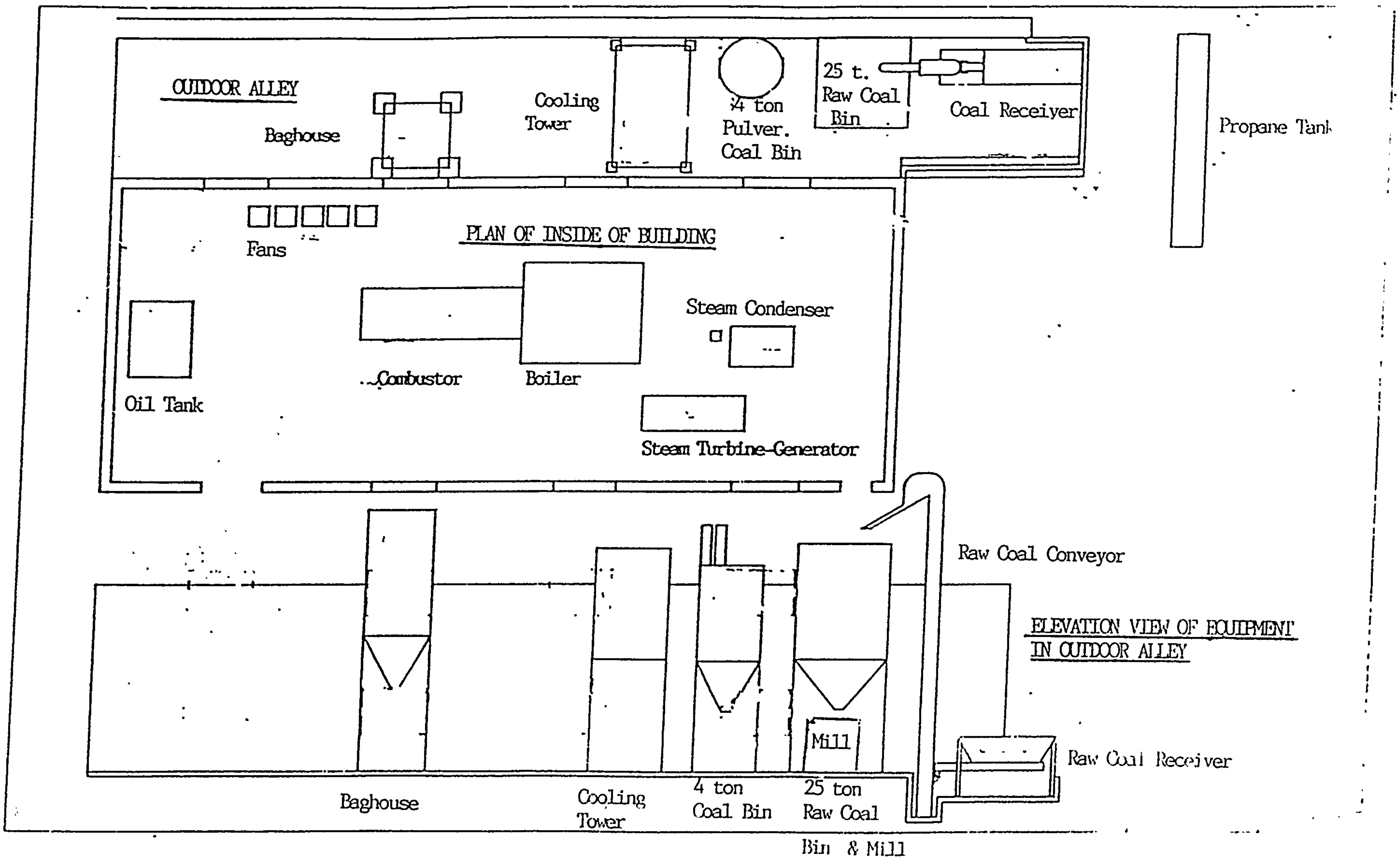

Figure 1: Plot Plan of the 20 MMBtu/hr Combustor-Boiler Task 5 Test Site in Philadelphia.

Figure 2: Photograph of the 20 MMBtu/hr Main Combustor Section Installed on its Support Stand in Front of the Boiler (at Rear Right)