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

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TABLE OF CONTENTS

1. SUMMARY

In the third quarter of calendar year 1996, 13 days of combust-boiler tests were performed, including 3 days of tests on a parallel DOE sponsored project on sulfur retention in a slagging combustor. Between tests, modifications and improvements that were indicated by these tests were implemented. This brings the total number of test days to the end of September in the task 5 effort to 41, increased to 46 as of the date of this Report, 10/27/96. This compares with a total of 63 test days needed to complete the task 5 test effort.

As reported previously, the only major modification to the Williamsport combustor has been the addition of a new downstream section, which lengthens the combustor and improves the combustor-boiler interface. The original combustor section, which includes the fuel, air, and cooling water delivery systems remained basically unchanged. Only the refractory liner was completely replaced, a task which occurs on an annual basis in all commercial slagging utility combustors. Therefore, this combustor has been operated since 1988 without replacement.

The tests in the present reporting period continued the excellent slagging combustor performance experienced in the previous quarter, when slagging opening conditions were first tested in this upgraded combustor. The present quarters tests confirmed that the present 20 MMBtu/hr combustor design is far superior to the previous one tested since 1988 in Williamsport, PA. Again the previous quarter's very important result with over 95% of the slag drained from the slag tap in the combustor was confirmed. This compares with an range of one-third to one-half in Williamsport, with the balance of the slag flowing into the boiler furnace section.

In the present quarter another extremely important result was obtained. By properly controlling the combustion conditions it was possible to replenish the combustor's inner refractory wall with the ash in the coal for the first time. Previously in the Williamsport 20 MMBtu/hr combustor, liner replenishment required the injection of additional coal fly ash to accomplish this task. In the present combustor, the thickness of the refractory liner remained in a very narrow band of thickness, which could be increased or decreased by adjusting the combustor cooling and combustion conditions.

Much of the balance of the effort in this quarter was on improving the operation of the auxiliary components. Of these the most important one was the operation of the slag tap, where a series of improvements were installed that resulted in essentially trouble free operation of the slag tap during routine coal fired operation.

Due to software problems with a newly purchased upgrade of the original computer process control software, all the combustor tests were performed with basically manual operation of the combustor. The previously used software was used primarily for data acquisition. A key function of the original computer process control was to maintain a constant combustor inner wall temperature. However, in the course of operating the present combustor with manual control, it was determined that the combustor wall temperature could be maintained in a very narrow band by adjusting the combustion conditions, and it was not necessary to use the complex control of the previous combustor.

Another very important result is the development of a new heatup and cooldown procedure which allows very rapid startup and shutdown of the combustor with very much reduced gas and oil utilization compared to the previous combustor in Williamsport.

Three of the tests in this quarter were performed under a parallel project whose objective was to achieve sulfur capture in the combustor and its retention in the slag. The results are reported in that project's progress reports.

Another very important result has been the improved operation of the entire system, which can now be operated with as few as 2 persons. This compares with 5 to 7 persons in the previous combustor in Williamsport.

To date, the performance of this combustor has exceeded the design objectives for this second generation 20 MMBtu/hr combustor. Based on this performance it is planned to begin the commercial introduction of this technology. The balance of the test effort in task 5 will be devoted to further testing to improve the reliability of the system and to fully automate its operation.

2. PROJECT DESCRIPTION

2.1. Objectives

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

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

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

2.2. Technical Approach

2.2.1. Overview

The work of this Phase 3 project is being 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 are being implemented at a new site in Philadelphia, PA which was selected after the completion of the task 3 tests. The combustor has undergone development and demonstration testing since 1987. The primary fuel has been coal. Other tests, including combustion of refuse derived fuels and vitrification of fly ash, have been successfully performed.

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

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

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

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

2.2.2. Task Description

Task 1: Design, Fabricate, and Integrate Components

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

Task 2: Preliminary Systems Tests

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

Task 3. Proof of Concept Tests

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

Task 4. Economic Evaluation & Commercialization Plan

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

Task 5. Conduct Site Demonstration

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

Task 6. Decommissioning Test Facility

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

3. PROJECT STATUS.

3.1. Task 5. Site Demonstration

The installation of the combustor-boiler facility at the Philadelphia site was completed at the end of 1995 and initial shakedown tests began. It had been planned to divide the task 5 tests into two phases. In the first phase, it was planned to operate the first 16 days (nominally 100 hours) of the 63 days (nominally 500 hours) of the task 5 combustor tests with off-site pulverized coal. The final 400 hours were to be performed using the on site raw coal storage and pulverization system. However, an economic tradeoff analysis performed late in 1995 showed that using off site pulverized coal for the bulk of the task 5 tests was more cost effective if a simple method of loading the off site pulverized coal into the existing 4 ton bin could be developed. An effective means for accomplishing this was tested in the previous quarter and perfected in the present quarter. Coal is delivered in ten 1 ton supersacks from a processing plant in Western Pennsylvania. It is loaded into the 4 ton pulverized coal bin pneumatically from the supersacks using a procedure perfected during this quarter. As a result of this simple and low cost procedure, it is now planned to eliminate the use of on-site coal pulverization, as it is no longer cost effective for the objectives of the present project.

All the tests to date have continued by manual control. It had been planned to proceed to computer control early in this quarter with upgraded software that was purchased in early May. However, this upgrade has proven very difficult to program. Also, excellent results were obtained with manual control, especially in the critical area of control of the combustor wall temperature. Accordingly, the original computer control program was used mainly to collect data and to perform several simple functions such as fuel feed rate control. A very important aspect of the control effort has been the great reliability of the PLC control, which has replaced many of the previous relay control functions used in Williamsport. The simplified control has enabled us to operate the combustor-boiler system with as little as two operators, which is less than one-half the personnel used previously.

The bulk of the effort in the present quarter has been on improving the operation of the auxiliary components. In addition major progress has been made in using the combustor's operating conditions to maintain the durability of the combustor's inner refractory liner and in improving the reliability of the operation of the slag tap.

A total of 13 days of combustor operation were performed in this quarter, of which three test days were under a parallel project on sulfur control during combustion. The latter results are reported in that project's progress report. This brings the total number of test days to 41, and to 46 days as of the date of this report 10/28/96.

There were two objectives to these tests. One was to improve the performance of the combustor's combustion efficiency and environmental control. The other was to improve the reliability of the combustor and its auxiliary components. In the both cases, excellent progress was made.

In the following sub-sections, the progress made in the past quarter will be summarized.

3.1.1. Combustor-Boiler Tests.

Coal fired combustor tests were performed in all three months of the present quarter. 6 tests days were performed in July, 5 test days in August, including one for the parallel sulfur-slag project, and 2 days in September, both of which where on the other sulfur-slag project. All the tests were with coal firing under slagging operating conditions. This brings the total number of test days in task 5 to 41 days, compared to the maximum planned 63 test days.

Improvements in Combustor and Auxiliary Component Reliability.

Combustor Durability: A key durability issue in this combustor is the air cooled refractory liner. As reported in the last quarter, it has been possible to further improve the use of operating conditions to maintain and replenish the refractory liner with slag without the use of additive injection, such as coal fly ash. On the other hand, in the course of testing for the parallel sulfur control project, it was determined that proper injection of ash additives can also rapidly replenish the combustor liner.

Slag Tap Performance: Maintaining an open slag tap inside the combustor is critical to its operation, and this has been one of the major development items in this project. In the prior 20 MMBtu/hr combustor in Williamsport, a combination of mechanical and thermal methods for keeping the tap open had been perfected. This procedure was also used in the present combustor. However, it was noted that on shutdown, especially unscheduled shutdowns, the slag tap tended to plug with frozen slag, which had to be hammered out after each test.

Accordingly, in the present quarter, considerable efforts was expended on improving slag tap performance. This included attempts on changing the heat source to the tap, modifying the location and orientation of the heat source, changing the means for controlling the heat source, adding additional thermal input, replacing and relocating the power source for the mechanical slag tap breaker, and adding additional mechanical slag tap breaker capability. These various methods were tested during the various test operations at the end of the previous quarter and in the early part of the present quarter. The result was that the slag tap has remained open during unscheduled or unscheduled combustor shutdowns.

As discussed in the last quarterly report, due to poor welding by the fabricator of the slag tap water cooled section, two incidents of serious water leaks were experienced in this section, which necessitated its removal and repair. To eliminate the risk of future water leaks, the operating procedure for water cooling this section was modified by limiting the water pressure during combustor operation and by eliminating the possibility of overpressure after shutdown. These changes, implemented at the end of the previous quarter, have apparently eliminated this problem.

As part of the parallel project on sulfur control, very high rates of injection of mineral material have been tested. For example, with coal feed rates of 1000 lb/hr using a 14% ash coal, the 140 lb/hr of coal ash have been augmented by a mixture of silica, alumina, and calcium oxide compounds at rates as high as 350 lb/hr. Under this conditions, which corresponds to about a one-third mineral content of the solids injected, one case of plugging of the slag tap has been experienced. It occurred as a result of an unscheduled shutdown. However, even in this case, by modifying the restart procedure, this problem has been eliminated.

Consequently at present the operation of the slag tap is satisfactory and, except as noted above, it has not required any mechanical clearing after combustor shutdown.

Slag Removal: The slag drops through the slag tap into a water filled slag tank, from which it is removed by a belt conveyor. This conveyor, which had been purchased from a specialty conveyor manufacturer in 1990, has been modified numerous yimes by Coal Tech in order to maintain reliable operation. In the early part of the present test effort problems developed with frequent belt breakage. The source of the problem was finally identified at the end of the last quarter and since that time, the conveyor has operated reliably.

Some of the smaller slag grit falls off the conveyor belt and collects on the floor of the slag tank. Considerable effort was devoted to develop a procedure for removing this grit during combustor operation. The technique was tested and found to be very effective in grit removal from the floor of the slag tank. However, it has not been used because the combustor is only operated on a single shift basis, where it is simpler to remove the accumulated grit after each test. The grit removal procedure can be readily automated. However, this is not warranted for the present operating conditions.

The third element of slag removal involves the cooling of the water in the slag tank by a water-water heat exchanger. Once a procedure for preventing slag grit from entering the heat exchanger was developed, this cooling system has operated trouble free.

Baghouse Operation: Another area of extensive effort has been operation of the stack gas cleanup system. As previously reported, low cost low temperature bags have been used. This requires cooling of the gas by several 100°F to about 250°F. It is accomplished by humidifying the gas upstream of the baghouse inlet. Another consideration in selecting this approach is that humidification is used in some power plants to reduce SO_2 concentrations in the stack gas.

In the present tests, the major problem encountered with stack gas humidification has been the build up of ash deposits in the stack duct upstream of the baghouse. In the early tests in the last quarter, this buildup was such as to almost block the duct with deposits within several hours of coal fired operation. Different approaches were tested to cool the gases and procedures were developed to minimize the deposits to acceptable levels. However, there was only little additional SO_2 reduction at the stack outlet to the atmosphere in several dozen tests conducted to date (See below). It is believed that this is due to an inadequate residence time of less than 1 second in the humidified section of the duct. This is substantially less residence time than exists in large scale power plants.

Since satisfactory SO_2 reduction is being obtained with sorbent injection in the combustor and boiler, it has been decided to stop further work on optimizing the stack gas humidification method of SO_2 reduction. The induced draft stack fan was originally used for the wet particle scrubber which had a much higher pressure drop than the present baghouse duct system. Consequently, the fan speed was reduced for the lower pressure loss in the present system. Due to excess fan motor capacity, the fan speed is being increased to allow operation with suction of atmospheric air into the baghouse duct inlet to cool the stack gas to a temperature compatible with the bags with minimal humidification of the stack gas.

Sootblowing: Sootblowing continues to be very effective in cleaning the water tubes in the convective section of the boiler. Due to much better ash retention in the present combustor, the stack gas temperature at the boiler outlet has remained in the one average over 100°F lower with coal firing than in the Williamsport installation. Therefore, periodic sootblowing has reduced the stack gas temperature by less than 100°F compared to well over 100°F in the previous unit.

Other Improvements in the Combustor-Boiler Operation: A key objective of this test effort is to introduce improvements that increase reliability of the entire system, reduce losses, and reduce component and operating costs for future commercial systems. In connection with this the following improvements were introduced:

Since this is an air cooled combustor, with some or all of the combustor cooling air used for combustion air, control of the air flow is very critical to proper combustor operation. The air cooling configuration was designed on the basis of the operating results obtained in the previous combustor. This configuration was based on the elaborate combustor cooling scheme that was used in the previous combustor. However, the initial group of tests in the previous quarterly period revealed that this complex control scheme was not necessary. In addition, the control scheme limited the ability of the combustor to operate under fuel rich conditions and it also resulted in too high excess air conditions in the boiler. Accordingly, the combustion air configuration was substantially changed early in this quarter to correct these deficiencies.

In the course of making these corrections it was determined that the pneumatically controlled valves purchased for the present combustor were very susceptible to breakdown. On the other hand, the previous valves which have been in operation since 1987 continue to perform satisfactorily.

The controller on the coal feeder was upgraded by replacing the motor starters for the bin vibrators and rotary valve, by improving the coal level control, by improving the coal metering and the pneumatic coal feed to the combustor.

In the previous combustor an elaborate pneumatic control system had been developed for assuring uniform feed of coal into the combustor. In the present modified coal feed system, this control system has not been needed.

The refill cycle to the feedwater heater was shortened to reduce steam pressure fluctuations in the boiler.

Attempts to use a pitot tube with a differential pressure instrument to measure the steam flow from the boiler have been to date unsuccessful. In the previous installation an orifice plate had been used with no difficulty. The steam blowoff piping is such that an orifice plate cannot be inserted without extensive repiping.

The heatup and cooldown cycles on daily operation have been greatly shortened. From a cold boiler start, coal firing is initiated in about 2 hours of operation on gas and oil. From a hot boiler start, coal fired operation begins within 1 hour. Also, the quantity of gas used for heatup is about one-sixth of that use in the previous combustor, and the oil use is about one half. Cooldown from high rates of coal firing to complete shutdown requires about 1 hour. This has resulted in substantial saving in gas, oil, and combustor cooling water consumption.

The above and other incremental improvement have greatly improved the operation of the entire facility to the point where it can now be operated with only two operators, compared to an average of 5 in the previous combustor.

Summary of Slag Retention, SO_2, NO_x Reduction

The tests in this quarter resulted in about the same level of slag retention and NO_x reduction that were initial slagging operation tests in the second quarter. The analysis of this data is incomplete. However, generally the NO_x and slag retention data are similar to that reported in the previous quarterly report. The lowest NO_x measured at the stack in the present quarter was 0.41 lb/MMBtu, (reported as NO2). No correlation of the NO_x data to combustor stoichiometry has been made as yet. However, based on the absolute magnitude measured, it appears to be similar to previously reported results in the Williamsport installation.

Slag retention is in the same range as observed in the previous quarter, namely, about 2/3 of the mineral matter is retained as slag in the combustor. Of this amount about 95% is retained in the combustor as slag wall replenishment or drained through the slag tap. A minor amount ranging from 0% to about 5% flows out of the exit nozzle to a combustor-boiler interface section from which it can be readily removed during combustor operation.

Ash deposits in the boiler continue to be modest and have as yet not required real time removal from the boiler floor. The bulk of the mineral matter is collected as fly ash in the baghouse.

SO_2 Reduction in the Combustor: Figure 5 in the previous quarterly report showed the SO_2 reduction measured at the boiler outlet as a function of sorbent injection into the combustor or furnace section of the boiler. This figure showed the actual instrument reading without any correction factor. In that report, it was stated that there was a need to clarify the proper correction factor to be used for the pulsed fluorescence SO_2 instrument. According to the manufacturer, if a

calibration gas containing SO_2 (500 ppm in our case) in a nitrogen atmosphere is used, the actual instrument reading must be increased by a factor of 1.35 to 1.38. Late in the present quarter, using dry air in place of nitrogen it was determined that the calibration factor for nitrogen was 1.25 not 1.35 to 1.38. Thus the SO2 reduction data in figure 5, which is reproduced in this report as figure 1, was reduced by 20%.

The best method for determining SO_2 reduction is to compare operation with and without sorbent injection. However, as some of the sorbent is used for slag conditioning, there is always some SO_2 reduction at very low sorbent injection rates. Therefore, in the present quarter the emphasis has been on determining the general relationship between sorbent injection and SO_2 reduction. Specifically, several different locations of sorbent injection were tested. The major differences between tests were injection location and quantity and type of sorbent. As reported many times previously, calcium hydrate is about three times more effective than limestone in sulfur capture, and this material was used exclusively for SO_2 control. Specifically, three injection locations were used. One was to mix the sorbent with the coal, the other was to inject the sorbent independently near the coal injection location, and the third one was direct injection into the furnace section of the boiler.

The furnace injection yielded the best reduction in the tests of this period. Injection of calcium hydrate into the boiler at a Ca/S mol ratio of 3.7 yielded a 72% reduction in 3.6% sulfur coal at the stack downstream of the baghouse. At a Ca/S ratio of 4.85, the reduction was 64% at the boiler outlet to the stack and 75% downstream of the baghouse. This reduction is in the same range as was measured with boiler injection of calcium hydrate in the Williamsport facility, where 81% reduction was measured at the boiler outlet with a Ca/S of about 4.

This result shows some modest improvement in the sulfur capture due to humidification is obtained upstream of the baghouse. However, this is almost insignificant compared to the reduction achieved in the combustor and/or boiler. Note that the high Ca/S ratio is not indicative of the calcium utilization because injection was only at one point to the side of the combustion gas inlet to the furnace. A post test inspection revealed that a substantial quantity of the hydrate was deposited on the floor of the furnace section of the boiler. It is probable that much of this hydrate did not react with the combustion gases. In view of this high deposition rate in the boiler, it was decided defer further work on this approach and focus on combustor injection of the sorbent. This latter approach has the added benefit that the reacted sorbent can be dissolved in the slag.

A series of tests were performed with injection of calcium hydrate into the combustor. Here the injectors used limited the quantity of sorbent that could be injected. Consequently a series of modifications were made to allow a greater rate of injection. This was especially the case when the sorbent was mixed with the coal and pneumatically injected. Here the quantity of sorbent was limited to a Ca/S mol ratio of less than 3 in the high sulfur coal. Recent work has corrected this problem and higher level of sorbent have now been injected with improved sulfur capture. This work will be reported at the end of the present (4th quarter 1996) reporting period. The tests in the present reporting period (3rdQ,1996) yielded SO_2 reductions at the boiler outlet of up to 50% at Ca/S mol ratios of less than 3.

Substantially better SO_2 capture results have been obtained in the most recent tests. Therefore, further comments on the results of the present reporting period will be deferred until these tests are completed.

Conclusions: The results of the test effort in the present third quarter of 1996 confirmed the conclusion from the initial tests in the previous quarter, that this second generation combustor's performance is very much superior to the previous first generation 20 MMBtu/hr combustor that was tested in Williamsport. The present combustor-boiler system has all the key features that would be incorporated in a commercial system. The test effort also resulted in substantial progress on the auxiliary components and sub-systems of this technology. A most encouraging result is that the combustor-boiler system can be rapidly started and shut down in single shift operation with no need for any internal maintenance between tests. At present the only factor limiting continuous operation is personnel availability and resources for the needed additional consumable storage. There is no evidence that the combustor could not be operated continuously.

4. Effort of the Next Quarter

The task 5 demonstration test effort will continue in the next quarter. The focus of the tests will continue to be on optimizing the combustor's combustion efficiency and environmental performance, especially SO_2 reduction. In addition, it is anticipated that the upgraded combustor process control software will be finally ready to allow essentially automatic operation of the combustor.

In addition, a major effort will be mounted to find joint venture partners, and/or licensees to market this coal fired combustion-steam generation technology worldwide in the 1 to 20 MWe output range. The results confirm that this technology is most probably the lowest cost coal fired system on the market.

Fig. 1: SO2 Reduction vs Ca/S Mol Ratio of Sorbent Injection

May/June 1996 Tests

Data Corrected 10/27/96 for Instrument Calibration