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

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Twenty First Quarterly Technical Progress Report

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ABSTRACT

In the first quarter of calendar year 1997, 17 days of combustor-boiler tests were performed, including one day 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 February 1997 in the task 5 effort to 74 days. This compares with a total of 63 test days needed to complete the task 5 test effort, and it completes the number of tests days required to meet the task 5 project plan. The key project objectives in the areas of combustor performance and environmental performance have been exceeded. With sorbent injection in the combustion gas train, NO_x emissions as low as 0.07 lb/MMBtu and SO_2 emissions as low as 0.2 lb/MMBtu have been measured in tests in this quarter. Tests in the present quarter have resulted in further optimizing the sorbent injection and NOx control processes. A very important milestone in this quarter was two successful combustor tests on a very high ash (37%) Indian coal. Work in the next quarter will focus on commercialization of the combustor-boiler system. In addition, further tests on the NO_x and SO_2 control process and on the Indian coal will be performed.

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1. EXECUTIVE SUMMARY

The present quarterly reporting period was the most productive, in terms of accomplishments and new results, for this project. Specifically, the most number of test days per month, were completed, the new NOx emission control process was fully validated, extremely high ash Indian coal was successfully burned and used to demonstrate high sulfur retention in slag, very coarse pulverized coal was burned, and improved calcium utilization with boiler injection of sorbent was implemented.

Test Operations Completed: In the first quarter of calendar year 1997, 17 days of combustor-boiler tests were performed, including one day 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 February 1997 in the task 5 effort to 74 days. This compares with a total of 63 test days needed to complete the task 5 test effort, and it completes the number of tests days required to meet the task 5 project plan. The key project objectives in the areas of combustor performance and environmental performance have been exceeded. With sorbent injection in the combustion gas train, NO_x emissions as low as 0.07 lb/MMBtu and SO_2 emissions as low as 0.2 lb/MMBtu have been measured in tests in this quarter. Tests in the present quarter have resulted in further optimizing the sorbent injection and NO_x control processes. A very important milestone in this quarter was two successful combustor tests on a very high ash (37%) Indian coal. The following is a brief summary of the key results:

NOx Emission Control with Sorbent Injection: In the previous Quarterly Report, the first results of a new method for reducing NOx emissions from the air cooled, 20 MMBtu/hr slagging coal combustor was reported. In the present quarterly reporting period a major focus of the tests was directed at understanding this process and on optimizing the NOx reduction. Sorbent injection in the combustion gas train for NOx control was implemented in the majority of the 17 test days performed in this period. The results validated the earlier observation that this process is very effective in reducing NOx emissions. Under fuel rich combustor operation, the additional use of sorbent injection lowered the NOx levels from about 0.4 lb/MMBtu to as low as 0.07 lb/MMbtu. This is by far the lowest emission level reported for coal combustion. Furthermore, and of even greater significance to the effort for NOx control in coal fired boiler, under fuel lean combustor operation, the NOx emissions were lowered from over 1 lb/MMBtu to as low as 0.2 lb/MMBtu. This result meets one of the three key environmental performance goals of this project, namely to lower NOx from coal combustion to at least 0.2 lb/MMBtu.

SO2 Reduction with Sorbent Injection into Boiler: It has been previously observed that over 80% SO2 reduction was measured with calcium based sorbent injection into the test boiler. However, the calcium utilization was relatively low. In the present quarter, an improved injection procedure was tested which resulted in much improved calcium utilization. SO2 reductions to 0.2 lb/MMBtu were achieved in 1.5% sulfur coal, representing a 90% reduction in sulfur emissions. Testing was initiated on this procedure with higher sulfur coal, and it will be completed in the next quarter.

High Ash Indian Coal Tests: Two 1 day tests were implemented with a 37% ash, low 0.4% sulfur Indian coal. In the first test, the coal was successfully burned with excellent slagging, and with fairly low levels of NOx and SO2 emissions. The latter result was achieved despite operation at high excess air conditions where these emissions are at a maximum. In addition, in a parallel DOE sponsored project, 20% of the sulfur injected into the slagging combustor in the form of gypsum remained in the slag. This is over two times the highest level reported previously. Due to the low solubility of sulfur in liquid slag, previously measured sulfur levels ranged from negligible to at most 10%.

Coarse Coal Combustion: Due to the high cost of pulverizing coal, commercial slagging coal combustors use crushed coal. However, this operating condition results in extremely high NOx emission levels. Coal Tech has used finely pulverized coal in a size range found in conventional coal fired boilers, namely 70%, passing 200 mesh (average size 74 micrometers) in almost all prior tests. One brief test was implemented in the present period with a very coarse coal. Due to the higher density of this material, the air fuel ratio was set too low for complete combustion, resulting in excess carbon loss. If time permits, this test will be repeated.

Combustor Operation: Continued incremental improvements were made in this period on various elements of the combustor-boiler system. These were designed to improve operation and reliability of the various components in this system. For example, an improved air delivery supply was installed for sorbent injection and slag operation was modified to improve reliability.

Conclusions: The total of 74 test days completed in task 5 by the end of this quarter without any significant refurbishment of the combustor indicates that the combustor is nearing commercial readiness. The modifications and maintenance performed are relatively minor in nature. Most of these modifications are the result of the daily startup and shutdowns and the frequent changes in operating conditions. An indication of the excellent performance of this combustor is that a total of 17 days of combustor operation was implemented in January and February

Very significant new results were obtained in this quarter, including confirmation of the sorbent injection process for NOx control, successful operation with high ash Indian coal, high sulfur retention in slag using the Indian coal, and improved sorbent injection into the boiler to reduce SO2 emissions. These results represent a major advance in the operation of the slagging combustor under stringent environmental control conditions.

2. RESULTS AND DISCUSSION

2.1. PROJECT DESCRIPTION

2.1.1. 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 NOx 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 NOx emission goal will require a modest improvement over maximum reduction achieved to date in the first generation combustor to a level of 0.26 lb./MMBtu. In the present second generation combustor, the best NOx levels with fuel rich conditions in the combustor was in the range of 0.3 to 0.4 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.

2.1.2. Technical Approach

2.1.2.1. 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, 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. 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. NOx 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. Recently this result has been duplicated in gas samples taken in the boiler furnace. However, the SO2 reduction in the stack for the same conditions were less, and no conclusive explanation for this has been as yet been found.

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 refurbish-ment.

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.

2.1.2.2. 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. For a number of reasons, this effort is being implemented in single daily shift operation with minimal combustor refurbishment between tests. The 500 hours are thus equal to 63 days of single shift operation. As of the end of the present reporting period, 57 test days have been completed.

Task 6. Decommissioning Test Facility

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

2.3. PROJECT STATUS.

2.3.1. Task 5. Site Demonstration

Background: The installation of the combustor-boiler facility at the Philadelphia site was completed at the end of 1995 and initial shakedown tests began in December 1995. 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 mid-1996. Coal is delivered in groups of 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 at Coal Tech. As a result of this simple and low cost procedure, all the tests in task 5 were implemented with this method. Also, with the resources available to this project, it was not possible to perform round the clock combustor operation. Therefore, all the tests were performed in single day shifts. Thus the 500 hours are equal to 63 days of single shift operation. This procedure provides a more rigorous test of the combustor durability because the many start up and shutdowns place a greater stress on the combustor internals.

The effort in the present quarter was the most productive in the Task 5 test effort. A total of 17 days of testing was completed in a two month period. This included a one day test in a parallel DOE project on sulfur capture and retention in the slag of the combustor. This brings the total number of test days to 74, versus the 63 days planned. These tests have shown the need for additional tests to clarify the two major advances made in this quarter, namely greatly improved NOx control and successful combustion of a very high ash (37%) Indian coal.

The 16 tests on the present project focused on optimizing the NOx control process that was discovered at the end of the previous quarter, and on further improvements in the combustors operation. In addition, an outside company was retained to sample stack gases for particulates and combustion gases. As a result of the success with the high ash Indian coal, this coal was used in the parallel project to test sulfur retention. As predicted, due to the high ash content of the coal, 20% of the sulfur injected as gypsum remained in the slag. This sulfur content is more than twice the highest level previously measured, and it is due to the very high slag mass flow rate.

The following highlights the results of the tests in the present reporting period.

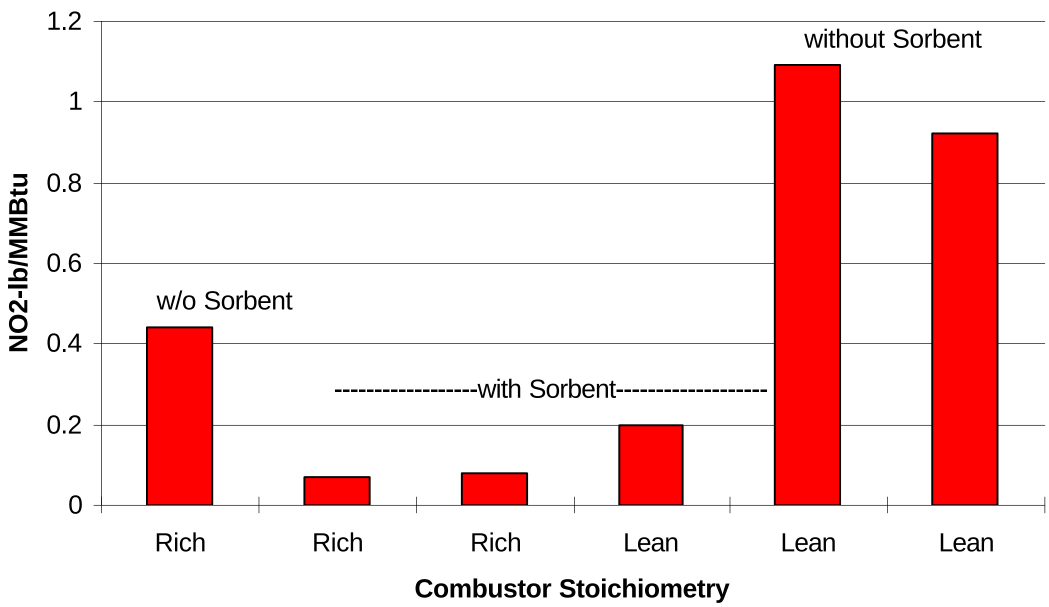
2.3.1.1. Combustor-Boiler Tests:

January 1997 Combustor Tests: The tests in the present quarter were performed in January and February and the results are reported for each month separately. Ten test days were performed in January, on the 6th, 7th, 8th, 10th, 15th, 16th, 21st, 23rd, 28th, and 30th. This brought the total number of test days on this combustor to 67 days, and it completed the required test days for task 5. However, in view of the excellent progress made in these tests, additional testing was performed in this quarter and additional tests are planned for the next quarter.

In addition to the high ash Indian coal tests and the NOx control tests, important incremental improvements were made on components of the system. A simpler and much more thermally efficient slag tap assembly was tested, and a more efficient means of feeding the sorbent powders was installed and tested. Also, as components wore, important information on reliability and equipment quality was accumulated. For example, high pressure fans are obviously a core component in an "air cooled" combustor. To date, reliability problems have been encountered in the fans supplied by three different manufacturers, some of which were manufacturing defects. For example, the bearings on the high pressure fan in current use have been noisy since its purchase and the noise has recently increased. On replacement of the bearings in January, it was determined that the fan shaft had not been properly secured during assembly at the factory. This accounted for the degradation of the bearings.

<u>NOx Control Tests:</u> The tests on January 6th, 7th, 8th, and 10th focussed on NOx reduction with sorbent injection into the combustion gas flow train. Operation under both fuel rich and fuel lean conditions was performed. Various methods of injection were tested resulting in different degrees of NOx reduction. Figure 1 shows the results obtained in the tests of January 7th. The greatest percentage reduction was obtained under fuel lean conditions in the combustor, with over 80% reduction to 0.2 lb/MMBtu. Under fuel rich conditions, a value of NOx as low as 0.07 lb/MMBtu was been measured. In all the tests, when the injection ceased, the

Figure 1: NOx Emission in the 20 MMBtu/hr Combustor with & w/o Staged Combustion & with & w/o Sorbent Injection- 1/7/97 Test



NOx level returned to the prior non-sorbent value. Various methods of injection were tested in order to optimize this process. A considerable amount of information on this NOx control process has been accumulated in these tests and in subsequent tests in February. Some of these data will be reported at the DOE NOx Control Conference on May 15, 1997. In addition, the data is still being evaluated. Consequently, only general information on the results are given here.

As noted, the results in figure 1 are typical of the results obtained with sorbent injection under fuel rich and fuel lean conditions in the combustor. The figure shows that the NOx reduction level achieved by staged combustion in the combustor is augmented by the sorbent injection process to approximately the same degree.

Since the description on these data may not always align with the graph, the following elaboration is given. The first and last two of the six columns represent the fuel rich and fuel lean NOx emissions, reported as NO_2, as measured without sorbent injection downstream of the combustor. The middle three columns show the result for rich and lean combustor conditions with sorbent injection downstream. Note that the reductions are proportional to the initial NOx levels. Therefore, to achieve the lowest NOx levels, 0.07 lb/MMBtu in this case, fuel rich staged combustion is advantageous. However, this condition leads to unburned carbon in the fly ash as well as potential increased corrosion of boiler tubes due to sulfur compounds in the gases.

The NOx reduction achieved with this process varied according to the quantity of sorbent and the injection process. Numerous graphs similar to the one some in figure 1 were obtained from the NOx control tests in January and February. However, each graphs consumes substantial amounts of floppy disc space, and as this report must be submitted to DOE in disc format, the number of floppy disc required would grow substantially. Therefore, in the interest of economy and in view of the fact that all aspects of these data have not yet been evaluated, they are not included in this Report.

The significance of the new NOx results is that the second of the three emission goals of this project has now been achieved. The first one, SO_2 emissions below 0.4 lb/MMBtu was achieved earlier in the project. SO_2 levels as low as 0.2 lb/MMbtu have been measured at the stack in coal with 1.3 to 1.7 % sulfur. The NOx emission goal was 0.2 lb/MMBtu has now been achieved. The particulate goal is 0.02 lb/MMBtu. The baghouse in use is able to achieve this result. The results of the stack particulate measurements in February will be discussed below.

The next two tests on the January 15th and 16th involved injection of a mixture of metal oxides that simulated an artificial coal “ash”. The objective of the tests was to evaluate ash replenishment of the combustor wall using oxide particles that are large enough to be retained in the cyclonic flow in the combustor. One of the metal oxides agglomerated and plugged the pneumatic feed line. This problem could have been corrected if the pneumatic capacity of the mixture line had been greater. On several previous occasions, a diesel compressor had been rented for this purpose. However, this proved to be an unsatisfactory solution, and in order to solve this problem once and for all, the decision was made to acquire added blower capacity. One option, to install a higher capacity motor on the existing blower was eliminated as it would have driven the blower too near its upper manufacturer design point. Accordingly, a second high pressure blower was acquired, and it was installed for the later tests in January.

A second objective of these two tests was to investigate the effectiveness of liquid lime injection into the boiler and the stack as a means of reducing SO2 emissions. Several injection methods were tested, none of which proved satisfactory. Both the injection methods proved to be unreliable and the measured SO2 reduction was relatively small. It is not known at this time whether these results are due to the injection method, the condition of the lime, an improper temperature range, or inadequate residence time. It is suspected that the injection method was the most probable cause of the poor results because excellent results have been achieved with powder hydrate injection in the boiler.

To assure that these results were not due to instrument errors, replacement O2, NO, and CO sensors were purchased. The results were the same. Furthermore, on February 20^{th} an outside stack testing company was retained to measure the stack gas samples, and the results were in reasonable agreement with the in house instruments.

The primary purpose of the test of the January 21st was to burn all the remaining coal in the pulverized coal bin. This was done to allow testing of the high ash Indian coal, to be described below. Again the opportunity was used to further test sorbent injection for NOx control under different operating conditions. Again substantial NOx reduction were measured. Once all the NOx tests are completed, the results will be analyzed to determine the controlling parameters. It is to be noted that there are significant differences between the various injection methods.

The Indian Coal Tests. As early as 1989, Coal Tech performed tests in the Williamsport 20 MMBtu/hr combustor in which coal fly ash was injected into the combustor with coal to achieve over 50% ash content in the mixture. However, due to the small ash particle size, (<10 microns), much of the ash was blown out of the combustor. The highest ash content in coal tested was about 15%. Last fall, a substantial number of tests were performed in which the artificial ash was injected into the combustor. These tests were performed for the parallel sulfur in slag project, and in the present project, as reported above. But these tests had specific objectives and they may not represent actual conditions of combustion of high ash coal. The latter coals are widely available in certain European and Asian countries.

At the DOE Clean Coal Conference on January 9th, the PI learned from DOE-FETC personnel that several tons on 37% ash, 0.4% sulfur, 8100 Btu/lb Indian pulverized coal were stored at a DOE warehouse in Pittsburgh. It was shipped to Philadelphia, and on the 23rd and 28th tests on this coal were performed. The results were excellent, far exceeding expectations. Excellent slagging was achieved and the ash deposits on the combustor wall substantially reduced the wall heat transfer.

In view of the excellent results with this coal, the second test on the 28th was performed under the parallel sulfur in slag project. Gypsum was injected to determine the suitability of high ash flow rates on retention of sulfur in the slag. As observed previously, the calcium sulfate greatly increased the slag viscosity. As a result, slag removal from the slag tank nearly ceased late in the test. After draining the slag tank at the end of the test, slag were found to have filled the slag removal duct beneath the combustor. It was very easy to break it apart and remove it. The results of this second test on Indian coal are contained in the Technical Quarterly Report for that project for the period 1/1/97 to 3/31/97.

The following two curves show the results of the SO2 and NOx emissions obatined during the two Indian coal tests:

Figure 2: SO2 Emissions with Indian Coal vs SR1. -1/23/97 Test

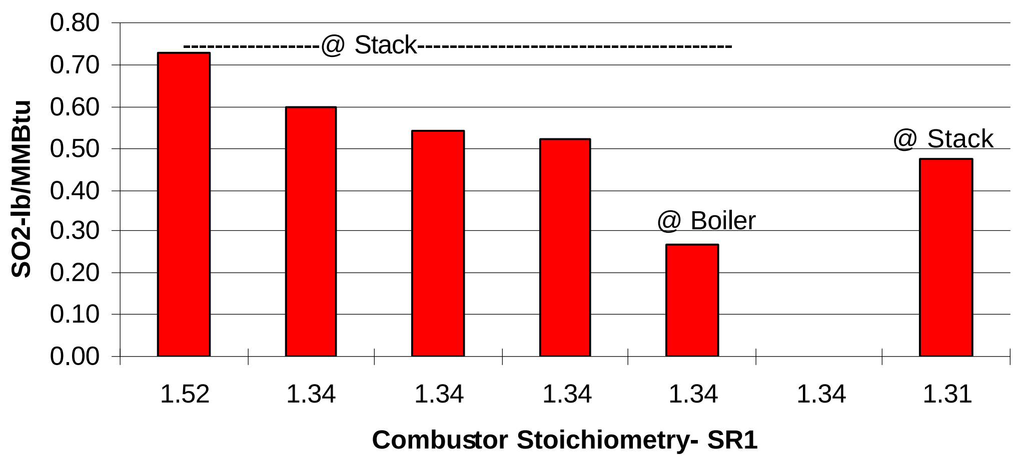
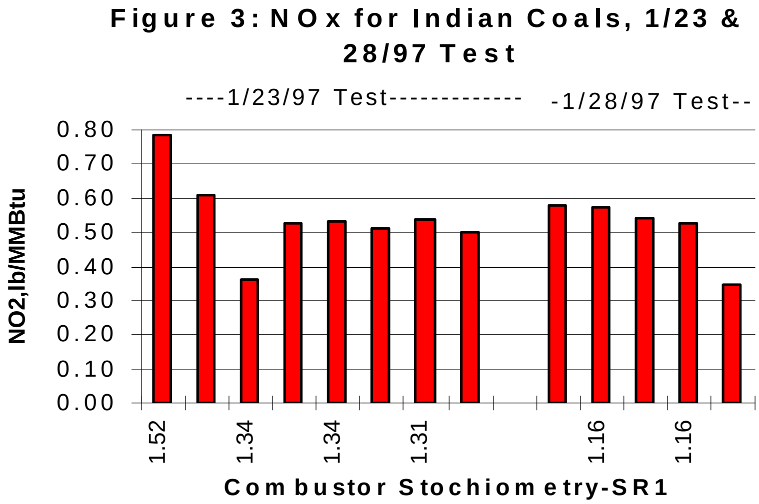


Figure 2 shows the SO2 results measured with a probe in the boiler and at the stack outlet from the boiler. The former probe always yields a much lower reading that the latter. No conclusive explanation has been obtained for this result. These results were obtained under high excess air conditions where SO2 emissions are highest. No special sorbent injection to control SO2 emissions was used. The average 0.5 lb/MMBtu emissions are below New Source Performance Standards of 0.7 lb/MMBtu, and they are near the 0.4 lb/MMMtu standard for this project.

Figure 3 shows the NOx emissions measured for the Indian coal tests. These tests were conducted under high excess air conditions and one notes that the NOx emissions average only 0.5 lb/MMBtu which is excellent considering to no effort was made to reduce the NOx level by staged combustion or sorbent injection in the boiler.

Based on these limited results it is concluded that firing Indian coals in the air cooled combustor yields excellent slagging performance as well as acceptable SO2 and NOx emissions.

In the final test in January the low ash, high HHV bituminous coal used in the previous tests was used. In this test much of the slag deposited on the combustor walls during the previous Indian coal test was released. Also in this test, the new blower was used to inject calcium hydrate into the combustor and into the boiler. The SO2 reduction in the combustor was about 50% at a Ca/S for hydrate of 2. This compares with a reduction of about 1/3 at a Ca/S mol ratio of 1.8 for limestone injection only. The SO2 reduction from boiler injection of dry pulverized were about the same due to limitation in the injection rate from the small pneumatic feed line. It is planned to repeat this test with a larger feed line in early February.



February 1997 Combustor Tests Seven days of combustor tests were performed on this project during this month, on the 6th, 10th, 13th, 17th, 18th, 20th, and 27th. The focus of the tests in this month were on optimization of SO2 and NOx control by injection of sorbents into the combustion gas flow train downstream of the combustor, on modified operation of the slag tap, and on stack gas testing using an outside stack gas sampling company.

NOx Results: In all the tests of this month, part of the focus was on NOx reduction with sorbent injection into the combustion gas flow train. Operation under some fuel rich and mostly fuel lean conditions were performed. Various methods of injection were tested resulting in different degrees of NOx reduction. As in the previous month, the number and nature of the sorbent injectors were changed from test to tests. A number of unusual results were observed. These operational results are still being evaluated. In general, NOx reductions ranged from over 50% to as much as 80%, with levels as low as 0.1 lb/MMBtu measured.

SO2 Reduction: Various methods of injecting sorbents into the hot gas stream, downstream of the combustor were tested. Furnace injection had been attempted earlier in this project. However, the Ca/S mol ratio in those tests was relatively high. In the present tests, the objective was to minimize the Ca/S mol ratio to below 3. SO2 reductions ranging from 50% upstream of the baghouse to 90% downstream of the baghouse were measured. In the latter case, the SO2 measured was as low as 0.2 to 0.3 lb/MMBtu. These tests were performed with low sulfur coal, S< 2%. Later in the month, higher sulfur (S>2%) coal was received. However, due to a number of operational problems, the number of tests with hot gas stream sorbent injection was limited and further tests will be performed in the next quarter. Before reporting the details of these SO2 reduction results, the sorbent injection tests into the boiler will be completed. The reason for this is that due to various operational factors, the optimum conditions needed to achieve the best SO2 reduction was not achieved. However, the results to date do show superior calcium utilization compared to the boiler furnace sorbent injection tests earlier in this project and in the previous 20 MMBtu/hr project in Williamsport, PA.

Combustion Efficiency: A technique that had been developed in Williamsport, but not used here, was tested to determine its impact on combustion efficiency. It was found that with its use, the carbon moNOxide level in the stack gas was reduced from the range of several 100 ppm to under 100 ppm. This occurred with fuel lean conditions in the combustor.

In almost all prior tests, the combustor was operated at stoichiometric ratios of unity or fuel rich conditions in order to minimize NOx emissions. However, with the success of the sorbent injection method for NOx control, most of the test conditions in the combustor are now fuel lean. With the more effective uniform coal feed rate tests this month, the fuel lean conditions resulted in consistent CO levels under 100 ppm.

Stack Gas Sampling Test: On February 20, an outside stack gas sampling company was retained to measure the stack gases, O2, CO2, CO, NOx, SO2, NH3, and stack particulates by EPA method 5. The purpose of the stack gas measurements was to determine the accuracy of Coal Tech's stack instruments. The O2, CO, CO2, and SO2 were in general agreement within 10% to 15% of the values obtained with Coal Tech's instruments

The stack particulate tests were designed to verify the performance of the baghouse. Surprisingly, the results showed particulate emissions in the range of 0.3 lb/MMBtu, or almost a factor of ten higher than guaranteed by the manufacturer. There was no evidence from visual stack gas observations that the baghouse had failed. Internal inspection of the baghouse walls on the clean (downstream) side of the bags and on the stack duct walls revealed a thin crust of material, that could be rust. This rust could flake off and impact the particulate measurements. The cause of the condensation is the numerous startup and shutdowns There is no indication that the result was due to bag failure. Nevertheless, a test is planned to measure the integrity of the bags.

Coarse Coal Test: A brief test was performed on February 16 in which a coarse coal, 30% passing 100 mesh, was used compared to the normal 70% passing 200 mesh used regularly. The volumetric coal feeder had not been calibrated for this test and it was determined that the actual feed rate was about 1/3 higher than normal. This was due to the greater density of this coarse coal. Consequently, the actual feed rate was over 1600 lb/hr, or over 21.5 MMBtu/hr, compared to the anticipated value of 1080, or 15 MMBtu/hr. Some unburned carbon passed out of the combustor since the combustor stoichiometry was only 0.84, or fuel rich. The test did not last long enough to determine overall combustion efficiency. However, it appeared from the brief run that this coarse coal could be burned efficiently if fuel lean conditions prevailed in the combustor. If time permits, this test will be repeated in the future.

3. CONCLUSIONS

The total of 74 test days completed in task 5 by the end of this quarter without any significant refurbishment of the combustor indicates that the combustor is nearing commercial readiness. The modifications and maintenance performed are relatively minor in nature. Most of these modifications are the result of the daily startup and shutdowns and the frequent changes in operating conditions. An indication of the excellent performance of this combustor is that a total of 17 days of combustor operation was implemented in January and February

Very significant new results were obtained in this quarter, including confirmation of the sorbent injection process for NOx control, successful operation with high ash Indian coal, high sulfur retention in slag using the Indian coal, and improved sorbent injection into the boiler to reduce SO_2 emissions. These results represent a major advance in the operation of the slagging combustor under stringent environmental control conditions.