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1. SUMMARY

The effort of the third quarter of calendar year 1994 focused on the task 5, "Site Demonstration". The purpose of the task 5 effort is to operate the combustor over extended periods in order fully simulate commercial operation under conditions that meet the combustion and environmental specifications for this project. To accomplish this, it is planned to extend the test duration beyond the scheduled 500 hours and recover part of the added costs by placing the steam production from the boiler to beneficial use. During the present third quarter reporting period, substantial progress was made in the task 5 effort in the areas of site selection, permitting, overall system design, fuel handling design, combustor fabrication, boiler acquisition and modification, and steam turbine generator selection. Note that task 5 duplicates on a small scale, the effort required to design, fabricate, and install a complete commercial scale power plant based on the air cooled, slagging combustor technology. Therefore, the experience gained in Task 5 will enhance the probability of successful commercialization of this technology. The following is a summary of the third quarter activities. This is described in more detail in Section 3 of this Report.

As reported previously, the original task 5 site requirements were as follows: Internal space in a separate building having at least 2500 sq.ft for the combustor boiler, external space of 2000 sq.ft for fuel storage and processing, blowers, and stack cleanup equipment, 250 kW power supply, and spring or river water for cooling and steam condensation. In addition, the site should have a requirement for at least 17,500 lb./hr of process or heating steam, and/or up to 300 kW of electric power. The revenue from this energy sale would be used to extend the combustor operating time beyond that in the original project plan of 500 hours.

In May 1994, a site that met all the Task 5 requirements was found in an industrial park in Philadelphia. It consisted of a one story 3000 sq.ft. building suitable for placement of the combustor-boiler and steam turbine without additional construction. An adjacent, walled in 15 ft. wide x 90 ft. long alley was suitable for the fuel storage and processing and stack gas control equipment. The building is within 200 feet of a tidal creek that drains into the Delaware river building. In addition, a water source was located about 100 feet away in an adjacent building. It had an apparent capacity of over 300 gpm which was assumed to be adequate for once through cooling of the steam and water cooled combustor sections. The building has 130 kW installed power with access to an additional 1000 kW in a sub-station 100 feet from the building. In July, a three year lease was negotiated and executed with an effective date of August 1, 1994.

This site in Philadelphia has more stringent regulatory and environmental requirements compared to the outlying suburbs. They include zoning, special permits for installation activities, and more stringent water and air emission regulations. Considerable effort was expended on this items in the past quarter, and to date no undue difficulties have been encountered. In general, once requirements were fully identified, alternate solutions were found that greatly simplified the permitting process.

A zoning permit for the proposed activities at the site was obtained in July. The site is in a flood plain, and a design was developed for installing a No.2 oil tank that meets the City’s flood plain regulations. Note that the oil is used for combustor startup and shutdown. Permit
requirements for water discharge to the municipal sanitary system or the river were identified and chemical tests of the proposed water source were performed. As a result of this effort, it was determined that the 300 gpm water source had only less than half this capacity and it was unsuitable for once through cooling. In its place, a novel low cost, cooling tower design was developed. This cooling tower eliminates the need for locating the planned commercial power plants in the 1 to 20 MW range near bodies of water. This greatly simplifies site selection, which enhances the commercial potential of this technology. This cooling approach is consistent with the global objective for this technology of minimizing its water usage and waste water discharge.

Another new design criteria was dictated by the high utility power costs. As a result, it was decided to add a diesel generator to the installation. Its used would cut power costs by over 50%, even after including the acquisition costs of the diesel. A steam turbine, rated at 600 kW and matched to the steam output of the boiler was located. Plans for its detailed inspection were formulated to determine if total acquisition cost. Analysis of its performance showed that it could produce between 400 and 500 kW with the present boiler system.

The 17,500 lb/hr boiler used in Williamsport for the past 7 years was purchased for the project. A detailed design was developed for modifying the front of the boiler for attaching the modified air cooled combustor. Fabrication of this boiler modification was initiated. This option was significantly lower in cost than refurbishing the boiler for the Williamsport site owner, as required by the terms of that lease, and purchasing another used boiler and modifying it.

The detailed design of the coal storage and feed equipment, including its installation at the site was completed. Fabrication quotes were obtained. A used coal mill suitable for the combustor was selected, and negotiations for its acquisition were initiated.

The fabrication of the extension to the combustor and a new exit nozzle continued in this quarter. Due to the specialized nature of the air cooling tube fabrication, the extension section is being fabricated by two companies. The air cooling tube assembly is being fabricated by the company that fabricated the original combustor. As work proceeded, the tube fabricator found that the present combustor design was substantially more difficult to produce than the previous one. This was due to the more complex cooling tube arrangement in the present design. Also, a discrepancy between the assembly and detailed drawings of the air cooling tubes was discovered during the tube fabrication. A key lesson for the future is to use three dimensional computer drawings of the tube design to verify dimensional clearances. 3D-CAD was considered initially for the present design but it was rejected as too costly for the perceived benefit. Due to the skill of the tube fabricator, all these problems have been satisfactorily resolved, and the air cooling tube assembly is within several days of completion. The second fabricator has machined the balance of the combustor assembly and completed 50% of the welding. It is anticipated that the entire combustor extension section will be completed by mid-December.

The detailed design of the coal receiving, storage and pulverizing system was completed. It consists of a 25 ton raw coal bin to receive run-of-mine coal from a dump truck. The coal will be pulverized in a small mill and transferred pneumatically to the existing 4 ton pulverized coal bin. A second baghouse will be added to the 4 ton bin baghouse to process the higher airflow.
The design specifications for the stack gas baghouse were completed. To reduce its cost, the stack gas temperature will be reduced. This allows the selection of less costly low temperature filter bags. In addition, detailed analyses were performed to improve the particle retention of the existing wet particle scrubber from 0.27 lb/MMBtu to 0.1 lb/MMBtu to meet the Philadelphia air emission standards. To accomplish this will require a 50 hp fan, which is about 3 times the power required for the baghouse fan. Also, sludge disposal will be more difficult. Therefore, the wet scrubber will be used only as a backup.

As a result of the difficulty in negotiating a satisfactory arrangement on the sale of either steam or power to a site host in both the initial and present sites, work continued in this quarter on finding means for using the energy produced by the combustor in an industrial process. An attractive is non-ferrous metal remelting from scrap. The economics are favorable provided low cost and low cost melting equipment power is available. Work on this approach is proceeding with Coal Tech resources.

A totally unanticipated difficulty arose in the implementation of the site modifications for the facility. For use in this project, the door to the Arsenal building has to be enlarged from $8 \text{ ft} \times 10 \text{ ft}$ to $12 \text{ ft} \times 14 \text{ ft}$ to allow installation of the boiler in the building. In addition, the alley in the rear of the building has to be paved with concrete to accommodate the coal handling, baghouse and cooling tower equipment, a water line has to be installed from the cooling water source in an adjacent building, an additional power line was to be connected from the sub-station, and a telephone line had to be installed to the building. All these items are specified in the lease. Detailed design drawings for the door and pad were prepared and submitted to the site manager at the end of August. Due to miscommunication and lack of a problem resolution procedure with the landlord, the site modifications have not been implemented as of the date of this report (11/14/94). A meeting was finally held with the landlord and his staff on November 11 and the problems appear to have resolved. It is anticipated that the modification work will begin before the end of November with completion by early December. At that time installation of the boiler, combustor, and auxiliary equipment will begin. Difficulties with the site owner is a factor that was not considered in the planning for task 5 effort. However, it will be incorporated in future planning on commercial installations. In addition, the installation design is being modified to minimize the on-site field work. This will allow rapid installation and removal of all the equipment for small power plants in the several MW range, or less.

Also in the present quarter, part of the combustor test data on mass balance for mineral matter in the combustor, boiler, and scrubber was reevaluated to obtain a more accurate assessment of slag retention in the combustor. Due to personnel changes and focus on the task 5 effort, much of the data from the task 3 tests performed after August 1, 1993 have as yet not been fully analyzed. The present reevaluation was performed in preparation for the Annual DOE Contractors Meeting and for the design of the task 5 stack cleanup system. During this reevaluation it was discovered that important additional information was overlooked in the scrubber data which would provide a more accurate description of the combustor's performance. Specifically, it was determined that the combustion efficiency and the total sulfur capture deduced from the scrubber solids were previously underreported.
The combustion efficiency, as deduced from scrubber samples, was several percentage points higher than previously reported. Similarly, a significant amount of additional sulfur capture, possibly as much as 33%, took place in the wet particle scrubber. While this phenomena had been reported several years ago during the Clean Coal Project, it had received little additional attention because sulfur capture in the scrubber was never a project objective. However, at present the apparent caging of sulfur capture in the combustor/boiler is about 85%. This will achieve at best 0.5 lb/MMBtu SO2 emissions in a 2% sulfur coal. The project objective is to achieve 0.4 lb/MMBtu. Therefore, the it is planned to consider SO2 reduction in the stack particle scrubber or baghouse as part of the task 5 effort.

In conclusion, the engineering work on the fabrication and installation of the combustor for the task 5 effort is proceeding satisfactorily. The schedule has slipped by several months due to delays in implementing the required site modifications necessary to install the equipment. However, major improvements and cost reductions in the total system design have been implemented. They will enhance the commercial competitiveness of this coal fired power system.

In the next quarter procurement of the balance of the equipment will be implemented and the installation of the equipment at the site will commence.
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 SO2 emissions, 0.2 lb./MMBtu of NOx 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 SO2 emissions goal may require a combination of sorbent injection inside the combustor and sorbent injection inside the boiler, especially in high (>3.5%) sulfur coals. Prior to the initiation of this project in 1992, SO2 levels as low as 0.6 lb./MMBtu, equal to 81% reduction in 2% sulfur coals, were measured with boiler injection of calcium hydrate.

It was originally planned 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 be 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. The commercialization effort indicated that more emphasis was required in the area of fuel flexibility in order to expand the near term market potential of the combustor. The extended operation tests will be performed in task 5 with the steam output used at the test site for either process heat or steam turbine power generation instead of being blown off.

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 will be 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 to be 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 SO2, NOx, 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. SO2 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. NOx is controlled by staged, fuel rich combustion inside the combustor. Final combustion takes place in the boiler.

As described in Section 2.1, 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 SO2 reduction in the combustor. Prior to the start of the present Phase 3 project, the peak SO2 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% SO2 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 SO2 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 4 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% SO2 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% SO2 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 will be accomplished by detailed engineering analysis on the use of the
combustor in one or more steam generating cycles. This effort includes an assessment of the requirements for commercializing the combustor for several industrial application. To assure successful commercialization of this technology, the final project task will be implemented in 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 three sub-tasks: 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.

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.

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.

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.

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.

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 3 Proof of Concept Tests

In the present quarter, part of the combustor test data on mass balance for mineral matter in the combustor, boiler, and scrubber was reevaluated to obtain a more accurate assessment of slag retention in the combustor. Due to personnel changes and focus on the task 5 effort, much of the data from the task 3 tests performed after August 1, 1993 has as yet not been fully analyzed. The present reevaluation was performed in preparation for the Annual DOE Contractors Meeting and for the design of the task 5 stack cleanup system. During this reevaluation it was discovered that important additional information was overlooked in the scrubber data which would provide a more accurate description of the combustor’s performance. Specifically, it was determined that the combustion efficiency and the total sulfur capture deduced from the scrubber solids were previously underreported for the following reasons:

The combustion efficiency can determined from three independent measurements.

a) The carbon in the slag: This method is not used by Coal tech because it overestimates the efficiency. The carbon in the slag is generally less than the detectable limit of 0.1%, which would yield over 99.9% efficiency. However, the slag does not account for unburned carbon particles escaping from the combustor, and therefore, it can substantially overestimate the efficiency.

b) The stack gas composition: Here also, the loss in efficiency due to unburned carbon is not accounted for. For example, in the four tests of November 9 and 10, 1993, the efficiencies were 102%, 107%, 112%, and 105%.

c) The unburned carbon in the scrubber water solids: After filtering and drying the scrubber solid sample, it is oxidized at a temperature of 750°C. The solids weight loss is reported as “loss on ignition” (LOI). In all prior analyses, it was assumed that the volatile matter consisted only of carbon from which the carbon balance in the entire system was computed and the combustion efficiency was determined. For the above-four tests, this resulted in values of 94%, 90%, 98% and 97%. All previously reported values of overall combustion efficiency were based on this third method of calculation.

In the present slag/ash mass balance reevaluation, it was discovered that calcium oxide that did not react with SO2 in the gas train would almost certainly react with the scrubber water to form Ca(OH)2. The chemical analysis of the scrubber solids would therefore consist of LOI, Ca and Si concentrations. The latter were reported as CaO and SiO2. However, the CaO in the solids was actually Ca(OH)2, and this compound decomposes at 550°C, or 200°C less than the oxidation temperature used to measure loss on ignition. As a result, part of the LOI consists of OH molecules that evolve during oxidation of the solid sample leaving CaO in the scrubber solids. From a reexamination of the measured LOI and CaO in a number of scrubber solids analyses performed during the past several years, it was determined that the contribution of the OH molecule to the LOI can account for about 1/3 of its value. For example, applying this correction
to the fourth test condition discussed above, where the combustion efficiency was reported as 97%, yields a corrected value of 99%.

This same procedure was applied to several other tests, and in many cases the effect was more pronounced. For example in a test on 1/24/93, the combustion efficiency was computed as 87.2% assuming all the LOI was carbon, while it was 90.9% when the OH effect is included. It is also possible that other OH, H2O compounds form with other metals in the ash which devolatilize in the LOI sample preparation. Therefore, the LOI test must be augmented with one that measures the carbon concentration directly. Unfortunately, as a result of the combustor relocation, all the slag, ash and scrubber samples were disposed, and these tests will have to await task 5 combustor operation. However, the present analysis shows that the combustion efficiencies were in all cases higher than previously reported.

The second item related to scrubber sample analysis concerns the sulfur mass balance in the system. The motivation for this reevaluation was the requirement that SO2 emissions be no more than 0.5 lb/MMBtu in Philadelphia. For the planned 2% S, PA bituminous coal, this requires 84% SO2 reduction. The average SO2 reduction with combustor sorbent injection was 70%, as determined from stack gas SO2 measurements upstream of the scrubber. While additional sorbent injection into the boiler could readily achieve the required reduction, this latter procedure would increase the mineral matter loading in the boiler. It was observed during the Clean Coal test effort, that the scrubber produced a modest additional SO2 reduction. However, since the scrubber’s impact on SO2 reduction was never a project test goal, little attention was placed on this SO2 reduction effect.

During the present reevaluation, it was noted that in addition to the Ca scrubber solids, a significant amount of Ca dissolve as ions in the scrubber water. The ions can result from the dissociation of Ca(OH)2 or CaSO4. In the latter part of the Clean Coal Tests and fly ash vitrification tests in 1989 and 1990, the scrubber water was analyzed for Ca++ ions and dissolved sulfate. The Ca++ test was eliminated at the end of vitrification project, and the sulfate test was replaced with one that measures dissolved sulfur in the water. However, this latter test has a sensitivity limit of 100 mg/l, while many of the final task 3 tests had a total sulfur content in the scrubber solids in the range of about 200 mg/l of scrubber water. Therefore a significant amount of the sulfur was not detected by this test.

In addition, the Ca++ x SO4^- solubility product used in evaluating the 1989/90 data was 2 x 10-5. More recent published data gives a value of 7.1 x 10-5 at 77°F. Therefore, the amount of sulfate in solution until saturation is reached can be substantial.

Since all scrubber samples from the task 2 and 3 tests have been disposed, the only dissolved Ca++, SO4^- data available was from the 1989/1990 test series. This re-evaluation yielded the result that about 50% of the sulfur in the scrubber samples was dissolved, and that the dissolved CaSO4 ranged from substantially below saturated levels to several times greater that saturated concentrations. It is not known what percentage of the sulfate in the water is due to Ca-sulfur reaction in the scrubber water or solution of CaSO4 captured in the gas stream.
Subsequent to this evaluation the manufacturer of this scrubber was contacted. According to the analytical model of this scrubber's performance, for the pH used in its operation, the SO2 reduction is predicted to be 33%. When combined with the 70% reduction from sorbent injection in the combustor, one obtains a total reduction of 80%, which is near the 84% required by the City.

It is planned to reevaluate all the SO2 data from the stack gas sampling, from the boiler ash samples, from the scrubber data, and from the gas sampling downstream from the scrubber. All tests between 1989 and 1993 will be reviewed. For the task 2 and task 3 tests, it will be assumed that 100 mg/l of sulfate is dissolved in the scrubber water. It is anticipated that despite the gaps in the data, a semi-quantitative picture will emerge on the role of the scrubber in SO2 reduction.

The final element in this reevaluation was to determine the effectiveness of the combustor's and boiler's slag and ash retention by separating the coal ash mass balance from the CaO sorbent mass balance. A preliminary result from the scrubber solids data is that in most of the task 3 tests, the coal ash retention in the combustor and boiler was much less than the CaO retention from either the limestone or hydrate. For example, in the November 10 test, the combustor boiler retention of injected CaO was computed at 81%, while that of the coal ash was only 59%. On the other hand, the slag removed from combustor for this tests shows that only 1/3 of the slag consisted of CaO. It is anticipated that this discrepancy will be resolved in future analysis of the data.

In conclusion, the prior analysis of slag/ash data in the combustor boiler and the scrubber data was incomplete. Therefore, a systematic data reduction of the results of task 3, combined with a reevaluation of the prior combustor data, will be undertaken to clarify the sulfur capture in the entire system and the slag/ash retention in the combustor boiler. The objective of this work will be to provide an improved data analysis procedure for the slag and ash mass balance in the task 5 tests. This work will be performed prior to the initiation of the task 5 combustor test effort.

There are two important lesson to be derived from the above discussion.

One is to retain all test samples from a project at least until all work is completed, and, if possible, to retain at least some samples until several years after the project is completed. This allows further analysis of the samples if additional insights in the data are obtained. Coal Tech's policy is to keep all raw test data on its projects for years after its completion. Slag and scrubber water samples from individual tests were kept for many months after test completion. Due to the high cost of sample analysis, only a limited number of samples were submitted to the test laboratory. However, evaluation of the scrubber samples submitted to the laboratory exhibited considerable scatter in the combustor boiler slag/ash retention results. Accordingly, beginning in mid-1993, all scrubber samples were dried and weighed by Coal Tech. A substantial number of these samples were then sent to the laboratory for testing of loss on ignition, i.e. carbon content. For the balance, the average LOI was used to determine the residual ash in the scrubber samples. In retrospect, a small number of samples should have been retained for future analysis. This procedure will now be implemented in future test.
The second lesson is to perform a second independent analysis of the test data. Unfortunately, to perform this on a regular basis is extremely costly for a small project. Therefore, a critical review of the test data should be implemented at regular intervals. This does not guaranty that the above information would have been uncovered. For example, in all tests for dissolved sulfur it was assumed that all sulfur in the scrubber water was accounted for. It was only when the above analysis was performed and the analytical methods for sample analysis were reviewed that the shortcomings of the dissolved sulfur test were uncovered.

In conclusion, the overall lesson from this experience is to keep representative test samples from each test for extended periods of time to allow revisiting of the raw data.

3.2. Task 5. Site Demonstration

3.2.1. Discussion of Site Selection Criteria:

In addition to technical site requirements such as building specifications, electric power, cooling water, the original site selection criterion included the sale of process or heating steam and/or steam turbine generated electric power to the site host. The revenue from these sales would allow substantial extension of the task 5 tests time beyond the planned 500 hours.

To implement this approach, the initial site selection, which began in December 1993, focused on industrial steam users such as paper plants, industrial parks or colleges with substantial steam heating and power requirements. A paper plant and an industrial park were selected at the beginning of this year and negotiations were initiated on installation and energy sales terms. The details are given in the prior, 10th Quarterly Technical Progress Report. However, these negotiations were terminated because the site hosts required reliable and continuous energy production. While this was a reasonable requirement for a fully commercial system, its acceptance for the task 5 effort could have severely limited the flexibility needed to properly implement the task 5 test effort. In effect the primary purpose would have been to assure regular energy supply with the potential for high costs to meet them instead of project revenues. This would be especially the case for electric power production were costly equipment would be needed to assure proper phase machining with the backup utility power source.

Accordingly, this approach was abandoned in April 1994, and the site search focused on technical requirements only. The focus turned solely to the technical site requirements. Several suitable sites were identified in May, and a site in an industrial park in Philadelphia was selected in June. A 3 year lease for the building at this site was executed in July, with an effective date of August 1, 1994. To obtain project revenue, various energy intensive processes were examined for use of the output of the combustor-boiler energy. After examining a variety of processes, it was determined that non-ferrous scrap metal remelting offered the most cost effective use of the energy production.

In addition, as the installation design proceeded, it was discovered that the site requirements could be substantially relaxed. The use of non-contact river or well cooling for the steam condenser was replaced by a modified compact cooling tower with over a factor of 10 reduction in...
water consumption. The use of the local utilities power for daily startup and shutdown of the combustor-boiler system was replaced with a diesel generator. The wet particle scrubber was replaced with a low cost baghouse. The water cooled sections of the combustor and steam condenser were cooled with very compact plate heat exchangers. A low cost coal pulverizer was selected. The overall objective of these designs was to produce a very compact, low cost energy system that could be rapidly designed, fabricated, and installed, and that did not have restrictive site requirements related to water and power supply. The present design meets these requirements.

3.2.2. The Task 5 Test Site Modifications & Permitting

The task 5 test site will be a 3000 square foot building (No. 238) in the Arsenal Business Center, 2275 Bridge Street, Philadelphia, PA 19137. The site is within 100 feet of a tidal stream that drains to the Delaware River about 1000 feet away. It is on the former Frankford Army Arsenal which opened in 1816 and was closed by DOD in the late 1970's. Figure 1 shows a plot plan of the building and figure 2 shows a photograph of the building and the adjacent alley which will be used for fuel storage and auxiliary system installation. This event completed the 8 month site search for the task 5 effort.

The following site modifications were evaluated and designs for implementation were completed. As this work progressed substantial modifications were made to accommodate permit requirements, site characteristics, landlord actions, and cost objectives. They are:

Concrete Pad for Outdoor Equipment: A concrete pavement with a spill containment barrier was designed in August for the alley adjacent to the building (see figure 1) for raw coal receiving and storage, coal pulverization, fans, blowers, and baghouse for stack gas cleanup. This was subsequently modified several times to reduce the costs quoted for the original design by 5 different vendors. The original design called for a 4 inch gravel base topped by a plastic vapor barrier and 6 inches of wire mesh reinforced concrete. In addition, a 2 foot deep x 3.5 ft wide x 24 ft long concrete pit is to placed at the open end of the alley for installation of a screw feeder and conveyor belt (see figure 3). A coal dump truck would back into the driveway and drop the coal onto this conveyor for delivery by means of the conveyor to the top of the 25 ton raw coal bin.

Although the entire coal handling system is to be enclosed, it is not possible to prevent minor spills of a few pounds coal dust on the ground during piping changes. To prevent washing or storm water runoff of this material, the entire pad was to be sealed at the joints with the three walls, and a 4 inch high concrete barrier is to be placed on the open fourth side to retain the water. The original design called for installation of two drains in the concrete to direct the water to the sanitary sewer that runs under the alley floor. However, this would not solve the problem of draining the coal receiving pit into the sanitary drains. It was therefore decided to direct the entire runoff into the coal receiving pit and install a sump pump therein. During normal operation, this pump would direct the rain and wash into the sanitary drains. During a coal dust spill, the pump outlet would be connected to a filter to remove the coal dust prior to discharge into the sanitary drains. This approach eliminates the need for a storm runoff permit from the PA Dept. of Environmental Resources or the Delaware River Basin Commission. A permit is required from the
Philadelphia Water Dept. However, our average total daily discharge would be less than 25,000 gallons per day which does not require any special permit.

**Propane Fuel Supply:** The building is currently serviced by a propane tank with 840 gallon (about 75 MMBtu) capacity. A capacity of 1.3 MMBtu/hr is required for pilot gas ignition of the combustor. A series of concrete filled steel poles and a fence must be installed to prevent the coal and oil truck from hitting the propane tank.

**No. 2 Oil Tank:** Initially, a 1000 gallon, aboveground, No.2 oil tank was to be installed adjacent to the propane tank. The oil is used for daily combustor preheat. This tank would have a metal dike which was designed to capture the entire contents of the main tank. It was to be mounted on a 2 foot high steel platform to accommodate the City rule of installation 1.5 feet above the 100 year flood elevation. This was an added precaution because the entire Arsenal site is surrounded by an earth dike whose top is above the 100 year flood level. An oil flow and return pipe from the tank to the building was to be installed above the elevation of the oil tank past the propane tank to the far wall in the alley and cross the alley into the building. This required a total one way pipe run of 100 feet. It was planned to use doubly contained piping for this purpose.

However, Philadelphia licensing regulations require the use of certified tank installers for this purpose. In addition, the City prefers the use of a concrete, sand filled containment chamber for aboveground oil tanks. This approach is totally unsuited for the present project where removal within three years is contemplated. Any oil leakage or seepage into the sand and concrete will require its disposal in a special landfill at very high cost. To obtain a license for our option of a dike tank could have require a two step process, beginning with the Department of Licenses. It could have been approved at this step, but if refused by an appeal to the Safety Board of the Fire Department, where it would have almost certainly be approved. However, regulations require the use of the licensed tank installer for this application process at a cost of $865 per step.

A bid package for installation of the oil tank and a pumped feed line to the building was submitted to three installers licensed in Philadelphia in early September. One bid that over 4 times the cost of the oil tank, and another bid that was 7.4 times the cost of the tank were received. This is another example of the problems caused by the complexity of regulations as only a licensed installer is allowed to install an oil tank. After these quotations were received, a further study of City regulations revealed the installation of a boiler can be accompanied with a 550 gallon tank without the need for this installation permitting process. Accordingly, all the test data from 1992 to 1993 re-evaluated, and it was determined that this smaller tank would have adequate capacity for heatup and cooldown with one week intervals between refueling.

Therefore, the installation design was changed. It is now planned to either install the oil tank inside the building, which is already elevated by 1.5 feet over the 100 year flood level, or in the alley. Either approach will shorten the oil pipe run, eliminate the need for installation of truck crash poles around the tank, and of course sharply reduce the cost of the tank and its installation.

An added benefit of the oil tank installation is that is can be used to power a diesel generator, which it is planned to acquire for backup power and startup and shutdown.
**Enlarged Equipment Door**: A design for opening the main door in the building from 8 ft x 10 ft to 12 ft x 14 ft was prepared in August and submitted to the landlord on August 30th. It included a steel roll up door to replace the small dilapidated wooden door. This item has become a major source of delay due to the failure of the site manager to follow the requirements in the lease and obtain three independent quotations for this work. After receiving only one bid in September from the landlord’s in-house staff to perform this work, Coal Tech contacted at the end of September three contractors for bids on this work. All three bidders responded in early October with bids that averaged 30% below the landlord’s bid. After landlord’s agent agreed in mid-October to allow Coal Tech’s to contract for the door opening, he refused to allow the contractor access to the site on October 13th.

It has taken one additional month to November 11 to clarify this matter. It appeared that there was a miscommunication between the landlord’s agent, and Coal Tech on concerns by the landlord on the structural integrity of Coal Tech’s door enlargement design. In addition, Coal Tech’s design utilized two steel channels to support the new lintel. This exposed channel would clash with the historical landmark designation of the building, which according to blueprints at the Arsenal dating from World War II was constructed some time after the War. Note that much of the Arsenal has a historical landmark designation since many buildings date to the 19th Century. According to the landlord, historical designation applies to buildings over 40 years old. It is, therefore, not possible to contract this designation as we have no information on the construction date after the War.

These issues were communicated for the first time to Coal Tech at the meeting between the landlord, his agent, and Coal Tech on November 11. The door design has been modified by the landlord’s architect to meet these objections, and the door enlargement will be implemented by the Arsenal personnel at a price that is in the competitive range with the other bidders. The meeting appears to have resolved all other problems which were caused by poor communications. A problem solving procedure has been established. It anticipated that the door, water line (discussed below) and concrete pad work will begin before the end of November and be completed by early December. Note that Coal Tech was prepared to unilaterally terminate the lease at this time. Negotiations on an alternate site in suburban Philadelphia that Coal Tech had investigated in the Spring were at the lease negotiation stage when this resolution meeting took place.

**Telephone Line**: A similar problem occurred with installation of the telephone: Here also despite the lease requirement for three competitive bids, the landlord’s site agent submitted a single quote for the installation of the telephone line from an adjacent building by site personnel of $3800 in early August. The agent claimed that an above ground line was not allowed at the site. Coal Tech found a means of running a line through the service tunnels that cover the entire site. In the interim the Philadelphia Installation Office of Bell of PA obtaining approval from the landlord to install an overhead phone line between the two buildings. After additional delays due to miscommunication, the phone was installed in late September at a total cost of about $240.

**Lessons from Installation Efforts To-date**: These events have been included into this technical report because site requirements are a major element in installation of power plants. The above comments show that clearly defined requirements and problem resolution procedures must
be established in negotiations with site owners. During Coal Tech's contacts with independent power developers in the past several years it was found that site permitting is considered a major cost and time element in the installation process. Approval cycles of 2 years and costs in the several million dollar range are not unusual even for plants rated at 10 to 20 MW. For this reason, most of these developers will not consider projects under 50 MW.

Coal Tech's new approach to site issues is to identify the potential problem areas and find alternate solutions that will mitigate the complexity of the approval process. In addition, Coal Tech is adopting a design approach in which much of the power plant can be assembled in modules in a factory and moved to a site for rapid installation. In this way installation of the power plant can proceed rapidly as soon as site related issues have been resolved. To test this design approach it is planned to modularize the electrical, water piping, gas ducting, electrical connections, and auxiliary components, such as fans, pumps, blowers, etc., for the present installation. This is the only way in which power plants in the 1 to 20 MW range can be installed at attractive costs. This approach will minimize installation costs. Other such examples which impact cost in areas such as cooling water and parasitic power will be given next.

Additional Parasitic Power: The building has a 200 Amp., 480 V, 3 phase installed power. Assuming an 80% power factor due to the large number of motors used, this yields 133 kW of installed capacity. It was originally planned to add an additional 100-kW power capacity from a sub-station 100 feet away to assure adequate power during daily combustor startup and shutdown. This would cover the initial estimate of the parasitic power needs for the combustor-boiler, coal handling system, stack gas system, and boiler-steam turbine system. In addition, it had been planned in the future to install 500 kW of total capacity to the sub-station for future power sales from the steam-turbine generator to the site owner.

This plan was based on the assumption that local utility power costs were $0.14 /kW. However, after analyzing the first electric bill, it was found that there is a very high capacity for this utility due to its heavy reliance on nuclear power. As a result, the heatup and cooldown time of about 55 hours per month, would be less than 80 hours per month. For that time of use, the power cost is $0.23/ kW!!!. Therefore for 150 kW capacity, the monthly charge would be $1900, or $23,000 for one year. This substantially exceeds the rental costs for the site. As a result, the acquisition of a used diesel generator was investigated and it was found that the diesels power production costs, including acquisition cost, would be one-third of the utilities charge. Another consequence of this effort has been to carefully re-evaluate the total parasitic power needs. This analysis showed that 150 kW would be adequate, compared to the original estimate of between 200 kW and 250 kW when the design effort began.

Combustor Cooling & Steam Condensation: The initial cooling plan was to use only an adjacent "well" whose water temperature remains at about 60°F all year round. The water cooling load is about 17 MMBtu/hr. The initial effort was directed to identifying the source of the "well" water, i.e. well, groundwater seepage into the building, or river, and its peak flow rate. A series of pumping tests were performed. The first one was performed in June before signing of the lease with a 30,000 gph, self priming pump. The pump test continued for about 2 hours, during which time the water level in the well decreased by 18 inches. During this test period, the water level in
the adjacent river decreased toward low tide. About 2 hours after the test stopped, the water level
in the well rose by about 4 inches, the last 1.25 hour of this period corresponding to a rising tide.
This suggested that the “well” was connected to the river.

The “well” was connected to the large basement of this building. Subsequent pumping
tests were performed in which the water level was lowered up to 4 feet below the level of the
basement, and about 8 feet from the floor of the “well”. This test showed that the bulk of the
water into the “well” came from the basement of the building. Furthermore, the estimated
maximum flow for our planned 8 hours of daily operation would be at most 8000 gph.

As part of the water permitting process by the PA DER for non-contact cooling water, all
the required chemical tests were performed. The results clearly showed that the water source was
groundwater, whose primary source was leaks into the basement of the building. It did not follow
the tidal water level in the river and was therefore not a river source. Neither was it due to leaks
from the municipal water supply. DER and the Delaware River Authority issue permits for non-
contact cooling water discharge into the river. The discharge temperature is limited to 110°F. For
8000 gph, 60°F source and 110°F outlet, the maximum cooling rate was 3.3 MMBtu/hr, or 20% of
the level needed for once through cooling.

One option is to discharge to the municipal sanitary system, where the peak limit is 140°F,
which would increase the capacity to 5.3 MMBtu/hr, or 32% of the total. The storm and sanitary
water system at this site is very complex. One difficulty is that the storm sewers are superimposed
on the sanitary sewers so that heavy rainfalls can impact the sanitary discharge. To assist in
resolving the water issue, Coal Tech retained in September a specialist in water management to
assure that an adequate water supply is obtained and that all regulations are met. In addition, by
coincidence, the Philadelphia Water Department is in the process tracing these underground pipes
at the Arsenal. After reviewing all this data, it was determined that this “well”, which was actually
a sump, could not be converted to a primary cooling water source. There exists another
substantially larger water source, but it is too far from the building. Another closer source was an
manhole opening in an adjacent parking lot that was directly connected to the creek and the river.
However, as the river temperature reached an average of 80°F in the summer, the 110°F discharge
limit would require 1130 gpm.

As a result, the option of using a cooling tower was re-evaluated. This option had been
discarded early in the design effort due to misinformation supplied by a cooling tower
manufacturer. This supplier proposed the use of three cooling towers, each having a 18 ft
diameter and 18 ft height, and at a prohibitive cost. Coal Tech performed a series of cooling tower
calculations that considered the high one atmospheric absolute pressure condensation from the
steam turbine. This allowed selection of a low cost, high average water circulation temperature.
The cooling tower is now only 12 ft long, 7 ft wide 11 ft. high.

Combined with the combustor cooling water requirement, the fresh water supply
requirement is now only about 50 gpm. This is almost one-half the level used in Williamsport. In
addition, since much of the water evaporates in the cooling tower, the discharge load to the
sanitary sewer is negligible, namely, between 3 and 15 gpm. This eliminates the permitting need
from both the River Authority and the DER, with only a routine permit required from the Philadelphia Water Department. The discharge rate is far less than the lowest level of 24,000 gpd below which no special permit is required. One change being made is to install a 2 inch fresh municipal water line, in place of the originally planned sump water source. The reason for this is that the cooling tower requires a water source with much lower dissolved solids levels than obtainable from the sump. While a 1-1/2 inch line would have been adequate, the high installation cost is such that providing excess water capacity is a good precautionary investment. Inadequate water supply was a major source of difficulty in Williamsport. In the present case, the 2 inch water line will be augmented by the “sump” groundwater source as needed.

**Zoning Permit:** The first important step in the permitting was the receipt on July 29 of a zoning permit from the City of Philadelphia. This allows Coal Tech to use the site for energy development and for the installation and operation of the combustor-boiler system. The importance of this step is that the site is in a flood plain and as such there are a number of restrictions on its use. For example, above ground oil tanks must be installed 1.5 feet above the 100 year flood elevation.

**Boiler Permit:** A permit is required from the PA Bureau of Labor & Industry-Boiler Section for moving and installing a boiler in the state. This permit was obtained for the 17,500 lb/hr boiler in September. A final inspection will be required by PA L&I prior to operating the boiler.

**Water Discharge Permits:** As reported above, the original plan for river discharge would have required permits from the Delaware River Authority and the PA Dept of Environmental Resources, Water Division. With the decision to use a cooling tower, neither permit is needed, and the Municipal Permit application is anticipated to be routine.

**Air Permit:** Philadelphia manages its own air emission program, instead of the State. The emission limits are 0.1 lb/MMBtu for particles, 0.5 lb/MMBtu/hr for SO2.

A detailed modeling analysis by the manufacturer of the wet scrubber that was used in Williamsport showed that a pressure drop of 50 "w.g. would be required across the scrubber for this particle emission rate. (See figure 4). This would require a 50 hp fan, compared to the 20 hp used in Williamsport. The air flow is about 6000 acfm, and from figure 4 this would require between 45 and 50 gpm, with about a three gpm evaporative loss. Using the sump water supply would eliminate the cost of water for a once through system. By combining this flow with the combustor water cooling circuit the total discharge to the sanitary drain would not increase. The solids loading in the discharge would be the same as that used in Williamsport. The alternative of operating the scrubber in a closed loop circuit with filtering would be complicated by the problem of disposal of the sludge. It could be dried and reinjected into the combusor, but this would require development work. As noted the scrubber would also contribute to the sulfur reduction needed to meet the SO2 emission limits.

The main disadvantage of this approach is the high electric power needed by the fan, which is very costly. Also in a commercial installation the no cost water source would not be available.
Also, with the exception of the relatively new scrubber inlet section, the balance of the scrubber wall material is badly worn and will have to be replaced. For these reasons, it was been decided to replace the scrubber which a baghouse. This can readily achieve 0.03 lb/MMBtu emissions. In addition, with stack injection of sorbent, upstream of the baghouse it will be possible to remove a high percentage of the SO2 without sorbent injection in the combustor. Accordingly, two vendor quotations for a baghouse were solicited. Both were in the same price range, with the main difference between them being the projected material lifetime and the recommended bag material.

Due to the high cost of bags operating above 250°F, this temperature was set as the limit. It is planned to lower the stack gas temperature which averages 450°F with soot blowing to the lower temperature by installing an economizer in the boiler outlet. The economizer was designed to decrease the stack gas temperature to 360°F, while increasing the feedwater temperature by 30°F. The additional temperature drop will be achieved by water droplet injection in a water-sorbent mixture. Due to the high basic content of this injection, the impact of the SO3 acid dew point on stack/baghouse metal materials should be neutralized. A design of the stack duct system was completed (see figure 5). The baghouse will be located in the alleyway, and the stack from the boiler to the baghouse has a horizontal section to exit the building through a window. Penetration of ducts through the walls or roof is not allowed by the landlord.

In addition, to low particulate emission to 0.03 lb/MMBtu and added SO2 control to at least below 0.5 lb/MMBtu, the baghouse offers two other advantages. One is its ability to capture submicron size particles and the other is the ability to pneumatically reinject the fly ash into the combustor for vitrification. Therefore, a baghouse will be used in task 5. The scrubber which is owned by Coal Tech, will be used for specialized test purposes and as a backup system to the baghouse.

One final important element in the air emission permit application is the requirement by the City that the SO2 emissions at ground level at the boundary of the site be less than 3 ppmv at any time, less than 0.5 ppmv over 15 minutes, and less than 0.1 ppm for an 8 hour period. To determine this level, a screening model was downloaded from EPA’s software library. The analysis computes the SO2 emissions at various elevations for various terrain’s as a function distance from the site fence line, 1050 ft (323 m.) in the case of the Arsenal, as a function of the stack geometry and flow conditions and SO2 concentrations at the stack exhaust. Several scenarios were calculated for 20 MMBtu/hr thermal input, 13,000 Btu/lb HHV and 2% S coal. Figure 6 shows the groundlevel SO2 concentration in $\mu$gm/m$^3$ as function of distance from the stack for 85% SO2 reduction at the stack. The SO2 is 104$\mu$gm/m$^3$, equal to 0.09 ppmv, at the site fence line. The 8 hour average is 0.06 ppmv for 8 hour average time. Here it is assumed that 70% reduction is achieved with combustor injection and an additional 60% reduction is achieved with stack sorbent injection. For 70% SO2 reduction at the stack, the fence line value is 210 $\mu$gm/m$^3$, equal to 0.17 ppmv, at the fence line. The 8 hour average is 0.12 ppmv. Therefore one can conclude that a combination of proven combustor SO2 reduction with some modest additional stack reduction will meet the City’s 0.1 ppmv emission requirement at ground level.
3.2.3. Status of the Combustor Modifications:

**Combustor Extension and Exit Nozzle:** The fabrication of the extension to the combustor and a new exit nozzle continued in this quarter. Due to the specialized nature of the air cooling tube fabrication, the extension section is being fabricated by two companies. The air cooling tube assembly is being fabricated by the company that fabricated the original combustor. The balance of the work is being performed in a machine shop. The orders were placed in May. Both fabricators have slipped delivery schedules by several months. As work proceeded the tube fabricator determined that the present design was substantially more difficult to produce than the previous one. Also, a discrepancy between the assembly and detailed drawings of the air cooling tubes was discovered during the tube fabrication. As a result, the inner diameter of the exit nozzle would be increased from 50% to 57% of the combustor internal diameter. This was discovered after all the tubes had been cut and it was too costly to procure a new set tubes. It occurred despite the use of AutoCAD for the drawings and the use of two independent checkers of the drawings.

After reviewing the literature of cyclonic flow it was determined that this change was not substantial. In fact it would be beneficial because it simplifies the internal maintenance of this combustor. Another difficulty experienced was the need to modify the fabrication of the tubes near the slag tap chamber. Again this design differed from the one used in the present combustor. A key lesson for the future is to use three dimensional computer drawings of the tube design to verify dimensional clearances. 3D-CAD was considered initially for the present design but it was rejected as too costly for the perceived benefit. Due to the skill of the tube fabricator, these problems have been satisfactorily resolved to date, and the air cooling tube assembly is within several days of completion. The other fabricator has machined the balance of the combustor assembly and completed 50% of the welding. It is anticipated that the entire combustor extension section will be completed by mid-December.

**Coal Storage, Pulverization, and Fuel Feed:** Final design and vendors quotations for purchased and fabricated equipment for the coal system was about 90% completed in this quarter. Negotiations were entered into with a manufacturer of a coal mill to refurbish at Coal Tech’s expense a discontinued model of a compact low cost mill. A draft agreement was prepared and it is ready for signature once the problem of revenue sharing from inventions, that may be made in improving the performance of the mill, is resolved. Protecting the government’s interest, the manufacturer’s interest, the subcontractor in charge of the refurbishment’s interest has proven to be a complicated procedure. In the meantime, another used mill of identical design has been located and its acquisition and refurbishment cost is being evaluated as an alternative option. It is anticipated that this will be resolved within the next few weeks. Multiple quotations were obtained for the coal screw feed, conveyor belt, mill refurbishment, and coal bin baghouse. Quotations for fabricating the 25 ton bin are anticipated shortly. The overall design of the coal feed system was shown in figures 1 and 2 in the previous Quarterly Progress Report.

**Boiler Acquisition & Modification:** The 17,500 lb/hr boiler used in Williamsport for the past 7 years was purchased for the project. A detailed design was developed for modifying the front of the boiler for attaching the modified air cooled combustor. Fabrication of this modification was completed in October. It consist of an extension section into which the
combustor’s exit nozzle is inserted. This section allows the removal of any ash or slag that is carried over into the boiler without entering the boiler. Therefore, ash/slag removal can be implemented without combustor shutdown, if needed to clear accumulated slag or ash.

At the beginning of October the boiler was removed from the Williamsport boilerhouse and temporarily stored in the outdoor lot of the rigging company, pending its removal to Philadelphia. This will occur as soon as the building door is enlarged.

In addition, a steel structure was designed for placement of the boiler at the new site. This design allows the installation of a bottom ash removal section which can be used while the boiler is in operation.

Note that purchase of this boiler was significantly lower in cost than refurbishing the boiler for the Williamsport site owner, as required by the terms of that lease, and purchasing another used boiler and modifying it.

Steam Turbine: A suitable steam turbine, rated at 600 kW and matched to the steam output of the boiler was located and plans for its detailed inspection were formulated. Analysis of its performance showed that it would produce between 400 and 500 kW with the present boiler system. The output range depends on the steam conditions. The steam input can be between 100 and 220 psig, either saturated or with 100 F superheat. The steam discharge is either 1 psig or 10 in. Hg absolute. One factor in the power output selection will be the cost of replacing the nozzles in this single stage turbine versus the required power output. As noted originally it had been planned to sell the power to the site owner. However, this will require replacing the governor and adding power synchronization with the utility grid. This is a costly option and the site owner has as yet not expressed any interest in purchasing this power at a cost that would be financially attractive to Coal Tech. As a result, the final decision on the selection of this turbine will be the level of power needed for in house power utilization.

Internal Use of Energy Generated by the 20 MMBtu/hr Combustor: As noted above, due to the site selection difficulties, the internal use of the combustor’s energy output has been investigated and reported in the previous Quarterly Report. At present the most attractive option is non-ferrous metal scrap remelting. This option is being investigated with Coal Tech internal funds. Preliminary feasibility tests are planned in the before the end of the year. If successful, a full remelting operation capable of utilizing the power output of the turbine and diesel will be installed and operated.

4. Effort of the Next Quarter

The focus of the next quarter will be resolve the difficulties with the site owner in implementing the terms of the lease that impact this project. This will be followed by completion of the site modifications and the installation of the boiler, combustor, and auxiliary components. Also, the other components needed for the installation will be procured. In addition, the permit applications will be submitted to the appropriate agencies.
Figure 1: PLOT PLAN OF THE TASK 5 COMBUSTOR-BOILER DEMONSTRATION SITE
PHILADELPHIA, PA

Control Room is on left side. Main Combustor-Boiler Room is at right. Propane tank in upper right is for pilot heat. The building is a single story brick structure, with two rooms, one is 76' x 29', and the other is 31' x14'. both with 22' high ceilings to the flat roof. The L shaped partition on top is an 18 foot high concrete wall that encloses two sides of an alley next to the building. The alley will be used for coal storage and feed system, stack cleanup equipment, and fans, blowers, oil tank.
TASK 5 DEMONSTRATION SITE IN PHILADELPHIA INDUSTRIAL PARK

Building size is 100 x 30 feet x 20 feet high
Figure 4: Particle Retention of the Existing Wet Particle Scrubber at 50" Draft Vs Water Flow Rate

Coal Tech - MS 400 H

Pressure Drop ("W.C.

Liquid Rate (gpm/1000acfm) & Efficiency (%)

98.26 98.72 98.97 99.13 99.25

5 7.5 10 12.5 15
Figure 5: Stack Duct Configuration for the 20 MMBtu/hr Combustor-Boiler at the Arsenal
Figure 6: Ground Level SO2 Emissions at Arsenal Test Site for 0.5 MMBtu/hr SO2 at Stack, Equals 85% Reduction in 2%S Coal & 20 MMBtu/hr Firing Rate. (100 μg/m³ = 0.09 ppmv)

Maximum concentration 1.044E+002 μg/cubic m at 0.423 Km (Automated Distances)