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## 1. SUMMARY

In the fourth quarter of calendar year 1995 the installation and checkout of the 20 MMBtu/hr combustor and auxiliary equipment in Philadelphia was completed. The task 5, "Site Demonstration Testing", combustor-boiler tests on gas, oil, and coal were initiated.

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 up to 500 hours of testing. The focus of this testing will be on the component and environmental performance of combustor, boiler, coal preparation and feeding, and the stack gas equipment. The facility can be converted to a 500 kW power plant by the addition of a steam turbine, condenser, and cooling tower. However, this added effort is beyond the current work scope and its implementation will depend on recovering the added costs by placing the steam production from the boiler to beneficial use.

During the present quarterly reporting period, all the components needed to implement the initial 100 hours of testing under task 5 were installed at the test site, and checkout of this equipment was performed. Since the present installation contained substantial improvements and simplifications to all sub-systems that had been used in the Williamsport facility, each component and sub-system had to be tested individually. The checkout tests involved the following sub-systems:

- a- The combustor's combustion control system which was converted from electric relay control to programmable logic circuit control (PLC).
- b- The power system for combustion air fans, air compressors, air blowers, water and oil pumps. The power consumption was reduced by about two-thirds from the level used in Williamsport.
- c- The main combustor's pilot gas burner and slag tap burners, which was converted from gas to propane.
- d- The stack gas particle cleanup system, which was converted from a wet particle scrubber to a baghouse.
- e- The pulverized coal and sorbent feed streams to the combustor which was converted from compressed air drive to low pressure blower drive.
- f- The boiler which was converted from plant heating involving water recirculation to once through water flow.
- g- The refurbishment and installation of a novel, low cost coal pulverizer for in house coal preparation versus off site pulverization in Williamsport.
- h- The installation of a non-contact water cooling system versus the once through water cooling system used in Williamsport.

In the course of the installation and checkout tests, it was determined that several sub-systems, such as the slag tap gas burners had been improperly installed and operated in Williamsport. This was corrected. Also, it was determined that substantial cost savings could be effected by introducing improvements in several commercially available components, such as the coal feed pneumatic blowers, the combustion air fans, and the baghouse.

The project plan for this task 5 installation and checkout test effort was based on using the same key personnel that had been involved in the installation, operation, and maintenance of the combustion-boiler system controls in the 20 MMBtu/hr combustor-boiler facility in Williamsport. However, due to scheduling conflicts, these individuals were not available for most of this effort in the fourth quarter of 1995. As a result, this work was performed by Coal Tech's in-house staff with the assistance the technical support staff of the manufacturers of this equipment. This turned out to be quite beneficial in that a number a defects in the Williamsport installation, such as the slag tap burner controls, were uncovered and corrected. Of even greater importance is that this process thoroughly familiarized the in-house staff with all aspects of the operation and maintenance of the facility. As a result, the initial shakedown tests, which included 6 days of combustor-boiler operation in a four week period at the end of this quarter, were performed with only 2 to 3 test engineers. This is one half of the staffing used in Williamsport.

The following highlights some of the accomplishment of the present reporting period. Details are given in Section 3.

Several sections of the combustor and the slag collection tank are water cooled. In the present system, water cooling is being implemented through a heat exchanger. This greatly reduces water consumption and improves flexibility in directing water flow to sections that require more cooling. It also, eliminates the discharge of process water in the slag tank to the drain. The closed cooling system is more complex that the once through system used in Williamsport. Checkout tests were performed without and with combustion. They showed that the present system is much more effective in maintaining the water cooled sections within the desired temperature range.

A major reduction in cooling air fan capacity was implemented in the present design. Consequently, considerable attention was devoted to controlling and measuring the air flows. Each differential pressure flow gage was calibrated with a manometer. One problem was identifying minor air leaks in the measuring tube circuits. This led to the decision to separate the control function from the measuring function in these circuits, as had been used previously.

In Williamsport, compressed air was used for all pneumatic solid powder transport and control functions. This required a large air compressor. In the present installation, pneumatic transport of coal and sorbents is being implemented with a high pressure blower. This reduces the compressed air requirement by a factor of about four. A positive displacement was purchased and installed with silencers and motor on an in-house fabricated stand. A series of checkout tests were performed to obtain the proper air flows for coal and sorbent feed to the combustor.

Low temperature bags were purchased for the baghouse, which are low in cost. This requires cooling of the stack gases upstream of the baghouse. A novel stack gas cooling system was installed. Combustion tests in December showed it to be very effective in maintaining the stack gas temperature at the inlet to the baghouse at a level compatible with the peak gas temperature capacity of the bags.

Gas heaters are used to maintain the slag tap in the proper temperature for slag tap removal. These burners were subject to considerable operational problems in Williamsport. This had important consequences in that major reliance had to be placed on the development of a mechanical breaker to keep the slag tap open. As a result considerable attention was devoted to assuring that the proper operation of these heaters. This installation and test work was performed by Coal Tech. In a series of tests over a period of several weeks, the control wiring was corrected and defective components in the flame safety system were replaced. By early December, all the problems had been resolved, and reliable and repetitive ignition and combustion was obtained using propane gas with full control by the flame safety system. As a result less reliance need be placed on the mechanical slag breaker.

By the end of November, the combustor was ready for combustion testing. A total of six days of testing was performed. The first test was performed at the end of November. Its objective was to check the ignition and combustion of the main propane pilot burner which is used to ignite the oil burner. As noted, all combustion controls were converted from relay control to PLC control. In Williamsport, multiple UV and IR flame detectors were installed. However, their placement was changed in the present installation to eliminate blinding by the injected coal. Unlike in Williamsport, where ignition proved to be a major problem, ignition was readily achieved, and once the proper air fuel combinations were adjusted, gas combustion was maintained. The present system operates on propane versus natural gas in Williamsport.

The second test, on December 5th, was performed to check out additional combustor components and the stack gas cooling circuit. The total heat input was 2 MMBtu/hr. No water was placed in the boiler so the test had to be terminated after several hours. The stack gas cooling was very effective. The tests revealed that several combustion gas leaks in the combustor has to be sealed, and that the water cooling circuit required several piping adjustment.

The next test was performed on the 7th with water in the boiler, but with only manual boiler feedwater control. This was the first test in which oil firing was added, and total heat input reached over 4 MMBtu/hr. This test revealed the need to utilize the induced draft stack fan in order to prevent combustion gas leakage from combustor and boiler into the room. However, the stack damper control for this ID fan was found to be non-operational. Also several other minor modifications were indicated.

The next test was on December 11, and for this test the automatic boiler feedwater refill was utilized. Combustion was maintained over a 5 hour period and the heat input on propane and oil was increased from 2 to 7.25 MMBtu/hr. The feedwater control did not function properly, due to incorrect connection of the water level sensing probes. Also, the post test cooling water circuit had to be re-connected to allow post test water cooling at low water flows. Again the stack damper system did not function properly. On the other hand the combustion system functioned properly with no problems.

Before the next test, the boiler feedwater control circuits and feedwater valves were properly reconnected. Further corrections were made to the post test water cooling circuit, and the stack damper control circuit was modified and it appeared to function properly.

## 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<sub>2</sub> emissions, 0.2 lb/MMBtu of NO<sub>x</sub> emissions, and 0.02 lb. particulates/MMBtu. To meet the particulate goal a baghouse will be used to augment the slag retention in the combustor. The NO<sub>x</sub> 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<sub>2</sub> 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  $\text{SO}_2$ ,  $\text{NO}_x$ , 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.  $\text{SO}_2$  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.  $\text{NO}_x$  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  $\text{SO}_2$  reduction in the combustor. Prior to the start of the present Phase 3 project, the peak  $\text{SO}_2$  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%  $\text{SO}_2$  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  $\text{SO}_2$  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%  $\text{SO}_2$  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%  $\text{SO}_2$  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

### 3. PROJECT STATUS.

#### 3.1. Task 5. Site Demonstration

The installation of the combustor-boiler facility has been divided into two phases. The first phase, which consists of preparing the facility to operate with off site pulverized coal, was completed in the present quarter. The second phase includes the installation of the raw coal storage and pulverization system. The focal point of this effort is a novel, low cost coal mill, whose refurbishment was nearing completion in the present quarter.

The phase 1 effort is further divided into two stages. In the first stage, the combustor will be operated by manual control in order to develop the input parameters to program the computer control of the combustor. In the second stage of phase 1, computer control of the combustor will be used. The reason for delaying the Phase 2 effort with on site coal pulverization is dictated by resources. The original project plan for task 5 did not incorporate on site pulverization. The primary motivation for incorporating on site pulverization was to develop a low cost pulverization system that would produce a coal size that was coarser than pulverizer coal of 70% through 200 mesh as is produced by costly ball mills. The present mill is a low cost mineral product mill that produces a product that is somewhat coarser than the ball mill product and that is much lower in cost. Therefore, the focus to date had been on refurbishing a mill that has been loaned to Coal Tech and validate its capability to produce an acceptable product. If validated, then a simple raw coal storage system with at most 12 tons capacity and the appropriate hot combustion gas ducting will be installed to allow on site pulverization. However, as this is a secondary objective versus the combustor-boiler, this effort will be implemented only after the combustor has been fully tested with off site pulverized coal.

The initial part of the present quarterly reporting period was devoted to completion of the installation of the combustor and boiler controls. It had been planned to use the sub-contractor personnel that had installed and maintained this equipment in Williamsport for this task. However, they were unavailable and the work was performed by Coal Tech. This turned out to be beneficial, as a number of deficiencies in the slag tap burner control system used in Williamsport were uncovered and corrected. Also, the in-house work familiarized Coal Tech personnel with the maintenance and operation of the combustion and boiler controls. This enabled test operations to proceed with about one-half of the staffing plan, which was based on the staff levels used in Williamsport.

The second half of the present quarter was devoted to checkout of the various sub-systems, culminating in the performance of 6 one day combustion tests in a four week period in November-December. Propane gas and oil were used in these tests. Heat input was increased gradually to 10 MMBtu/hr, or one-half of the rated input of the combustor and boiler. In the last test, coal fired operation was briefly implemented.

In the following sub-sections, the progress made in the past quarter will be summarized, while noting some of the improvements that have been made. The discussion will be in general

terms because several aspects involve potentially proprietary and patentable designs and procedures.

### 3.1.1. Installation of Test Equipment

#### Auxiliary Components:...

Boiler: The installation of the boiler feedwater controls, pneumatically controlled feedwater valves, and the fabrication and installation of the boiler blowdown tank completed the boiler installation. During the combustion tests in December it was determined that the feedwater valves were connected in the fail open instead of the fail closed mode, and the boiler feedwater level control sensors were not wired correctly. These items were corrected and the boiler, which operates in the once through blowoff mode, functioned properly.

Power: The connection of the starter switches to the various fans and blowers were completed and tested early in the present quarter. Also, the motors that operate the reconditioned coal mill were installed and wired to the power system. Finally, the positive displacement blower use for pneumatic feeding of the coal and sorbents was installed and wired. This completed the power connections the entire system. All these items were connected to previously used switches and motor starters.

Controls: The controls, needed for operation of the combustor with the manual control used in the initial shakedown tests, were wired. This included the PLC unit which replaces all the previously used relay controls. The PLC was programmed. The computer control software will be programmed after the initial combustor tests.

Compressed Air & High Pressure Blower: A low cost pressure blower was purchased for pneumatically conveying the pulverized coal and sorbents. (Previously, compressed air was used for this purpose.) A motor previously used for boiler air supply was connected to this blower. The support stand and drive train were designed and installed by Coal Tech, at a total cost of about 50% of the cost of purchasing a complete blower package. motor.

The blower was tested with the pneumatic coal and sorbent feed system. It was determined that the reason a high pressure compressor was required in Williamsport for this coal feed was due to the use of an incorrectly designed motive air nozzle as delivered by the supplier. With the use of a proper nozzle and the proper pressure, the power consumption for the pneumatic coal and sorbent transport was reduced by almost a factor of three. Tests were performed toward optimizing this system, and it has been used in all the December combustor tests for cooling the coal injection ports and for the initial coal fired test.

Cooling Water System: This combustor's water cooling system was initially tested under cold flow conditions and a number of piping connection errors were corrected. The system water flow and pressure conditions were as predicted in the task 5 design analysis. The major effort in the checkout was eliminating trapped air and priming the circulating pump. Unlike the previously used once through cooling system, the present system uses a closed cooling loop and a water-

water heat exchanger. Once the piping arrangement was corrected, the pumped water flow rate was as computed. These test results suggest that trapped air may have been a contributing factor in the difficulties with internal combustor water leaks that were experienced with the water cooled sections in the Williamsport facility. The present system, with the water to water heat exchanger to cool several combustor sections is much superior in that it allows better control of water flow.

The propane and oil fired combustion tests conducted in December revealed that additional fine tuning of the cooling water system was necessary. Specifically, provision was needed for maintaining a low level of cooling water flow after combustor shutdown until the combustor cools down. Preliminary analysis of the cooling water data with combustion up to 10 MMBtu/hr heat input was found to be at or below the range anticipated from prior data obtained in Williamsport.

Coal Mill: A novel, low first cost, used coal mill is being refurbished under the direction of an engineer that was involved in its original development. Since off site pulverized coal will be used in the initial tests, work on the mill has proceeded slowly. As of the date of this report, the mill is almost ready for final reassembly and checkout with a small load of raw coal and limestone. This test will be performed early in the next quarter.

Combustor Cooling Air & Combustion Air: The primary combustor cooling and combustion air fan was tested with the various air flow control valves. With the exception of one new valve, all other pneumatically controlled valves were reassembled from the previous installation. With the current emphasis on reducing in-plant power consumption, special attention was placed on reducing compressed air consumption by the various valve controllers. One valve's pneumatic cylinder was found to have been damaged in transit from Williamsport, and it was repaired. The air consumption of the valve controllers was found to be higher than specified by the manufacturers. However, as this is a small fraction of the total compressed air consumption, no effort is planned at this time to further reduce this air loss.

The fan performance curve showed a discrepancy between fan power input and air flow, as measured by differential pressure gauges previously used in Williamsport. After recalibrating the gauges with a manometer it was determined that minor leaks in the tubing connecting the pitot tubes to the gauges affected the accuracy of the results. As a result, the measurement function in these circuits will be separated from the control function, both of which have been on the same circuits in Williamsport. Note that errors in the flow measurement affect the computation of the stoichiometry in the combustor. This in turn affects combustion efficiency and NO<sub>x</sub> and SO<sub>2</sub> control. After the initial series of coal fired combustion tests, it is planned to review some of the Williamsport test data to determine the existence of errors in the air flow measurement in those tests.

The large combustion air fan is installed inside the test building. As this fan was very noisy (>80 dB), the fan ducting was changed to reduce the noise. In addition, foam sound insulation was added. Measurement with a sound meter showed levels in the 75 dB range several feet outside the fan insulation housing, which is acceptable under OSHA standards.

Slag Removal Combustion System: Gas burners are used to heat the tap used to remove slag from the combustor. This system was relocated from Williamsport, and converted from natural gas to propane. On reinstalling the controls for this system by Coal Tech, it was discovered that in the course of using this system in Williamsport major operational changes were implemented which over time resulted in removal of many of the safety systems. One result of these changes was a reduction in the thermal input to the slag removal section as the combustor's thermal input increased. This is the exact opposite of the desired mode of operation. Furthermore, the air/fuel mixtures were not properly adjusted. This may explain the poor results obtained with these burners in Williamsport. As a result of this discovery, substantial effort was devoted on properly installing this system. All the flame safety components were replaced, the placement of the burners was changed from that used in Williamsport. The burner controls were installed to maintain constant thermal input at variable main combustor thermal input. The air/fuel mixture was optimized to achieve a constant thermal input. The system was then tested dozens of times and ignition was reliably achieved and combustion was maintained. With the present configuration and reliability, safer operation will be achieved, and it will most probably sharply reduce the need for mechanical slag removal procedures.

Main Gas Pilot Combustion System: As noted above, the entire combustion system has been converted from electric relay to PLC control. The motivation for this change was to reduce the problems encountered in Williamsport in the ignition and maintenance of the gas combustion system. Initial checkout of the flame safety system revealed that one of the two UV flame detectors was inoperative. This was found to be due to a stuck shutter and it was repaired.

While the UV detectors are used primarily for oil and gas, an IR detector is used for coal firing. A computer checkout of the flame signals to the PLC's revealed that the IR detector control board was defective in that it transmitted a flame-on signal irrespective of the flame input. It is not known when this defect appeared as the present control system which is designed to detect this problem was not used in Williamsport. We note that combustor shutdowns due to deficient flame detection was a problem area in tests conducted in Williamsport.

Following these preliminary checks, propane gas combustion was initiated in the last week of November. Ignition was achieved every time, and after relocating one of the UV flame detectors, combustion was maintained and the air-fuel mixture was optimized. This is a very important milestone in task 5 because pilot gas ignition and maintenance was a continuing problem in the Williamsport combustor. Unlike the relay control system used previously, the PLC system is very much easier to troubleshoot, and it is much more reliable.

#### 3.1.2. Combustor-Boiler Shakedown Tests:

Following the above combustion checkout tests in the slag tap gas heaters and on the gas pilot ignition, the first main combustor tests were initiated at the end of November, 1995. A total of 6 days of combustor tests were performed.

The first test (noted in the second previous paragraph) of the main combustion system was to check the ignition and operation of the propane fuel burner. This test was performed at the end

of November, and after relocation of one of the two UV flame detectors repetitive operation of the main gas burners was achieved. The total thermal input was 1.5 MMBtu/hr. Since the combustion air is greatly increased after gas ignition, it was necessary to increase the gas input to 2 MMBtu/hr to prevent flameout. However, after oil ignition is obtained, this heat input can be reduced.

The second main combustor test was on December 5, and it focused on the oil burner operation. The newly purchased motor driven, oil pump did not function properly, and after consultation with the supplier, it was determined that the supplier had improperly installed the motor cooling fan so that it scraped against the motor housing. Also, the motor was incorrectly wired resulting in reverse pump rotation. After correcting this, the oil burner was fired at several MMBtu/hr.

The next test was on December 7, and various levels of air atomization of the burner were tested to determine from visual flame observation the optimum condition. The test revealed that the low air pressure, that was used in Williamsport, yielded good atomization. Oil firing continued for five hours with the total heat input ramped up to 6.7 MMBtu/hr using oil and propane. Since the feedwater automatic control was not yet installed, the boiler feedwater was controlled manually. It was noted that positive combustion pressure of several inches water gage in the boiler resulted in water vapor and gas leakage from the combustor and boiler. This leakage was eliminated by operating the induced draft (ID) stack gas fan to produce a slightly negative pressure in the boiler.

In view of the need to use the ID stack fan to maintain a negative draft in the boiler, it was necessary to control the stack damper as the thermal input increased. In Williamsport, several attempts to obtain reliable stack damper operation were unsuccessful, and the ID fan was only turned on at high thermal input where the damper was wide open. This procedure was possible since the original natural draft stack had sufficient capacity to maintain a negative draft in the boiler at part load. This option is not available in the present system, and this means that the ID fan must be used at low thermal input. This in turn requires control of the stack damper. The electro-pneumatic stack damper control was first tested in the December tests.

The next combustor test was on December 19. Its main objectives were: to increase the thermal input to 10 MMBtu/hr, to check the automatic boiler feedwater controls, and to check the operation of the stack damper. A combined gas and oil thermal input of over 9 MMBtu/hr was achieved after 3 hours of operation. No problems were noted with the combustion system or the boiler feedwater control. However, the stack damper control tended to stick which made fine tuning of the damper impossible. As a result, flameouts occurred as the damper mechanism moved in irregular fashion. It was decided for the next test to perform this function manually by observing the draft in the boiler. For future tests, an improved damper control will be installed.

Another important result of these tests was in the control of the stack gas temperature. In order to sharply reduce the cost of the stack gas baghouse, low temperature bags were purchased. This required lowering the stack gas temperature upstream of the baghouse. A novel stack gas cooling system was used for this purpose, and it yielded effective control of the stack gas temperature.

The final test in this series took place on December 20. This was the first test with coal firing. The thermal input to the combustor was gradually increased over a period of nearly 5 hours to almost 10 MMBtu/hr with gas and oil. One of the bins was loaded with 1/3 ton of off site, pulverized, 0.7% sulfur, coal. After clearing the screw feeder of ice in the discharge tube, coal firing was initiated. After a short period, the flame detectors shutdown the combustor. At the same time, a leak developed in the discharge hose of the combustor cooling water circuit, and it was necessary to stop the test.

The exact cause of the flameout has not been determined. However, it is almost certain that it resulted from blinding of the fireeye flame detectors by injected coal powder. This problem occurred very frequently in Williamsport, and it was corrected by sighting one of the three detectors outside the coal injection area. The present combustor has a redesigned field of view for the detectors, and it was anticipated that this would solve the problem. In the next tests, the flame detector placement will varied to resolve this matter.

The water leak was a result of improper placement of the water pump, which caused excessive tension in a hose. This test also revealed that some modification to the water cooling circuit was necessary to allow use of a low water cooling flow rate for combustor cooling after shutdown. Due to the high cost of cooling water, a design change is being made to sharply reduce water consumption after shutdown.

In conclusion, six days of testing on the combustion-boiler system have been implemented in a period spanning under 4 weeks. Five of these tests took place in a two week period. In addition many brief tests were made of sub-systems such as the slag tap burners, and the boiler feedwater controls. This was accomplished with one half the staffing level used in Williamsport. Also, in the Williamsport facility, an average only one to two test days were implemented in a one month period. The redesigned facility and the daily hands-on supervision of the combustor facility installation by key Coal Tech personnel has greatly simplified the operation of the facility. This allows more rapid turnaround between tests.

#### **4. Effort of the Next Quarter**

The task 5 demonstration test effort will continue in the next quarter. As reported previously, initially off site pulverized coal will be used as was the case in Williamsport. There will be a major change in the approach to the test effort from that used in Williamsport. Since the technical staff was located at one-half day's travel from the test site, the test plan in Williamsport focused on one to two days of testing, followed by maintenance and modifications by several on site technicians and a local maintenance contractor. This approach allowed only general modification instructions to the on site staff. As a result many minor, but important, opportunities for improvements were overlooked. Furthermore, due to the limited test days, considerable pressure developed to complete a full day of operation. This resulted in the course of time in temporary fixes, such as the above noted removal of some safety features from the slag tap heaters, which tended to become permanent with time. On the other hand, in the present task 5 facility in Philadelphia, the daily involvement of the key technical staff with the installation and operation of the facility has resulted in the inclusion of numerous incremental improvements in all sub-systems

of the facility. Furthermore, the familiarity of the technical staff with all aspects of the facility has sharply reduced dependence of outside sub-contract personnel in the operation and maintenance of the facility. This not only results in more test time, but it also sharply reduces the personnel cost in operating the facility. This has already been demonstrated by the implementation of 6 days of testing in a one month period. In the next quarter, this approach of attention to detail and incremental testing will be continued. It is anticipated that within the next two quarters, the main performance aspects of this second generation air cooled, slagging combustor-boiler facility will have been fully characterized.

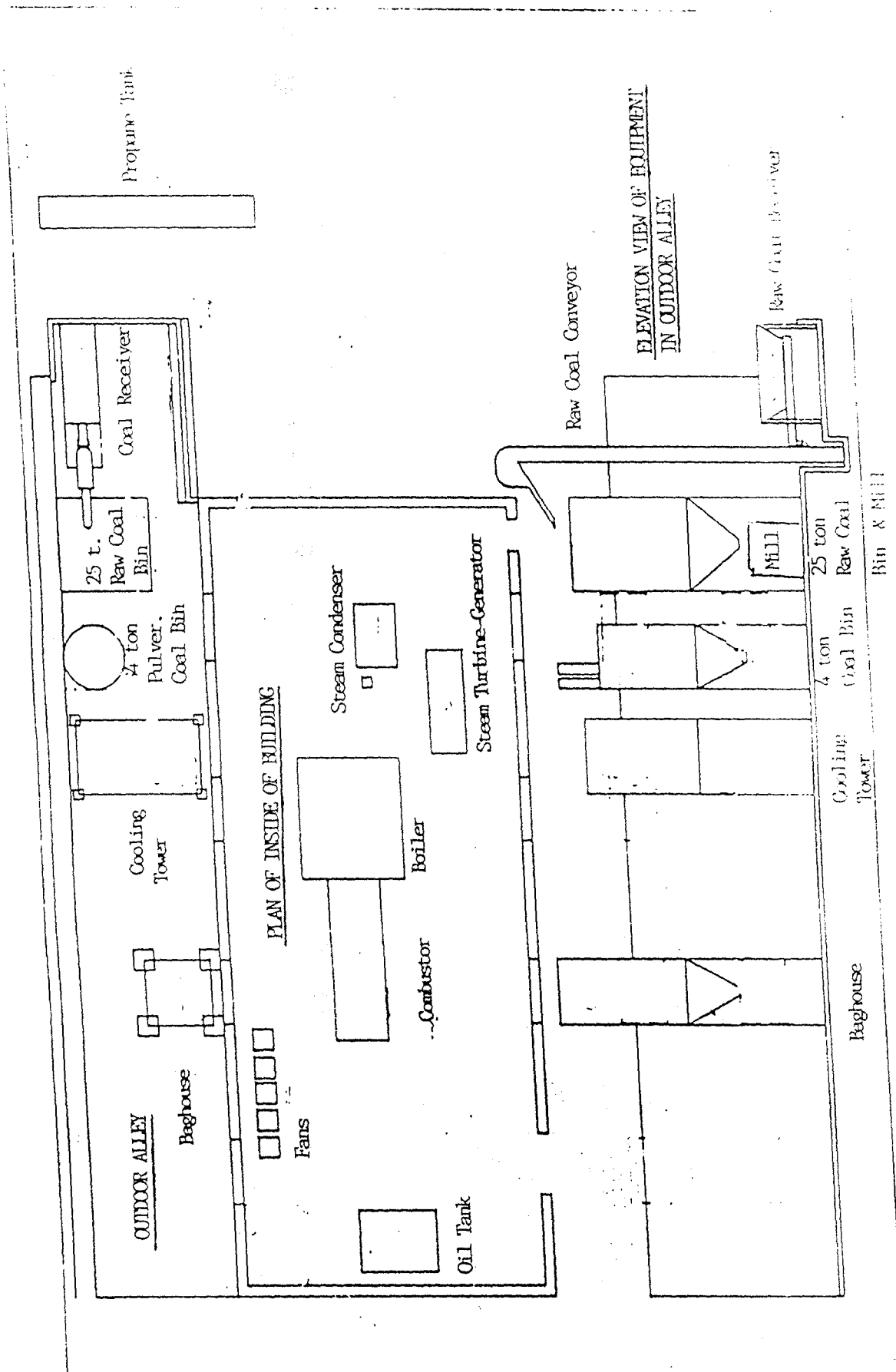


Figure 1: Plot Plan of the 20 MM Btu/hr Combustor-Boiler  
Task 5 Test Site in Philadelphia.

Figure 2: Recent Photographs of the 20 MMBtu/hr Combustor-Boiler Installation

