QUARTERLY TECHNICAL REPORT NO. 29-32

FOR THE PERIOD OF

JANUARY 1 TO DECEMBER 31, 1998

AND

STARTUP TOPICAL REPORT

PREPARED BY

ALASKA INDUSTRIAL DEVELOPMENT AND EXPORT AUTHORITY

FOR THE

US DEPARTMENT OF ENERGY

UNDER

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1.0 ABSTRACT

BACKGROUND

The Healy Clean Coal Project (HCCP) was one of thirteen projects selected out of forty-eight proposals submitted in 1989 to receive DOE funding under Round III of the DOE Clean Coal Technologies Program.

The total project budget of $267 million was obtained as a $117.3 million grant from the DOE; a $25 million state grant appropriated in 1990; $69.9 million in advance funding from the Alaska Industrial Development and Export Authority (AIDEA); $25.3 million in interest earnings; $15.5 million from power revenues and contributions from project participants valued at $14.3 million.

Project participants were AIDEA as Owner; the Golden Valley Electric Association, Inc. (GVEA), a Fairbanks utility, as Operator (who will pay for the power generated under the terms of the power sales agreement); and the Usibelli Coal Mine, Inc. (who will furnish coal to GVEA). The draft documents for the environmental permitting process were completed in November of 1992, but the permit process took an additional two years to complete because of the close proximity of HCCP (in Healy, Alaska) to the Denali National Park. The architect/engineer for the project was Stone and Webster Engineering Corporation and HC Price Company was the general construction contractor. HCCP is located adjacent to GVEA's existing Healy No. 1 power plant, which was constructed in 1967.

PROJECT OBJECTIVES

The objectives of HCCP were to demonstrate an environmentally sound technology for burning coal, create additional energy generation to serve the Alaskan interior and to show the attractiveness of Alaskan coal in combination with developing modern combustion technology.

General construction began in May 1995 and was completed by November 1997. Demonstration testing of the completed plant, required under the federal grant provisions, started in 1998.

REGIONAL COAL SIGNIFICANCE

The project will enhance export potential of all Alaskan coal and reduce dependence on imported oil by 30 million gallons per year or save four billion cubic feet per year of natural gas. It will also provide stabilization for coal mining and power plant operation, augment or replace aging coal powered generation and lock in known base load power via a long term coal sales agreement.

The primary fuel fired in HCCP is a blend of run of mine (ROM) and waste coals. ROM coal is a subbituminous coal with a higher heating value range of 7,500 to 8,200 Btu/lb, a low average sulfur content of 0.2 percent, and an average ash content of eight percent. The waste coal is either a lower grade seam coal or ROM contaminated with overburden material having a lower higher heating value range of approximately 5,000 - 7,500 Btu/lb, average sulfur content of 0.15 percent, and average ash content of twenty percent. The project is to demonstrate the ability of slagging combustors and downstream flue gas desulfurization (FGD) equipment to utilize a lower grade coal than could otherwise be used effectively in an environmentally acceptable manner.

Coal (provided by the Usibelli Coal Mine, located near the project site) is pulverized and fed to slagging combustors.

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TECHNOLOGY DESCRIPTION

HCCP slagging combustors burn coal in a fuel rich, high temperature atmosphere to minimize formation of nitrogen and sulfur oxides and to remove most of the coal ash as slag (molten ash). The resulting low concentration of fly ash in the flue gas allows pulverized limestone to be added effectively (i.e., with little dilution by fly ash) to the combustor and converted by heat in the flue gas to lime (CaO). A baghouse catches the unreacted lime and other fly ash constituents downstream of a spray dryer absorber (SDA). A slipstream of these solids is recycled and slurried with plant waste water to remove sulfur dioxide by spraying it into the SDA. The process uses a conventional boiler that produces steam for a conventional turbine to produce up to 55 megawatts of electricity for use by GVEA.

The slagging combustor is designed to operate under fuel-rich conditions and utilizes staged combustion to minimize NO_x formation. These conditions are obtained using a precombustor as an integral preheater for firing additional coal in the second stage fuel-rich slagging combustor. Then combustion is completed with excess air in the furnace. The first and second stages of combustion produce a temperature high enough (approximately 3,000° F) to melt the coal ash, while reducing the fuel-bound nitrogen to molecular nitrogen (N_2). The third and final stage of combustion in the radiant portion of the furnace occurs at a lower combustion temperature to minimize thermal NO_x formation in an oxidizing atmosphere.

The slagging combustor process assists the reduction of SO_2 emissions by using ash constituents and injection of pulverized limestone into the hot gases as they leave the combustor and enter the furnace. Calcium carbonate ($CaCO_3$) in the limestone flash calcines to calcium oxide (CaO) which reacts with the sulfur compounds in the exhaust gas to form calcium sulfate. The flue gas leaving the furnace contains the remaining unreacted gaseous sulfur compounds (primarily SO_2), particles of calcium oxide and other fly ash particles. The flue gas leaves the boiler and passes through the SDA and a baghouse for further SO_2 and particulate removal prior to exiting through the stack.

The innovative aspect of the concept being demonstrated is a lower level of NO_x and SO_2 emissions by combustion and reuse of the unreacted lime, which contains minimal fly ash in the second stage SO_2 removal. A portion of the solids collected from the SDA vessel and the bag filter are slurried with water, chemically and physically activated and then atomized in the SDA vessel for second stage SO_2 removal. Third stage SO_2 and particulate removal occurs in the fabric filters in the baghouse as the flue gas passes through the reactive filter and cakes on the external surface of the fabric filters.

TECHNOLOGY AND PROCESS SUMMARY

The use of limestone in the combustor, combined with the recycle system, replaces the more expensive lime required by commercial spray dryer absorbers, reduces plant SO_2 emissions, and increases SO_2 removal efficiency. The integrated process has at times achieved SO_2 removal greater than ninety percent and NO_x emissions down to 0.2 pounds per million Btu. The integrated process, if proven successful and economical on a commercial basis, is suited for new facilities or for re-powering or retrofitting existing facilities. It will, hopefully, provide an alternative technology to conventional pulverized coal-fired boiler flue gas desulfurization (FGD) and NO_x reduction processes, while lowering overall operating costs and reducing the quantity of emissions.

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2.0 INTRODUCTION

This report encompasses the Demonstration Test Program Quarterly Technical Progress Report No. 29-32 and the Startup Topical Report for 1998.

During the first quarter of 1998, HCCP progressed from firing oil at part load to firing ROM coal at full load with the baghouse and SDA in service.

Particular startup activities and objectives for the first quarter were to:
- Gradually increase the combustors' loads to maximum
- Carry out load rejection testing on the turbine/generator unit
- Achieve minimum break-in time on both pulverizers
- Carry out cyclone vent air transfer to the boiler NO_X ports
- Place SDA system in service
- Place limestone injection system into service
- Carry out the commissioning of the dry and wet unloading system
- Some preliminary characterization of the combustors for lower NO_X
- Tune the SDA slurry system to receive, store, recycle and reject SDA and baghouse solids for continuous SO_2 removal
- Refine startup and operation procedures

Activities from April through December of 1998 focused primarily on the sequence of actions needed to achieve sustained firing of blended coal without accumulating excessive slag in the precombustors. Section 3 (Summary) of this report lists stated startup activities and demonstration goals achieved. Brief discussions are provided to explain deviations from the stated goals. Section 4 (Operation) gives detailed reports of operation in a chronological format, with supporting graphs, figures and tables followed by Section 5 (Equipment and System Problems), which addresses solutions to equipment and system problems encountered during operation.

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3.0 SUMMARY

The following are totals for coal and energy generation for 1998:

Coal: 155,000 tons
Energy generation: 232,000 MW hrs (gross)
Maximum load: 64 MW (gross)

Gross and net generation, along with oil and coal consumption, for 1998 are shown on a monthly basis in Figures 3.0.1, 3.0.2 and 3.0.3, respectively.

Accomplishments achieved during the first three months of startup are listed below:

- Maximum loading of the combustors was achieved at an approximate coal feed rate of 40,000 lb/hr on ROM coal. The coal feed system cyclone vent air was successfully transferred from the precombustor NO_X ports to the boiler. NO_X ports were established at coal flow in excess of 17,000 lb/hr for each combustor.
- Load rejections for the turbine over-speed tests were successfully completed.
- The baghouse system was placed in service and stack opacity was in compliance.
- Limestone injection and the SDA system were commissioned and SO_2 capture in the ninety percent range was achieved intermittently.
- The boiler sootblowing system was put into service.
- Precombustor and slagging combustor stoichiometry was controlled automatically using the calculated heating value of the fuel. This value is calculated from the boiler conditions. The automatic stoichiometry control maintains constant air/fuel ratio as fuel heating value (Btu/lb) varies. This control was successful through a wide range of coal heating values. Preliminary adjustments were made to the precombustor and slagging combustor stoichiometry to characterize its effect on NO_X while maintaining proper slag quality without plugging the precombustor became an increasingly important objective. This was achieved while also accomplishing the demonstration goals listed below.

Demonstration Goal	Successfully Completed by:
1. Tune boiler master	6/30/98
2. Tune O_2 trim	N/A*
3. Preliminary adjustments to combustor for low NO_X	6/30/98
4. Tune SDA/limestone feed for maximum SO_2 capture	Ongoing*
5. Combustor and SDA characterization tests	7/30/98*
6. Full load turbine rejection tests	4/30/98
7. Turbine/generator system stabilization testing	4/30/98
8. Continuous emissions monitoring system ratification	6/30/98
9. Emission compliance testing	6/30/98

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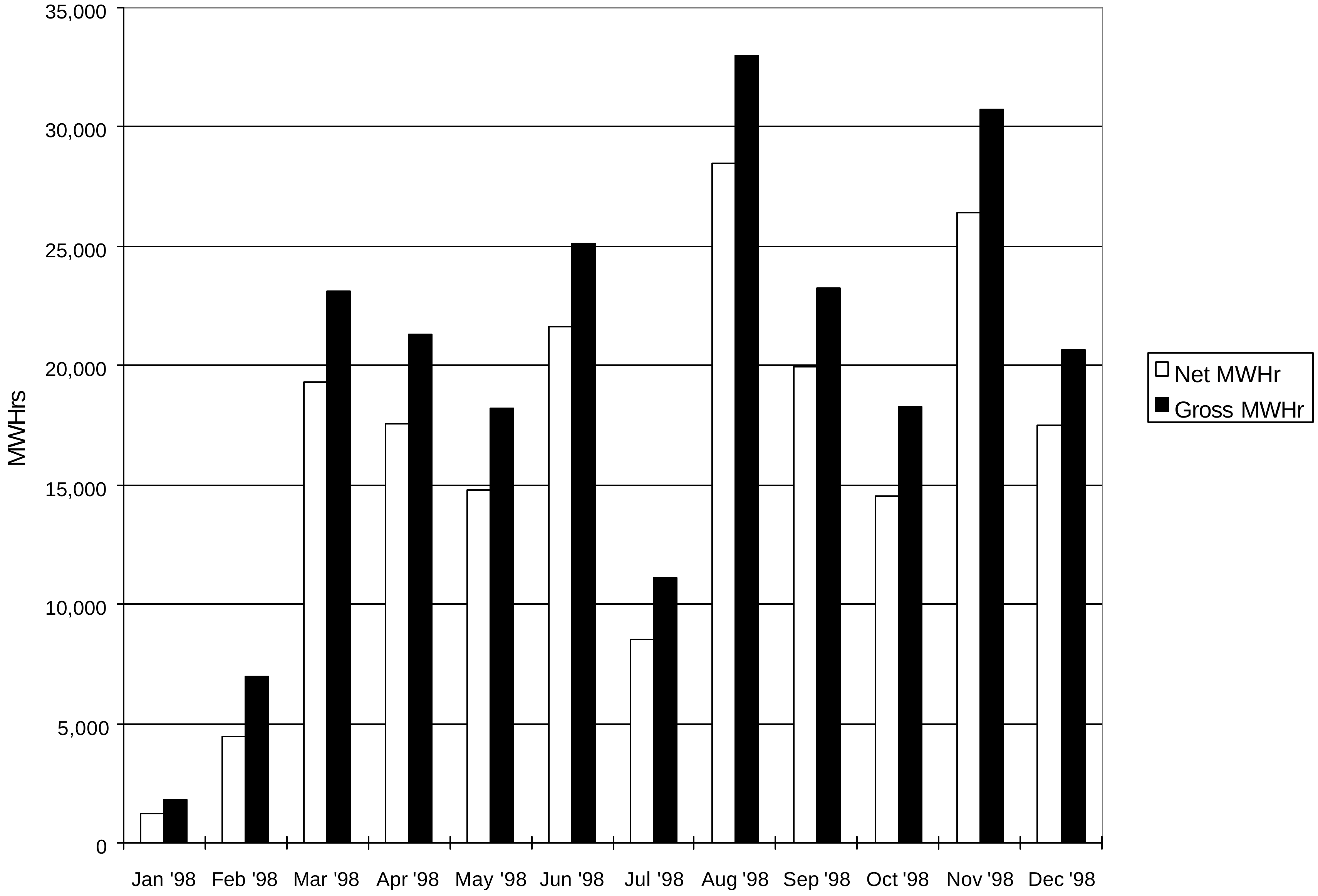
* Items discussed below

	Jan '98	Feb '98	Mar '98	Apr '98	May '98	Jun '98	Jul '98	Aug '98	Sep '98	Oct '98	Nov '98	Dec '98	Total
Oil (Barrels)	4,811	5,874	5,494	2,044	2,959	543	875	1,286	967	964	1,023	864	8,673
Coal (Tons)	275	4,077	13,403	14,845	11,890	15,995	7,884	21,140	15,831	12,788	21,977	14,693	87,586
Net MWHr	1,224	4,472	19,320	17,543	14,816	21,628	8,540	28,497	19,935	14,571	26,428	17,518	110,959
Gross MWHr	1,850	6,979	23,110	21,296	18,224	25,112	11,110	33,010	23,269	18,282	30,717	20,694	132,021

	Jan '98	Feb '98	Mar '98	Apr '98	May '98	Jun '98	Jul '98	Aug '98	Sep '98	Oct '98	Nov '98	Dec '98	Total
Net MWHr	1,224	4,472	19,320	17,543	14,816	21,628	8,540	28,497	19,935	14,571	26,428	17,518	110,959
Gross MWHr	1,850	6,979	23,110	21,296	18,224	25,112	11,110	33,010	23,269	18,282	30,717	20,694	132,021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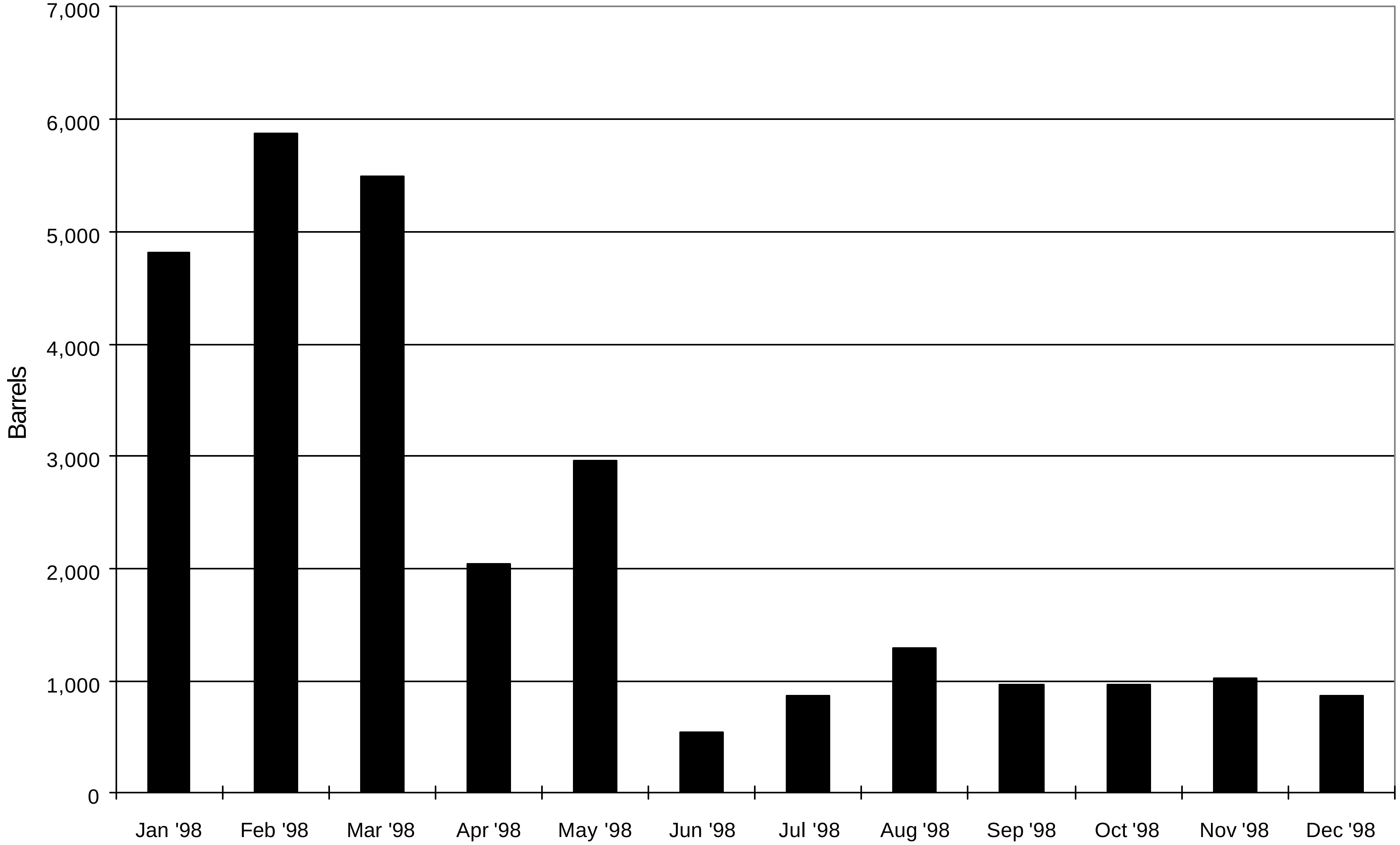

7,000
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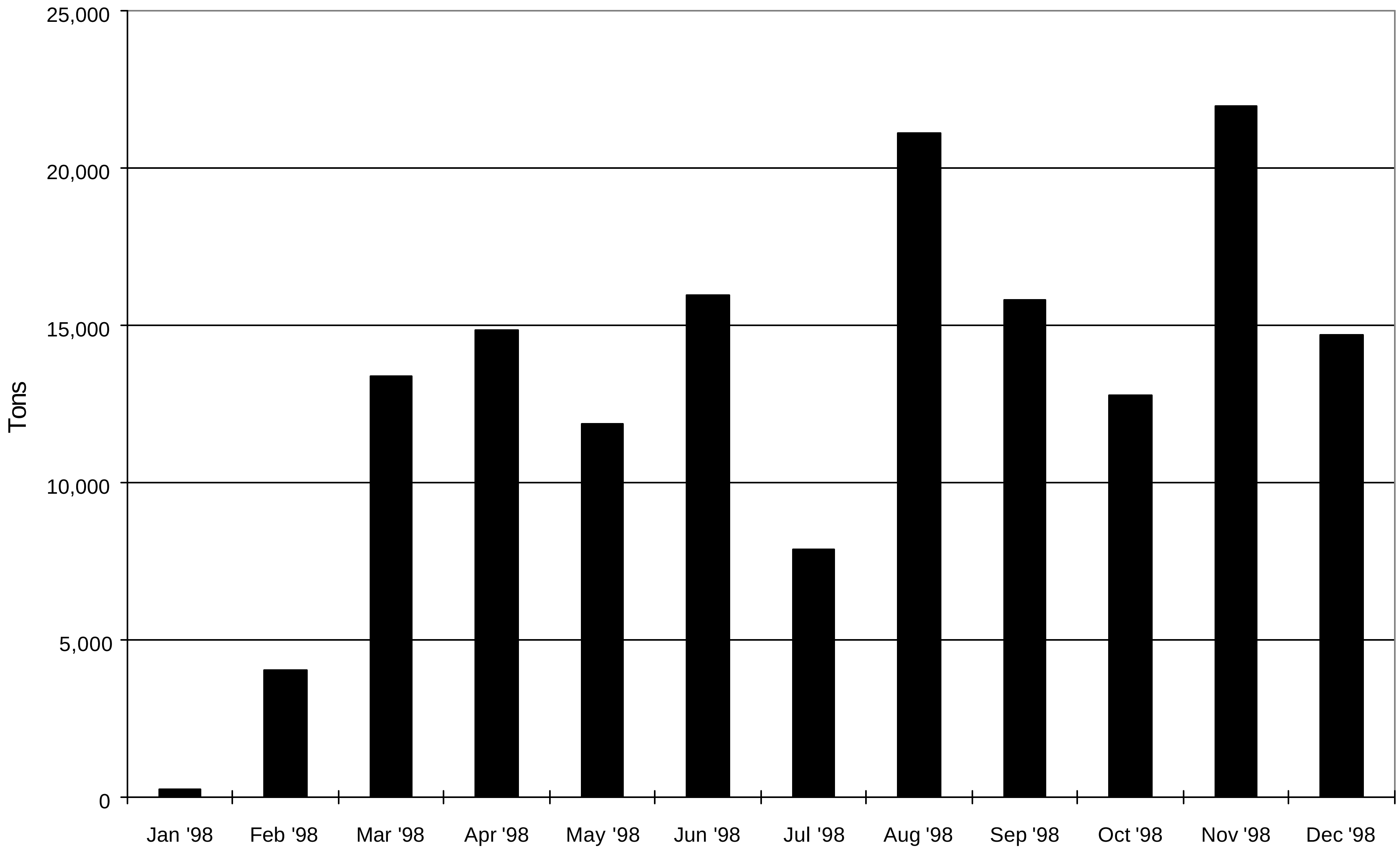

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Oct '98
Nov '98
Dec '98

TUNE O_2 TRIM

O_2 trim is the additional quantity of secondary air introduced to the furnace via either the boiler clean air NO_X ports or the overfire air ports. Because of the large mills required to pulverize the relatively low grindability coal at the Healy Clean Coal Project (HCCP), the quantity of air required to sweep them resulted in sufficient mill vent air flowing to the furnace NO_X ports to require the secondary furnace NO_X port and overfire air dampers to be closed. Therefore, no additional secondary air is typically required to obtain approximately twenty percent total excess air to the furnace.

TUNE SDA/LIMESTONE FEED FOR MAXIMUM SO_2 CAPTURE

The unit has run continuously within compliance, firing (in round numbers) 90,000 lb/hr of blended, 0.2 percent sulfur coal with a higher heating value averaging 7,000 Btu/lb, while injecting 25 lb/min of limestone and achieving 0.05 pounds per million Btu emission of SO_2. This corresponds to approximately ninety percent SO_2 removal with an overall Ca/S ratio of 2.0, assuming ninety percent $CaCO_3$ in the limestone and eighty percent conversion of $CaCO_3$ to reactive CaO. There is a time lag of several hours after increasing the rate of limestone injection into the furnace before the resulting FCM or flash calcined material (CaO resulting from thermal conversion of $CaCO_3$ to CaO and CO_2) passes through the baghouse hoppers, ash reclaim conveyors, recycle surge bin, recycle mix tank, feed slurry tank and, finally, the atomizer in the SDA. Because of this time lag, the variability in coal sulfur ash content and the need for HCCP to maintain SO_2 emission at no more than 0.10 pounds per million Btu, the risk associated with further maximizing SO_2 capture, versus optimizing limestone consumption, was not emphasized.

COMBUSTOR AND SDA CHARACTERIZATION TESTS

Test results indicate that, with this technology, emission of nitrous oxides was low and that limestone was effectively calcined in the furnace in sufficient amounts to supply reagent to the flue gas desulfurization system.

The goals for 1998 were to conduct the combustor characterization test program, evaluate the furnace sulfur dioxide removal as a function of the limestone fed into the combustor exhaust and to prepare the unit for commercial operation.

Reviewing the combustor technology, each combustor unit consists of two combustors, a precombustor and slagging combustor. The precombustor is provided to heat the combustion air for the slagging combustor and provide a gas swirl to improve the slagging combustor ash collection as molten slag. The precombustor heats the secondary air for the slagging combustor by burning thirty to forty percent of the total coal burned. The precombustor exit gas velocity is adjusted to control swirl, which affects combustion as well as the ash capture as slag in the slagging combustor with water cooled swirl dampers.

During the first quarter of 1998, the combustors fired oil and ROM coal (rather than blends with waste coal) to obtain operating characteristics with less difficult combustion conditions. The combustors performed well in all aspects. NO_X emission was as expected and significantly lower than permit limits. Slag accumulation in the precombustors was not excessive and the design amount (seventy to eighty percent) of the coal ash was rejected and captured from the slagging combustor as slag. Second and third quarter tests were performed to determine the effects of firing blended coal using up to fifty-five percent waste coal. The precombustor accumulated slag, when firing blended coal, to an extent that limited continuous operation. The third and fourth quarters were primarily dedicated to overcoming this problem. Various physical configurations and stoichiometric ratios were attempted to prevent slag accumulation in the precombustor. Slagging combustor stoichiometry was simultaneously maintained at an optimum level to minimize NO_X emission. Optimum slagging combustor stoichiometry was relatively independent of precombustor stoichiometry.

Initial tests with waste coal caused slag accumulation in the precombustor when the coal heating value was below 7,400 Btu/lb. Most slag accumulation was just downstream of the mix annulus. The accumulation was caused by 770° F air streaming in along the surface and creating a relatively cool area. Several tests were conducted to eliminate slag accumulation by changing the proportion of coal entering the precombustor (i.e., coal split), by adjusting the stoichiometry of the precombustor and by adjusting the precombustor swirl dampers to regulate precombustor exit gas velocity. The precombustor stoichiometry was adjusted to values significantly less than 1.0 in attempts to prevent formation of slag in the precombustor and to values close to and greater than 1.0 to cause the slag to be sufficiently fluid (or non-viscous) to drain out of the precombustor. The swirl dampers were suspected of damming the flow of slag, so they were opened wider. Swirl damper motor operation was difficult and impractical. None of the above changes eliminated slag accumulation. The dampers are now adjusted manually for full load operation.

The next set of tests dealt with configuration changes in the precombustor mix annulus area. Decreasing the open area of the mix annulus arc reduced the flow area of the mix annulus. This was not sufficiently successful, so efforts to enhance mixing at the mix annulus began. Pipe elbows were installed to direct the air entering the combustor from the mix annulus toward the center axis of the precombustor. The number of elbows was varied to cause high jet velocities to promote better mixing of the air from the mix annulus into the precombustor gas stream. These efforts improved the situation, but did not prevent eventual accumulation of slag.

Fluxing of the precombustors with limestone was attempted and appeared to be a marginal improvement; however, fluxing, by itself, was also unsuccessful.

The end result of the tests was a decision that the mix annulus air should be removed entirely from the precombustors and injected into the head end of the slagging combustors. By the end of the fourth quarter, modifications to accomplish this were performed and greatly reduced (and possibly eliminated) excessive slag accumulation in the precombustor.

Limestone calcination and sulfur dioxide removal in the furnace were tested, while attempting to resolve the precombustor pluggage problem. The limestone feeder was oversized and required a speed reduction to attain controllable results. Poor quality of the local limestone caused control difficulties, slurry piping flow/plugging problems and pugmill unloading plugging problems. Limestone calcination and sulfur capture in the furnace met or exceeded design expectations when ninety percent $CaCO_3$ limestone was metered into the system properly.

4.0 OPERATION

Operational history for 1998 is summarized in Appendix C.

4.1 GENERAL

The first quarter of 1998 was essentially devoted to placing equipment and systems into initial operation. This period is discussed below as the startup period. The months following the startup period are described below as the demonstration period. Final preparations for coal firing were completed during the first two weeks of October 1997. Golden Valley Electric Association (GVEA) delayed delivering coal until January 1998.

STARTUP OPERATION

Startup operation occurred during the first quarter of 1998. All plant systems were commissioned and placed in service.

The slagging combustors performed very well, and the combustor inspections during outages revealed good slag coverage in the slagging combustors areas. However, the precombustor NO_X port grooved end piping coupling gaskets leaked because of exposure to high temperatures. They were sealed by replacing the couplings with stainless steel expansion joints. The high temperatures resulted from the back circulation of combustion gas caused by low flow conditions in this piping, while firing oil prior to firing of coal.

The precombustor swirl damper drives proved to be undersized, and affected by surrounding temperature. Heat caused both the electric drive and the mechanical gears to fail so they were operated manually.

The pulverizers have performed well with no significant wear. Seam 6 coal (the uppermost layer of coal, which experiences contamination from weather and the top layer of overburden) and waste coal caused high pressure drops. This was mitigated by classifier adjustments and by controlling the quality of coal.

The mechanical seals on both pulverizer exhausters leaked. A new seal design requiring seal air was successfully implemented to stop the leaks.

Startup operation was also affected by a number of equipment problems with the slag ash removal system. The slag ash drag chain conveyor, transfer ash conveyor, and bucket elevator were modified to alleviate problems with plugging and jamming. A vibrator was added to the chute from the bucket elevator to the wet ash silo transfer belt to prevent the wet slag from plugging the chute and causing the bucket elevator to jam. Modifications to the slag ash drag chain conveyor breaker framework were made to prevent the flights from snagging on it.

Combustor coal flame detection was unreliable during the first quarter. The main problem of the scanners was slag covering the scanner so that the flame could not be detected. Additional scanners were added for redundancy and to allow for the cleaning of slagged over scanners while the remaining coal scanners detected the coal flame.

Boiler feed pump problems also caused several boiler trips. The boiler feed pump recirculation valve failed internally (not allowing minimum flow) causing Boiler Feed Pump B to experience water hammer. This resulted in damage to the pump seals as well as initiating pump trips because of the vibration. In addition, the recirculation valve for Boiler Feed Pump A did not fully shut-off recirculation to the deaerator during full load operation. This resulted in both feed pumps operating at full load when only one should be required, while the other should serve as a standby pump.

Section 5.0 (Equipment and System Problems) deals with the equipment problems in more detail.

DEMONSTRATION PERIOD

Operation focused on the objectives to determine the characteristics of NO_X emission reduction and to determine slagging characteristics in the precombustor and slagging combustor sections of the combustors. Emission of NO_X was primarily sensitive to slagging combustor stoichiometry and relatively insensitive to precombustor stoichiometry. Therefore, the discussion in Section 4.2 focuses primarily on precombustor stoichiometry and the precombustor configuration necessary to prevent slag accumulation in the precombustor, while maintaining the overall slagging combustor stoichiometry at its optimum (close to 0.80) for NO_X emission control. Detailed monthly descriptions pertaining to the combustors are provided in Sections 4.6 – 4.14.

COAL BLENDING

Testing during the second and third quarters established that precombustor slag accumulation was sensitive to coal quality. Waste coal constituents were unpredictable and since the heating value of waste coal sometimes exceeded that of run of mine (ROM) coal, coal blending from separate waste and ROM piles did not provide consistent coal quality. This problem was amplified by the inability to differentiate between the coal characteristics (primarily higher heating value) in Combustor A versus those in Combustor B. Limited success in melting out accumulated slag was achieved during June by supplemental firing of oil to raise the precombustor flame temperature.

The most effective method of achieving consistent coal quality was to create layers of ROM coal, waste coal, and coal fines in the yard pile and load a homogeneous blend of these layers. To accomplish this, the front end loader (provided for loading coal) was used to scoop vertically through the multi-layered pile. In addition, when loading coal into the silos, which feed their respective combustors, a diverter gate between Silo A and Silo B alternated coal flow between the silos after every fifty ton increment of coal loaded, to simultaneously provide a more homogenous and consistent quality coal to both combustors.

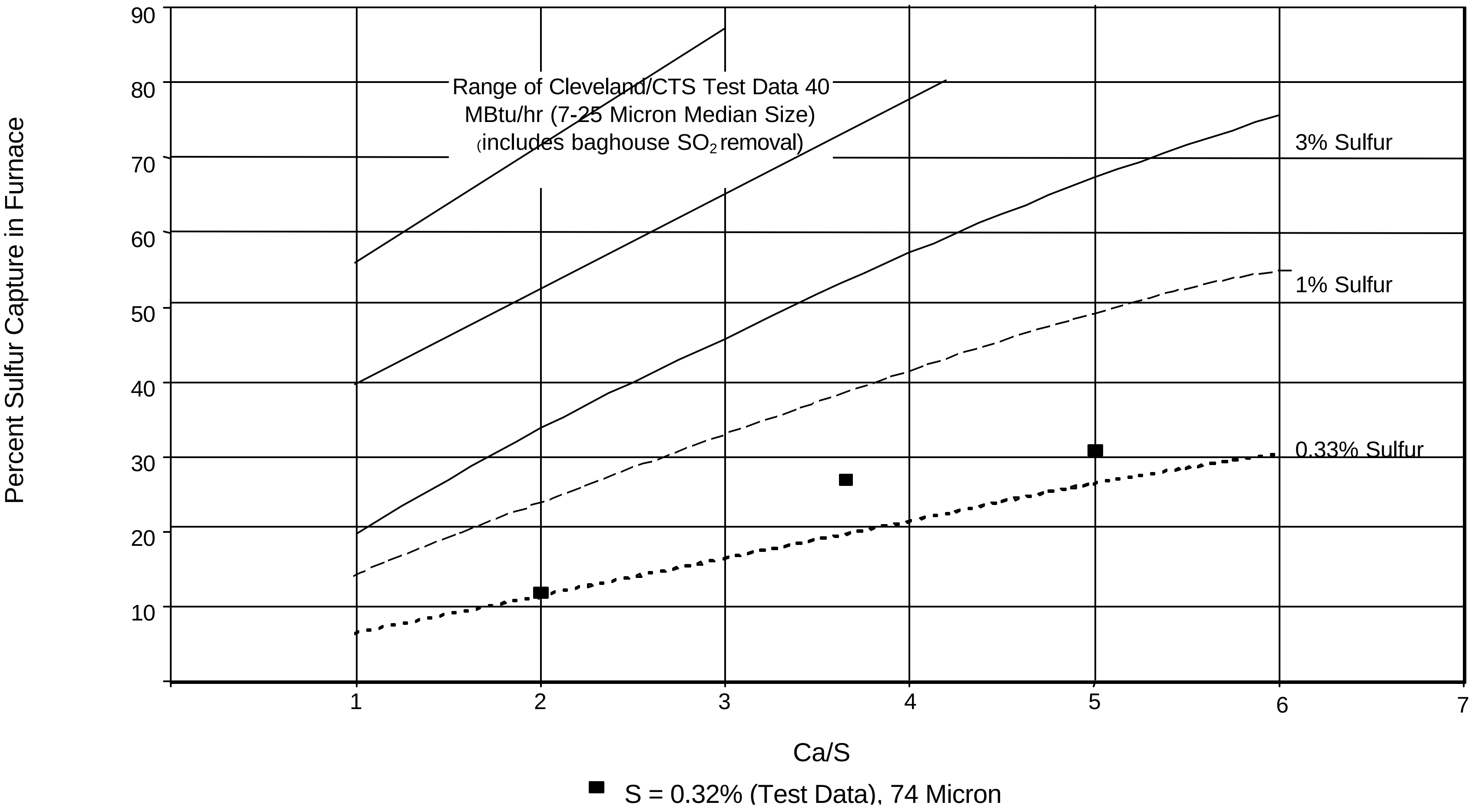
LIMESTONE INJECTION AND SO_2 CAPTURE

At the end of May, poor limestone quality (approximately sixty percent $CaCO_3$), in conjunction with the firing of relatively high sulfur (greater than 0.3 percent), high ash coal (greater than fourteen percent) and the affect on slag recovery (caused by lowering the exit velocity of the swirl dampers), resulted in poor SO_2 capture, even with stoichiometric ratios up to 5.0.

During two tests conducted in May, limestone flow rate was varied to assess its effect on SO_2 removal in the furnace and in the SDA. The limestone flow rate was varied over a range of 25 to 75 lb/min, which corresponds to a Ca/S ratio of 1.8 to 5.0, assuming a 0.4 percent sulfur in the coal. During test PERF-S4-8, conducted between May 27 and May 30, the SO_2 concentration at the SDA inlet was measured as a function of four different limestone flow rates (0, 30, 55 and 75 lb/min) which correspond to Ca/S ratios of 0, 2.0, 3.7 and 5.0 respectively. Each condition was maintained for a minimum of two and a half hours. A Ca/S ratio of 5.0 was used first, followed by Ca/S ratios of 3.7, 2.0 and 0. Because of the variability in coal properties, it is difficult to determine the actual SO_2 removal efficiency at any specific period of time but it is possible to determine overall trends. For this test, baseline SO_2 (ppm by volume on a wet basis) at the SDA inlet was 338 ppm, when there was no limestone injected. Using this SO_2 concentration as a baseline, the SO_2 removal in the furnace as a function of Ca/S ratio was established. Removal in the furnace increased from thirteen percent at a Ca/S ratio of 2.0 to thirty-one percent removal at a Ca/S ratio of 5.0. **Figure** 4.1.1 ***(lines)*** show analytically predicted SO_2 capture in the furnace as a function of the Ca/S ratio for three different coal sulfur contents and the ***square points*** shows empirical data from test PERF-S4-8. Several limestone samples taken during May indicated that the material was actually dolomite with a Ca content of sixty percent and Mg content of thirty-five percent. It should be noted that a reduction in slag recovery from eighty to sixty percent would halve the effectiveness of the FCM. Also, sixty percent versus ninety percent $CaCO_3$ in the limestone results in only two-thirds of the normal amount of calcium injected. The product of these two factors alone is 0.67 x 0.5 = 0.335, which would render the system approximately one-third as effective as operating under the correct conditions.

Proper limestone quality and flow controls were not achieved until about the fourth quarter. Then, the limestone injection rate was adjusted manually to control SO_2 emission to approximately 0.05 to 0.07 pounds of SO_2 per million Btu with approximately 185° F flue gas exiting the spray dryer absorber. This temperature, although not optimum, provides an effective short term means to quickly increase SO_2 capture by increasing spray flow, thereby reducing this temperature to a value closer to adiabatic saturation temperature where SO_2 removal efficiency improves. When the SDA temperature had to be maintained below 185° F to obtain the desired level of SO_2 emission, the limestone flow was increased according to the operator's judgement based on the SDA inlet SO_2 concentration trend, slag quality and the coal heating value trend. The amount of slag recovered indicates the proportion of coal ash recovered as slag, which affects the concentration of FCM in the fly ash. Coal heating value (often related to the percentage of ash in the coal) can also affect the concentration of FCM in the fly ash.

Figure 4.1.1 – Comparison of Analytical Predictions and Empirical Data for SO_2 Removal in the Furnace



4.2 COMBUSTOR OPERATION

The intervals of operation and shutdown periods are summarized in Appendix C. Sections 4.6 through 4.14 cover the combustor operation on a monthly basis with emphasis on the activities conducted in performing the precombustor test matrix as shown in Table 4.2.1.

TABLE 4.2.1 – PRECOMBUSTOR TEST SUMMARY

Mix Annulus Tests

Test Matrix Designation	Coal Type	Description	Gross Output (MW)	1998 Period	Total Duration (Hours)	Combustor Work Performed
ROM-S4-TRIAL	Seam 4 ROM/waste blend	PC A/B baseline mix annulus configuration PC phi 0.65-0.76, coal split 37-45%	40 - 56	4/23 - 4/27	87	Combustor inspected Cleaned out PC Six way splitter inspected
PERF-S4-2 PERF-S4-3	Seam 4 ROM/waste blend	PC A/B baseline mix annulus configuration PC phi 0.75-0.77, coal split 37-46%	57	5/1 - 5/5	87	Combustor inspected Cleaned out PC Cleaned six way splitter
PERF-S4-4-1 PERF-S4-7 PERF-S4-3	Seam 4 ROM/waste blend	PC A/B baseline mix annulus configuration PC phi 0.95-1.0, coal split 37-45%	58	5/14 - 5/18	96	Combustor inspected Cleaned out PC Repaired limestone injector
PERF-S4-1	Seam 4 ROM/waste blend	PC A/B baseline mix annulus configuration PC phi 0.7, coal split 30-32%	58	5/21 - 5/22	16	No combustor work
PERF-S4-3	Seam 4 ROM/waste blend	PC A/B baseline mix annulus configuration PC phi 0.7, coal split 30-32%	58	5/22 - 5/23	30	Combustor B inspected Inspected/patched dipper skirt crack Repaired PC mill air ports Cleaned out PC
PERF-S4-9	Seam 4 ROM/waste blend	PC A/B baseline mix annulus configuration PC phi 0.6, coal split 29-32% PC exit velocity 250 ft/sec	50	5/26 - 5/31	102	Combustor inspected Cleaned out PC
ROM-S4-1	Seam 4 ROM/waste blend	PC A/B baseline mix annulus configuration PC phi 0.6, coal split 30-32%	60	6/8 - 6/26	431	Combustor inspected Dipper skirt coupon, miter joint repaired, rewelded clamps Installed refractory on dipper skirt shield Cleaned out PC, plugged SC B 1:00 injector
PERF-S4-1A	Seam 4 ROM/waste blend	PC A/B baseline mix annulus configuration PC phi 0.6, coal split 30-32%		7/1 - 7/6	116	Combustor inspected (PC B windbox damage) Installed blank off plates in PC A Cleaned out PC
PERF-S4-1-7000	Seam 3 ROM/waste blend	PC A 45° openings on each side of mix annulus PC B offline PC phi 0.58, coal split 30-32%	27	7/10 - 7/12	41	Combustor A inspected Installed PC A mix elbows

TABLE 4.2.1 – PRECOMBUSTOR TEST SUMMARY

Mix Elbows Tests

Test Matrix Designation	Coal Type	Description	Gross Output (MW)	1998 Period	Total Duration (Hours)	Combustor Work Performed
PERF-S3-1B-7000	Seam 3 ROM/ waste blend	PC A 14 mix annulus elbows All PC NO_X ports open PC B offline PC phi 0.58-0.85, coal split 32-41%	27	7/16 - 7/18	27	Combustor inspected Cleaned out PC, blocked off top two elbows
PERF-S3-2-7000	Seam 3 ROM/ waste blend	PC A 12 mix annulus elbows All PC NO_X ports open PC B offline PC phi 0.85-1.0, coal split 41-43%	30	7/19 - 7/23	86	Combustor inspected, baffle bore close inspected Blocked off PC A NO_X ports, replugged top two elbows Installed 12 elbows in PC B Repaired PC B mix annulus Dipper skirt refractory work
PERF-S3-3-7000	Seam 3 ROM/ waste blend	PC A 12 mix annulus elbows No PC NO_X ports open PC B 8 mix annulus elbows All PC NO_X ports open PC phi 1.0, coal split 43%		8/4 - 8/11	150	Removed PC NO_X port plugs Plugged two elbows (PC A)
ROM-S3-1	Seam 3 ROM	PC A - 8 mix annulus elbows PC B - 8 mix annulus elbows	62	8/13 - 8/30	398	Combustor inspected Cleaned out coal in PC A NO_X ports
ROM-S3-1	Seam 3 ROM	All PC NO_X ports open	61	9/1 - 9/6	123	Combustor inspected Cleaned out PC Blocked off more elbows (A/B)
BLEND-1	ROM/waste blend	PC A 5 mix annulus elbows PC B 6 mix annulus elbows All PC NO_X ports open	62	9/10 - 9/13	76	Combustor inspected Cleaned out PC Plugged SC A 11:00 injector
BLEND-1	ROM/waste blend	PC A 5 mix annulus elbows PC B 6 mix annulus elbows All PC NO_X ports open		9/15 - 9/20	112	Combustor inspected Cleaned out PC Plugged additional PC mix elbows Installed new limestone feed system gear Repaired PC NO_X ports
BLEND-2	ROM/waste blend	PC A 4 mix annulus elbows (offline) PC B 5 mix annulus elbows All PC NO_X ports open	28 - 29	9/27 - 10/21	582	Combustor inspected Installed hot air lines to SC A head end Plugged remaining elbows in PC A Cleaned out PC

TABLE 4.2.1 – PRECOMBUSTOR TEST SUMMARY

Secondary Air to Head End of Slagging Combustor

Test Matrix Designation	Coal Type	Description	Gross Output (MW)	1998 Period	Total Duration (Hours)	Combustor Work Performed
BLEND-3	ROM/waste blend	PC A mix annulus blocked off, elbows packed with refractory Combustion air to SC head end (4 ports) All PC NO_X ports open		10/24 - 10/25	19	Combustor inspected Did not clean PC Installed hot air lines to SC B head end Plugged remaining elbows in PC B
BLEND-4	ROM/waste blend	PC mix annulus blocked off, elbows packed with refractory Combustion air to SC head end (4 ports) All PC NO_X ports open	56 - 57	10/29 - 11/15	389	Combustor inspected Removed mix elbows, installed blank off plates Repaired PC A swirl damper Repaired dipper skirt Installed more refractory in dipper skirt
BLEND-5	ROM/waste blend	PC mix annulus blocked off, elbows removed Combustion air to SC head end (4 ports) All PC NO_X ports open	57	11/19 - 12/3	174	Blanked off PC NO_X ports Installed two additional hot air lines to SC head end
BLEND-6	ROM/waste blend	PC mix annulus blocked off, elbows removed Combustion air to SC head end (6 ports) PC A no NO_X ports PC B NO_X ports open	57	12/7 - 12/21	303	Combustor inspected

4.3 JANUARY STARTUP OPERATION

The initial coal firing occurred during January, beginning on the 13th and continuing through the 24th. During the last week of the January, coal firing activities were shutdown in order to perform some repairs, including the repair of the condensate pump and the replacement of the coal feed system victaulic couplings with bellow assemblies. The following paragraphs summarize the highlights of the coal fired startup activities during January.

Coal firing activities were initiated on January 13 and continued through January 24. These initial coal firing tests were very successful. The objective for the first day was to operate each combustor individually on coal for approximately three hours. This was successfully completed on the 13th. The objective for the second day was to operate both combustors simultaneously for several hours of coal firing and to perform a trip of the turbine at half load. This was successfully completed on the 14th. Following this test, there was a three day shutdown to perform inspections and repairs, including the repair of the seal in the high pressure recirculation pump isolation valve, repair of the leaks in the coal feed system victaulic couplings at the precombustor mill air port interface and the preliminary inspection of the mills and combustor internal surfaces. Coal firing was re-initiated on January 21 with the objective of bringing both combustors to three-quarters load and then to trip the turbine. This objective was cancelled when it was discovered that the coal in the coal silo was smoldering. GVEA operations was instructed not to load smoldering coal from the coal pile and a policy of firing coal until both silos are empty, prior to extended shutdowns, was adopted. At that time, the objective became to simply burn the remaining coal in both silos and shutdown for more extensive repairs and inspections.

Specific results were as follows:

- The coal light-off was fairly smooth. Some operational problems were experienced with maintaining stable furnace pressure when opening the precombustor and slagging combustor coal fire valves following a master fuel trip (MFT). This was resolved through revised operational procedures and increasing the actuation time of the fire valves from fully closed to fully open to approximately twenty seconds.
- The quality of the slag on the slag ash drag chain was very good. The slag was typically a black, glassy, one-eighth to one-quarter inch granule, without any evidence of carbon.
- The slagging behavior on the internal surfaces of the combustor could not be observed online. Attempts were made to visually evaluate the slagging behavior through the furnace inspection door and combustor head end ports during coal firing. The flame was too intense at both locations; therefore, inspections could not be made online. Use of a camera at the furnace opening had not yet been evaluated.
- Post test observations of slagging behavior on the combustor internal surfaces indicated that the initial slag layer on Combustor A was very different than on Combustor B. This was attributed to Combustor A burning a lower ash coal (five percent ash) than Combustor B (ten percent ash) was burning and to Combustor A operating for five minutes at low coal load (10,000 lb/hr) without any oil ignitors prior to shutdown. The slag layer in the slagging stage of Combustor A was relatively thick, while the slag layer in the slagging stage of Combustor B was thin, black and glassy. The slag had partially stripped off the walls on shutdown. The head end of each slagging combustor had a thin, molten layer of slag. The baffle on Combustor B was approximately one-third covered with a thin molten layer of slag including a thin layer on the baffle bore. The slag recovery sections on both combustors had a thin molten layer of slag over the majority of the surface. The precombustors on both

combustors had a thin, black molten layer of slag over the last few feet of the combustion chamber and in the tangential inlet. The furnace tubes were coated with a light colored fly ash.

- Even though the baghouse was not in service during these initial coal tests, the stack plume was white during coal firing.
- The boiler water pH measurements taken during these early tests indicated very poor water quality. In particular, measured pH levels were well below desired levels, with measurements of 6 to 8.5. The iron levels measured were orders of magnitude higher than that specified with measurements as high as 200 ppm versus the required 5 ppb. These pH levels occurred during startup periods and the cause was attributed to Unit 1 condensate contamination, probably via Unit 1 condenser leaks. Unit 1 condensate was isolated from HCCP to resolve the problem.
- Some problems were experienced with combustor auxiliary equipment including coal leakage from the victaulic couplings at the coal cyclone vent air connections to the precombustor, intermittent failure of the swirl damper actuators to respond to a signal to open or close the swirl dampers, intermittent failure of the oil flame scanners in the precombustor and slagging combustor to detect a flame and higher than expected temperatures observed on the six-way slagging combustor coal splitter during coal firing.

Following the two weeks of coal firing activities, there was one week of inspections, repairs and modifications. The primary combustion system activities performed during January included the inspection of combustor gas-side surfaces (including the inspection of the dipper skirt and dipper skirt shield following a hard start during oil ignition on Combustor A), the installation of bellow assemblies to replace the mechanical (grooved end victaulic) couplings where the coal cyclone vent air connects to the precombustors and the inspection of the oil ignitors to determine the cause of the intermittent hard starts during precombustor oil ignition. In addition, the field of view of the precombustor and slagging combustor oil flame scanners was improved, refractory was installed in the base of the coal feed system six-way slagging combustor coal splitter to eliminate the potential for coal accumulation in this region and the coal feed system carbon monoxide analyzers were recalibrated. Finally, orifices in the air actuation line to the precombustor and slagging combustor coal fire valves were installed in order to slow down the actuation time from fully closed to fully open to approximately fifteen seconds. Additional details on these activities are provided below:

- A visual inspection of the combustor gas-side surface again revealed a difference in slag coverage between Combustors A and B, caused by very different operating conditions on the two combustors prior to shutdown (i.e., Combustor A had been operated exclusively on oil for several hours prior to shutdown). The slag coverage on the walls of Combustor B was excellent; the slag being approximately one inch thick, black and glassy with over ninety percent of the surface covered with slag. Although the shutdown had been initiated by a master fuel trip, the slag did not strip off the refractory covered walls.
- Based on visual observations of the Combustor A dipper skirt and dipper skirt shield, the recent hard start during oil ignition had not caused any obvious additional bowing or damage to the skirt or shield.
- Eight bellow assemblies were installed in the coal feed system precombustor mill (cyclone vent) air port piping to replace the twelve victaulic couplings. The location of the bellows was selected so that the bellows would be subjected to axial movement only during operation. The bellows were installed in a pre-constrained condition (one-quarter inch restraint), so that they would be in a normal position during operation. The bellows included a carbon steel liner to prevent erosion and abrasion of the stainless steel bellows assemblies and high

temperature packing installed at the interface between the bellows and the liner to prevent coal migration and packing.

- Inspection of the precombustor oil ignitor in Combustor A revealed no obvious cause for the intermittent hard starts when lighting Combustor A on oil. It had been suspected that the oil gun may be leaking intermittently, but there was no obvious evidence of that.
- One fin was removed from each of the four oil gun assemblies to improve the field of view for the oil flame scanners. Removal of the one fin did not provide a clear field of view for any of the scanners but did improve the previous view line.
- During two of the coal firing periods, temperatures of approximately 240° F were measured by a thermocouple installed on the inner annular region of the coal feed system six-way slagging combustor splitter, while the coal carrier air had been approximately 135° F. The splitter assembly was disassembled and inspected. There was no evidence of heat staining or hot spots. Approximately three inches of coal fly ash type material was noted in the base of the splitter. This region was subsequently modified to incorporate a refractory liner to prevent further coal accumulation.
- The coal feed system carbon monoxide analyzers were re-calibrated. It was also noted that the coolers on the analyzers were frequently overheating. Vortex coolers were installed on the instrument air lines to the coolers.
- Orifices were installed in the instrument air lines to the fire valve actuator cylinders to ensure these valves would not open too quickly.

4.4 FEBRUARY STARTUP OPERATION

Coal firing activities were re-initiated on February 2 and continued through February 28. Approximately two hundred hours of coal firing were accumulated in February including two tests of over twenty-four continuous hours and one test of sixty continuous hours. Slag characteristics were observed on March 4 following the sixty hour test.

The primary objective of the tests conducted during February was to stay online continuously at a steady-state coal load of 20,000 to 25,000 lb/hr, with minimum oil, in order to bring the baghouse and SDA systems online. Eleven tests were conducted during February with test durations varying from three hours to sixty hours. Two of the tests lasted twenty-four continuous hours and one test lasted sixty hours.

During two of the early tests, there were significant stoichiometry swings and pressure excursions within the precombustor. This was caused by large swings in the precombustor mill air port flow rate, with corresponding swings in the precombustor mix annulus flow rate in order to maintain overall stoichiometry. The precombustor mill air port flow oscillations were caused by occasional large pressure excursions in the furnace pressure (over three inches water gauge) and erroneous flow measurements because of periodic plugging and unplugging of the flow annubar. These flow oscillations were resolved by increasing the precombustor mill air port injection pressure margin by increasing the flow rate and partially closing the flow damper, by changing the combustion control logic so that erroneous signals from the precombustor mill air annubar would not affect the precombustor mix annulus flow rate and by increasing the purge frequency on the precombustor mill air flow annubar from once every twenty-four hours to once every hour.

All areas of the gas-side surfaces were completely covered by a molten slag layer. There were no bare regions. The drag chain flights were three-quarters full and few clinkers were observed on it during the longer duration tests. This was an improvement over previous slag tap behavior and was attributed to eliminating the flow and pressure oscillations within the precombustor, increasing the coal flow to 23,000 lb/hr within two hours of the start of coal firing and operating with greater than 23,000 lb/hr of coal flow.

Following the three tests of greater than twenty-four hours, slag accumulation was noted within the precombustor. This slagging behavior is attributed to operating with gas temperatures within the precombustor combustion chamber and precombustor exit (downstream of mixing with the mix annulus and precombustor mill air) that are higher than the ash fusion temperature for the ROM coal. Changes to the precombustor and slagging combustor stoichiometry were made in order to either reduce the gas temperatures below the ash fusion temperature (non-slagging precombustor) or to increase the gas temperatures well above the ash fusion temperature (slagging precombustor). This investigation was ongoing at the end of February.

The NO_X analyzer did not work, so no NO_X emission measurements were recorded in February. Initial SO_2 measurements were made after bringing the SDA equipment and limestone feed system online. The opacity decreased from sixty percent to three percent after the baghouse was brought online.

Specific test results are summarized in the following paragraphs.

On February 6 and 7, two tests were conducted. The first test (February 6) accumulated approximately fifteen hours on Combustor A and twenty-one hours on Combustor B. The second test (February 7) accumulated thirteen hours on both combustors. These were the first tests where a complete transfer of the mill fines from the precombustor NO_X ports to the furnace NO_X ports was achieved. These tests were both terminated with a master fuel trip following a trip of one of the mills. The mill trip was caused by high temperatures in the furnace NO_X port line which was caused by problems with combustion air flow stability following the transfer of the mill air from the precombustor NO_X ports to the furnace NO_X ports. This resulted in large swings in precombustor air flow rates, stoichiometry and chamber pressure. These problems were attributed to erroneous readings from the precombustor NO_X port and cyclone vent flow annubars (caused by periodic plugging), which resulted in large oscillations in the precombustor mix annulus flow rate in order to maintain the stoichiometry setpoint and to a precombustor NO_X port pressure margin which was insufficient to accommodate large pressure excursions (greater than three inches water gauge) in the furnace. Because of the large swings in precombustor and slagging combustor stoichiometry, as well as the low coal load, the slag tap behavior varied from very good (i.e., good quality and quantity of slag) to very poor (i.e., large slag clinkers and/or low quantity of slag).

On February 13 and 14, a thirty continuous hour test was conducted. The combustion air flow instability problems that had been identified during the February 6 and 7 tests were addressed via operational procedure changes including the following:

- Both the blowdown damper and the furnace NO_X port damper were maintained in manual operation to prevent erroneous readings from the annubars from affecting the precombustor mix annulus and coal carrier air flows.
- Flow conditions were changed in order to maintain 35,000 lb/hr on precombustor NO_X ports and coal carrier air and 40,000 lb/hr on furnace NO_X ports throughout the entire startup procedure. This ensured that the coal transport line velocity remained above saltation velocity with a sufficient pressure margin to prevent backflow of combustion products during furnace pressure excursions in excess of six inches water gauge.
- Stoichiometry control logic was changed to control precombustor air flow damper positions based on coal carrier air flow setpoint and precombustor NO_X port flow rather than measured annubar flows.

  As a result of these changes, the combustion air flows were stable during the thirty hour test. Overall, slag recovery was significantly improved over the previous tests in both quality and quantity. The baghouse and SDA were successfully brought online; 40 MW gross was generated for the majority of the test.

From February 15 through February 18, several relatively short tests were conducted. Problems were experienced with master fuel trips when the coal fire valves on the precombustor and/or slagging combustor were opened. Ultimately, the cause of these problems was determined to be the following:

- During the first two startup attempts on Combustor A, an attempt was made to open the precombustor fire valve with the primary air flow rate to the mill at too high a setpoint (85,000 lb/hr versus 55,000 lb/hr). As a result of this higher primary air flow rate to the mill, coal in the mill was transported to the precombustor and slagging combustor cyclones. Since the precombustor and slagging combustor fire valves were not open, the coal settled out in the bottom of the cyclones. This resulted in a large increase in power generation and furnace pressure increase when the fire valves were opened. Ultimately, the bottom of the slagging combustor cyclone plugged with coal and had to be manually emptied.
- The slagging combustor oil scanner on Combustor B was providing a marginal signal. This signal dropped to zero when the slagging combustor coal fire valve was opened and resulted

in a master fuel trip. The problem was resolved when the scanner amplifier was increased to a higher level and the tempering air flow to the slagging combustor oil ignitor was increased.

On February 19 and 20, an eighteen continuous hour test was conducted. The test was terminated because of a circuit board failure. This test was followed by a twenty-four hour test that was conducted on February 20 and 21. This test was terminated because the slag removal drag chain was stopped for seven hours in order to fix a broken flight in the bucket elevator. When it was restarted, the chain wouldn't move because of the large quantity of slag, so the unit had to be shutdown. The test was terminated by a trip on high drum water level when the coal load decreased too rapidly. Observations during the test included the following:

- The slag quality and quantity looked very good during the twenty-four hour test. There were few, if any, clinkers. This was attributed to increasing the coal flow rate from the minimum up to the nominal operating flow rate of 25,000 lb/hr within a two hour time period.
- Following the trip of the coal feed system at high coal load, the coal quantity remaining in the bottom of precombustor and slagging combustor coal cyclones was estimated by using a plumb bob to determine the depth of the coal. Based on this measurement, it was determined that there was less than seventy pounds of coal in the bottom of both of the cyclones. This measurement confirmed that, under normal conditions, there is little coal remaining in the cyclones following a master fuel trip. As noted above, the excessive amount of coal found in the slagging combustor cyclone on February 17 was attributed to having too high a primary air flow to the mill while opening the coal fire valves.
- Following the twenty-four hour test, it was determined that the previous problems with erroneous flow indications from the cyclone vent and precombustor mill port annubars was the result of periodic plugging of the annubars caused by an error in setting the purge frequency. It had been set at once every twenty-four hours instead of once every hour. This was corrected on February 21.

An inspection of the combustor gas-side surfaces was performed on February 24. In general, both Combustor A and B looked similar. The slagging stage of both combustors was completely covered with an approximately a one-half to one inch thick layer of black, glassy slag. Both precombustors had excessive slag accumulation upstream of the swirl dampers. The slag was molten in appearance, starting at the base of the precombustor combustion chamber and extending into the tangential inlet. The slag accumulation extended beyond the insertion depth of the swirl dampers, blocking approximately fifty percent of the cross-sectional area of the tangential inlet. The excessive slag accumulation was removed from the tangential inlet prior to the next test.

On February 25, a ten hour test was conducted. The operating conditions for this test were changed to minimize the slag accumulation within the precombustor by reducing the precombustor exit temperature to below the ash fusion temperature. This change in operating conditions appeared to have a somewhat negative impact on the slag tapping behavior. In particular, more slag clinkers were observed. These conditions were only used for the tests on February 25 and 26. The test was terminated by a master fuel trip, the result of an erroneous negative signal from the cyclone vent annubar that caused an artificially low stoichiometry trip.

On February 26, several combustion control logic changes were made to prevent erroneous annubar signals from resulting in a false low stoichiometry condition. These changes included eliminating the cyclone vent annubar from the slagging combustor stoichiometry calculation, adding an alarm prior to a trip on low stoichiometry and adding a sixty second delay on the low stoichiometry trip. In addition, the actuator air to the precombustor and slagging combustor fire valves and the slagging combustor coal purge valves were throttled so that the fire valves and purge valves would open over a couple minute time period. Coal was fired in Combustor A for approximately eight hours and in Combustor B for approximately three hours prior to a trip on the control module.

From February 28 through March 2, an approximately sixty continuous hour test was conducted. The operating conditions for this test were changed back to the higher precombustor exit temperature (approximately 2600° F) conditions used prior to the test on February 25. After approximately thirty hours of burning coal on Combustor A and thirty-eight hours of burning coal on Combustor B, an increase in the precombustor chamber pressure was noted, indicating slag accumulation in the precombustor. The precombustor and slagging combustor stoichiometries were changed to try and melt out the slag accumulation in the precombustor. There was only a minor decrease in the precombustor chamber pressure following the change in stoichiometry. However, post-test inspection revealed that the higher gas temperatures were at least partially successful in melting the slag accumulation within the precombustor. The test was terminated by a trip of the exhauster fans.

The combustors were inspected on March 4. The appearance of the slag in the slagging stage was different than that observed following the inspection on February 25. In particular, the slag was light brown in color and molten, but not as glassy in appearance. Precombustor A had significantly less slag accumulation than observed previously. The slag was very molten within the precombustor combustion chamber and remained very molten as it flowed through the tangential inlet into the slagging stage. Any significant growth appeared to have melted at the higher gas temperatures as a result of the higher stoichiometries in the precombustor and slagging stage. Precombustor B had slag accumulation similar to that observed previously.

4.5 MARCH STARTUP OPERATION

Combustor slagging characteristics were inspected on March 4 following the sixty-hour test (which started on February 28). Coal firing was re-initiated on March 3 and continued through April 2, accumulating approximately 420 hours of coal burn time, including approximately 215 hours without oil ignitors. Three long tests (76 hours, 99 hours and 136 hours) were conducted in March. The combustor gas-side surfaces were inspected on March 12, following a forty-two hour test and on March 23, following a seventy-six hour test. The following paragraphs summarize the highlights of the coal firing activities in March.

The primary objective of the first two tests conducted during March was the same as in February, to stay continuously online with a steady-state coal flow of 25,000 to 29,000 lb/hr, with minimum oil and with the baghouse and SDA systems in service.

Subsequent to the completion of this test objective, the oil ignitors were removed from service and test operations were focused on achieving the requisite gaseous stack emission levels required for the source test.

Eight tests, varying from eight hours to 136 hours, were conducted. Figure 4.5.1 shows continuous coal burn durations for the tests performed in March. As shown, five of the eight tests lasted longer than twenty-four hours. Approximately 420 hours of coal burn time, including approximately 215 hours without oil ignitors in service, were accumulated in March. Figure 4.5.2 shows the daily coal burn duration during March and, as indicated, over seventy percent of the test days exceeded twenty hours in duration.

Combustor operation without oil ignitors was excellent. There was no noticeable degradation in performance noted after removing the oil ignitors from service. Coal flames were very stable even at the lower precombustor and slagging combustor stoichiometries, down to 0.76 and 0.77 respectively. There was good slag coverage on the slagging combustor and slag recovery section gas-side surfaces, and few, if any, clinkers were observed on the drag chain.

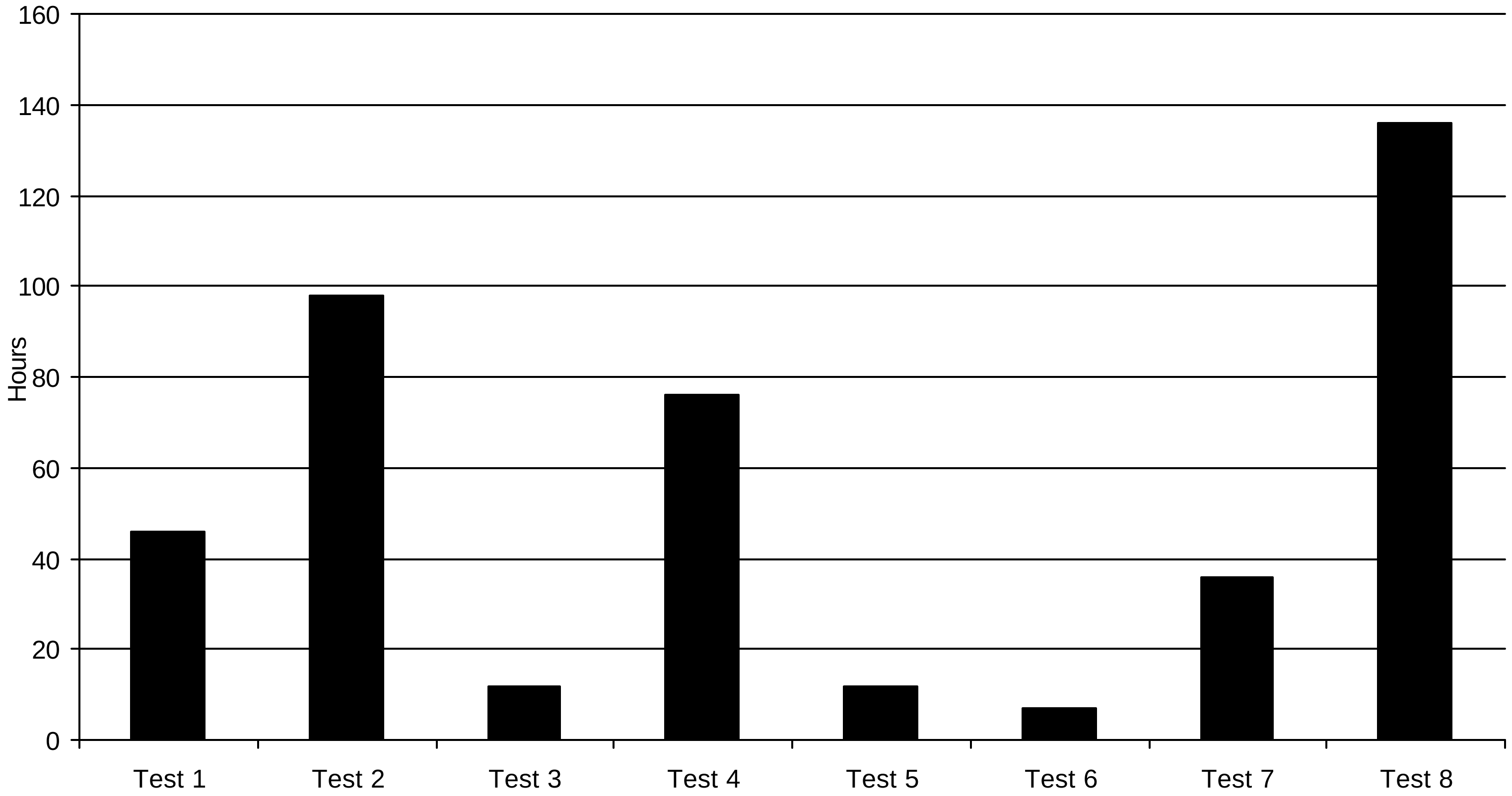
Two operational issues were observed in March. The first was occasional rapid increases in power generation with corresponding decreases in furnace oxygen and increases in furnace carbon monoxide, occurring approximately once every ten to twelve hours. This was attributed to coal accumulating somewhere in the coal supply system and then entering the furnace as a slug. The second issue was the reduced flame intensity on the slagging combustor coal flame scanners caused by partial plugging of the scanner ports with slag.

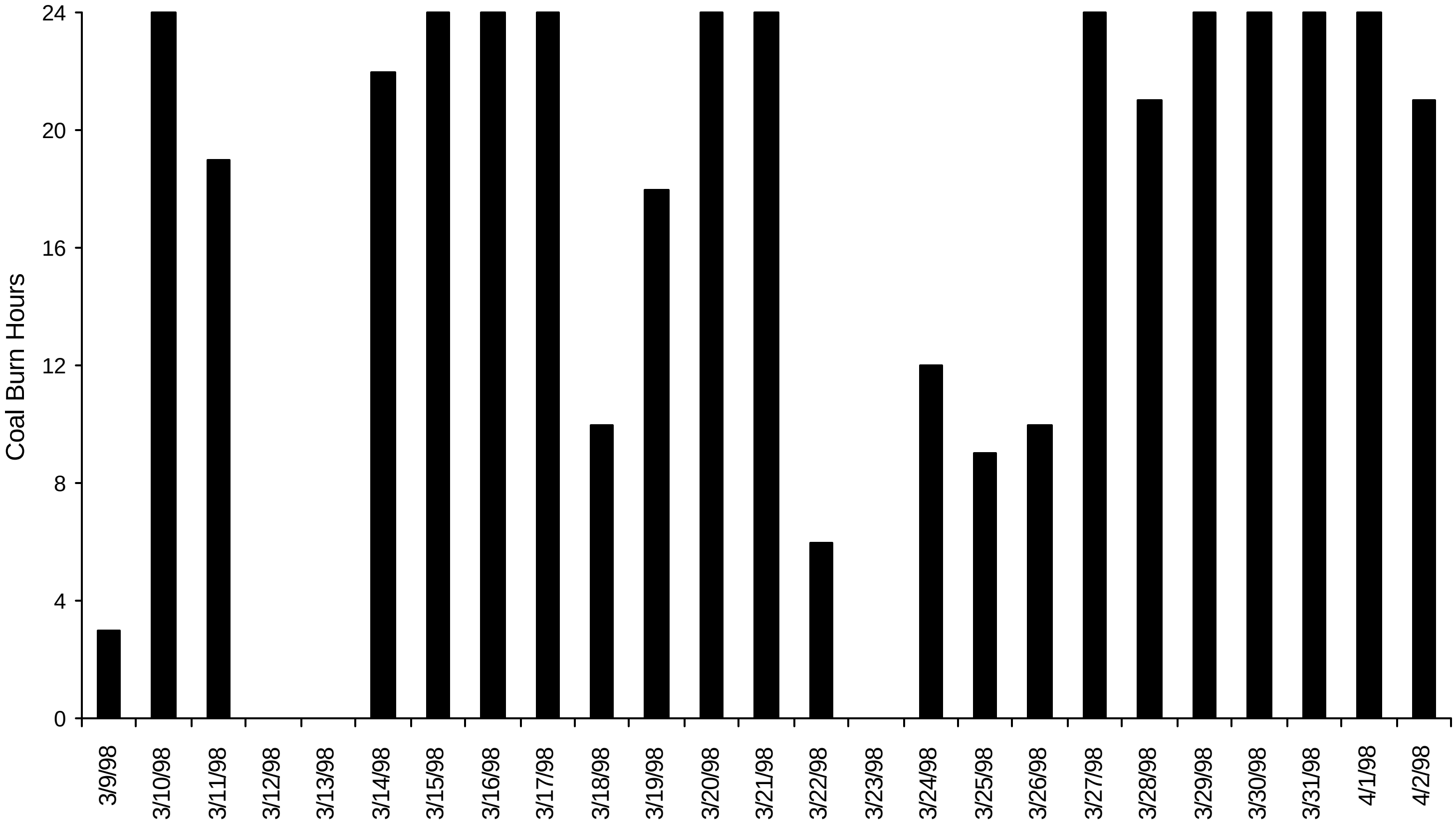
The coal slugging events were attributed to the possible accumulation of coal within the coal feed system chutes downstream of the precombustor/slagging combustor coal splitter, the horizontal piping leading to the furnace NO_X ports and/or the pulverizers. In order to minimize the potential for coal accumulation upstream of the precombustor and slagging combustor cyclones, the manual dampers located on the roof of the chutes downstream of the splitter were partially closed (by approximately fifteen degrees) to increase the velocity in this region from 65 ft/sec to approximately 75 ft/sec. The chutes were subsequently inspected during a downtime and there was no evidence of coal accumulation within the precombustor/slagging combustor splitter or the inlet to the cyclone.

The coal slugging events continued to occur after the change was made to the coal feed system roof dampers. Based on data analysis, these events were typically preceded by an increase and

3/9/98	3	46
3/10/98	24	46
3/11/98	19	46
3/12/98	0	
3/13/98	0	
3/14/98	22	98
3/15/98	24	98
3/16/98	24	98
3/17/98	24	98
3/18/98	10	12
3/19/98	18	76
3/20/98	24	76
3/21/98	24	76
3/22/98	6	76
3/23/98	0	
3/24/98	12	12
3/25/98	9	7
3/26/98	10	36
3/27/98	24	36
3/28/98	21	136
3/29/98	24	136
3/30/98	24	136
3/31/98	24	136
4/1/98	24	136
4/2/98	21	136

Test 1	46
Test 2	98
Test 3	12
Test 4	76
Test 5	12
Test 6	7
Test 7	36
Test 8	136


160
140
120
100
80
60
40
20
0
Hours
Test 1
Test 2
Test 3
Test 4
Test 5
Test 6
Test 7
Test 8



Coal Burn Hours
0
4
8
12
16
20
24
3/9/98
3/10/98
3/11/98
3/12/98
3/13/98
3/14/98
3/15/98
3/16/98
3/17/98
3/18/98
3/19/98
3/20/98
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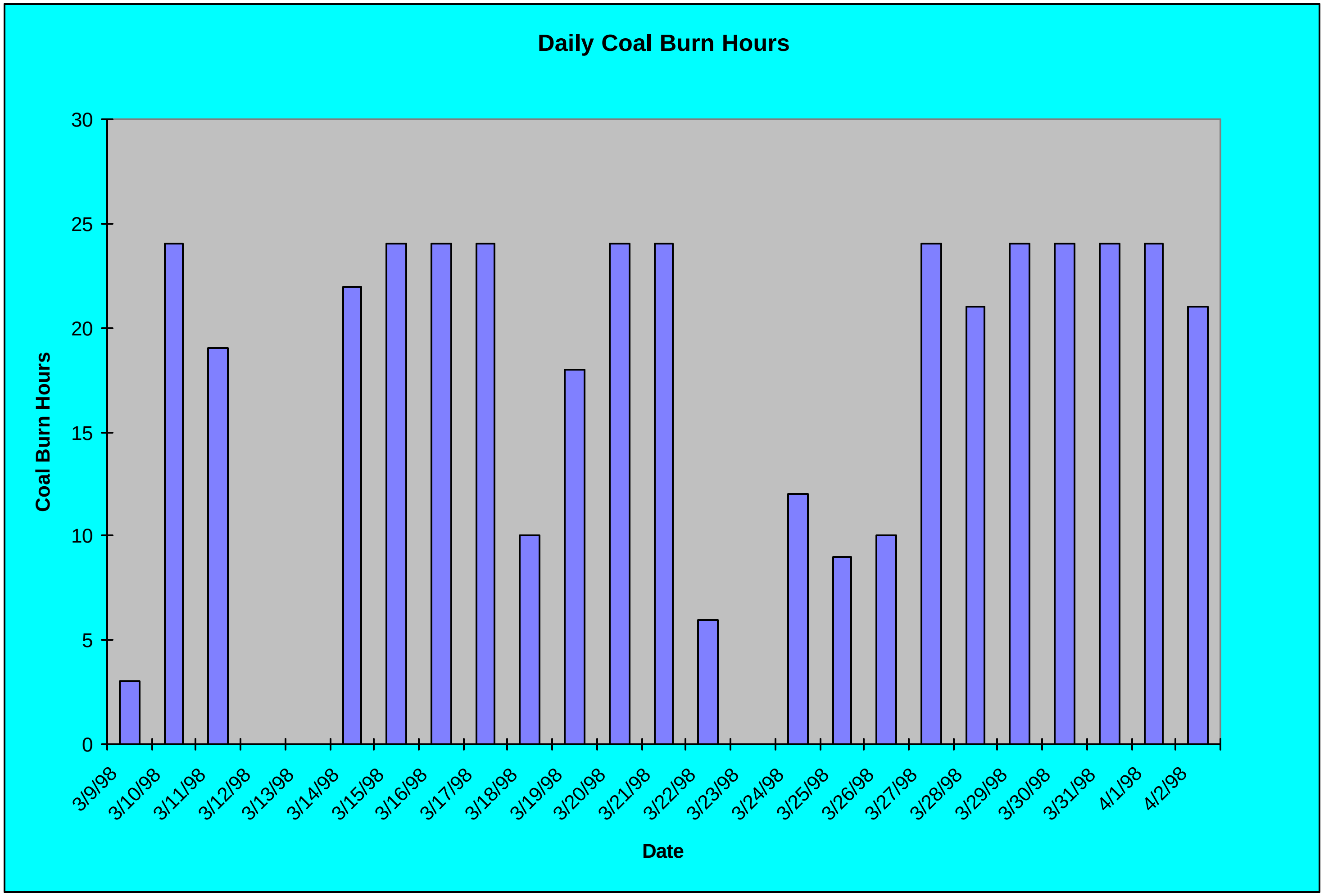
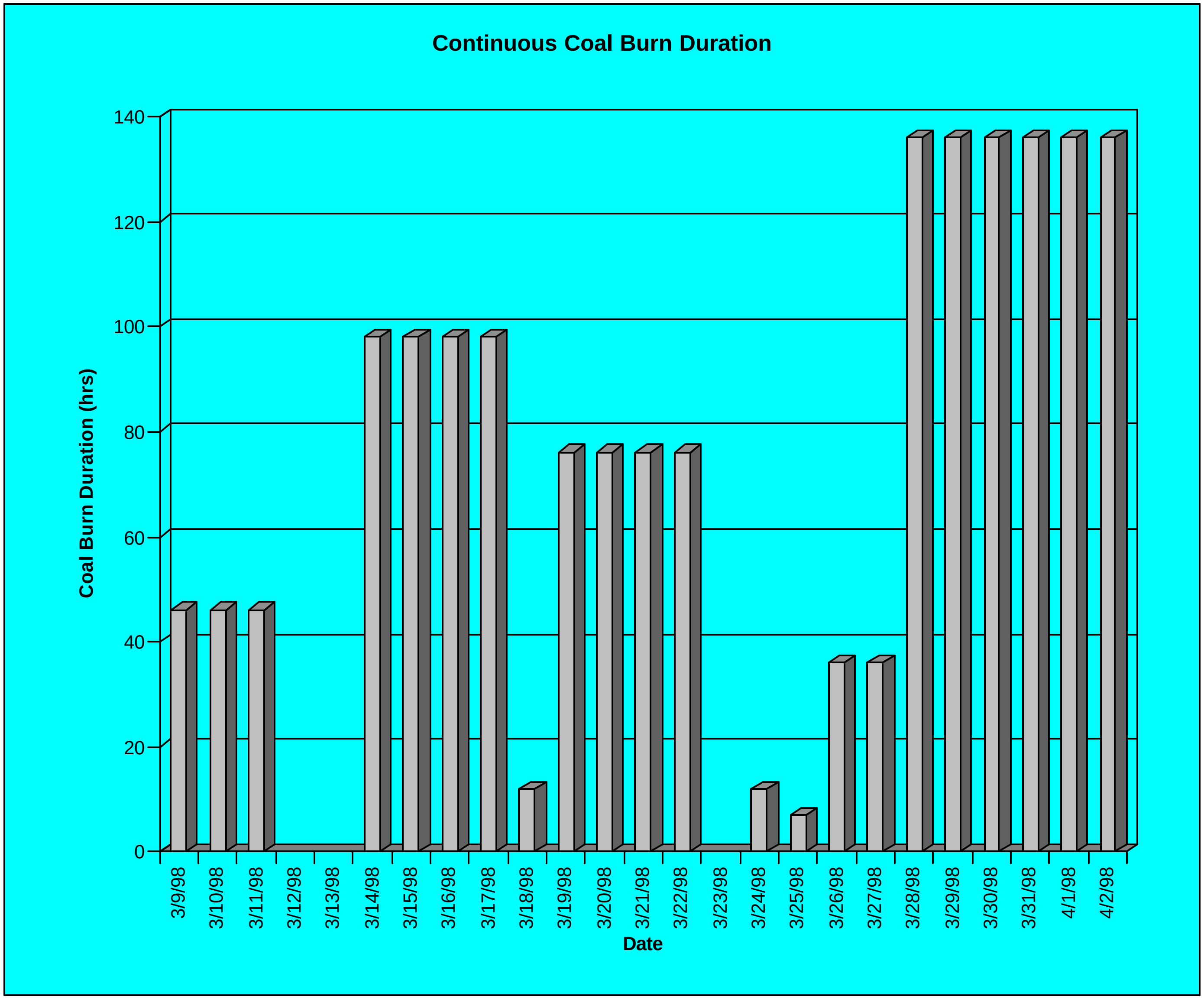
3/26/98
3/27/98
3/28/98
3/29/98
3/30/98
3/31/98
4/1/98
4/2/98


Daily Coal Burn Hours
Coal Burn Hours
30
25
20
15
10
5
0
3/9/98
3/10/98
3/11/98
3/12/98
3/13/98
3/14/98
3/15/98
3/16/98
3/17/98
3/18/98
3/19/98
3/20/98
3/21/98
3/22/98
3/23/98
3/24/98
3/25/98
3/26/98
3/27/98
3/28/98
3/29/98
3/30/98
3/31/98
4/1/98
4/2/98
Date


Continuous Coal Burn Duration
Coal Burn Duration (hrs)
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20
40
60
80
100
120
140
3/9/98
3/10/98
3/11/98
3/12/98
3/13/98
3/14/98
3/15/98
3/16/98
3/17/98
3/18/98
3/19/98
3/20/98
3/21/98
3/22/98
3/23/98
3/24/98
3/25/98
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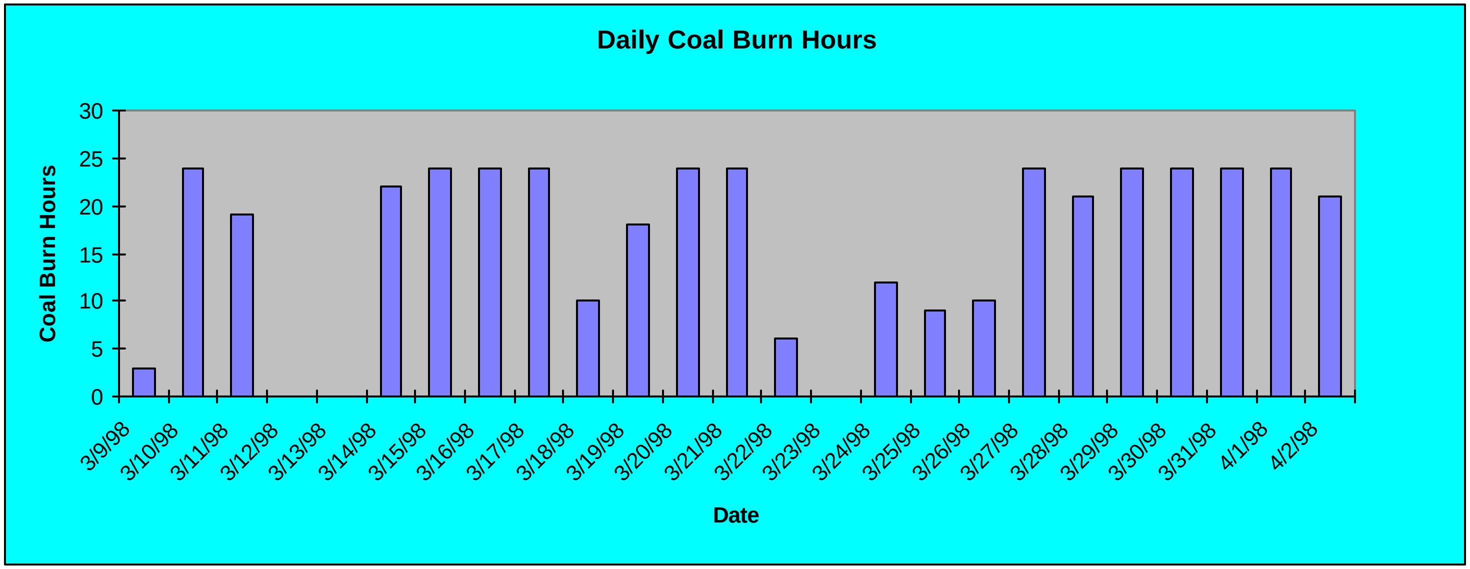
3/31/98
4/1/98
4/2/98
Date


Daily Coal Burn Hours
Coal Burn Hours
30
25
20
15
10
5
0
3/9/98
3/10/98
3/11/98
3/12/98
3/13/98
3/14/98
3/15/98
3/16/98
3/17/98
3/18/98
3/19/98
3/20/98
3/21/98
3/22/98
3/23/98
3/24/98
3/25/98
3/26/98
3/27/98
3/28/98
3/29/98
3/30/98
3/31/98
4/1/98
4/2/98
Date

then sudden decrease in pressure drop through the mill. This data implies that these events may be the result of coal accumulation (or loading) and then suddenly unloading from the pulverizers. The investigation of these events continued into April.

In order to resolve the loss of flame intensity on the slagging combustor coal flame scanners caused by the partial blockage of the scanner port with slag, the following changes were initiated. Additional scanners were added to the head end of the slagging stage in order to provide redundancy when the scanner ports are being cleaned out. In addition, eliminating the requirement for maintaining flame scanner indications in the slagging combustor, except during startup, was investigated. Potential elimination of the requirement for slagging combustor flame indication is based on the precombustor meeting and the National Fire Protection Association (NFPA) requirements for a continuous ignitor. Therefore, as long as the precombustor operates with a good flame indication, there would be no requirement for flame indication on the slagging combustor. This is consistent with the mode of operation that was used on the prototype combustor located in Cleveland, Ohio.

During February, slag accumulation was observed within the precombustor following the longer (greater than twenty-four) test operations. This was attributed to operating with gas temperatures that are higher than the ash fusion temperature for ROM coal within the precombustor combustion chamber and precombustor exit (downstream of mixing with the mix annulus and precombustor mill air). During March, the following operational and hardware changes were implemented to minimize slag formation within the precombustor. The precombustor combustion chamber stoichiometry was reduced from 0.86 to 0.76 in order to reduce the gas temperature and, therefore, slag formation within the combustion chamber. The precombustor burner inner register setting was reduced from thirty percent to fifteen percent to reduce the flame temperature within the core and the outer register setting was increased from forty percent to seventy percent to reduce the swirl. Finally, the insertion depth of the precombustor exit swirl damper located on the furnace side was decreased from twenty inches to eight inches in order to allow any slag formed in the precombustor combustion chamber to flow from the precombustor through the tangential air inlet into the slagging combustor. Because of the angle of the precombustor, slag flows by gravity toward the furnace side of the tangential inlet and when the swirl dampers are fully inserted, the slag dams up against the upstream side of the swirl dampers.

All three changes were beneficial in reducing the slag accumulation. In particular, reducing the precombustor stoichiometry successfully reduced the slag formation within the combustion chamber. Retracting the furnace-side swirl damper allowed the slag formed within the precombustor to flow into the slagging. Increasing the outer register setting reduced the swirl exiting the precombustor combustion chamber which minimized the slag flowing up the cylindrical walls of the precombustor mix annulus and precombustor mill air port. The change from thirty percent to fifteen percent on the inner register did not appear to have a significant impact on the slag formation. It was anticipated that, during operation with waste coal blends, the coal split between the precombustor and slagging combustor would also need to be changed to either increase or decrease the percentage of total coal flow to the precombustor. Specifically, to continue to operate the precombustor in a slagging mode with waste coal blends, the percentage of coal flow to the precombustor would need to be increased from a nominal thirty-eight percent to forty-three percent. In order to operate the precombustor in a non-slagging mode, the percentage of coal flow to the precombustor would need to be reduced to thirty percent, thus reducing the precombustor exit temperature (i.e., inlet to the slagging stage) below the ash fusion temperature. Both the slagging and non-slagging mode of operation was evaluated during the upcoming combustor characterization test series.

For a slagging combustor stoichiometry between 0.80 and 0.78, the NO_X readings were consistently below the environmental permit requirement of 0.35 pounds per million Btu, and typically in the range of 0.20 to 0.31 pounds per million Btu. At the end of March, the coal heating value correction to the stoichiometry calculation was placed in auto, so that the coal heating value correction was continuously updated based on the steam output. This resulted in even more consistent NO_X measurements of typically 0.20 to 0.28 pounds per million Btu for a slagging combustor stoichiometry of 0.80.

Measurements of SO_2 emission of less than 10 ppm at the stack were achieved. Tuning of the limestone system was later performed to determine the Ca/S ratio required during operation with performance coal. The SO_2 measurements recorded upstream of the SDA indicated approximately twenty to thirty-five percent removal. The stack opacity was typically less than seven percent compared to the twenty percent maximum allowable value.

4.6 APRIL COMBUSTOR OPERATION

During April, emphasis shifted from startup mode to the testing program shown in Table 4.2.1. Normal combustor and FGD operating conditions for firing ROM coal were established and two trial waste coal blend tests were conducted.

In all, five tests, with test durations varying from forty-five hours to 145 hours, were conducted during April. Approximately 413 hours of coal burn time, including approximately fifty hours burning blended coal, were accumulated. Figure 4.6.1 shows the daily coal burn duration for April. The average coal burn duration on test days was twenty hours. On April 5, a test was terminated as a planned shutdown to perform maintenance and repairs. The remaining four tests were terminated because of pulverizer trips and other non-combustion related trips.

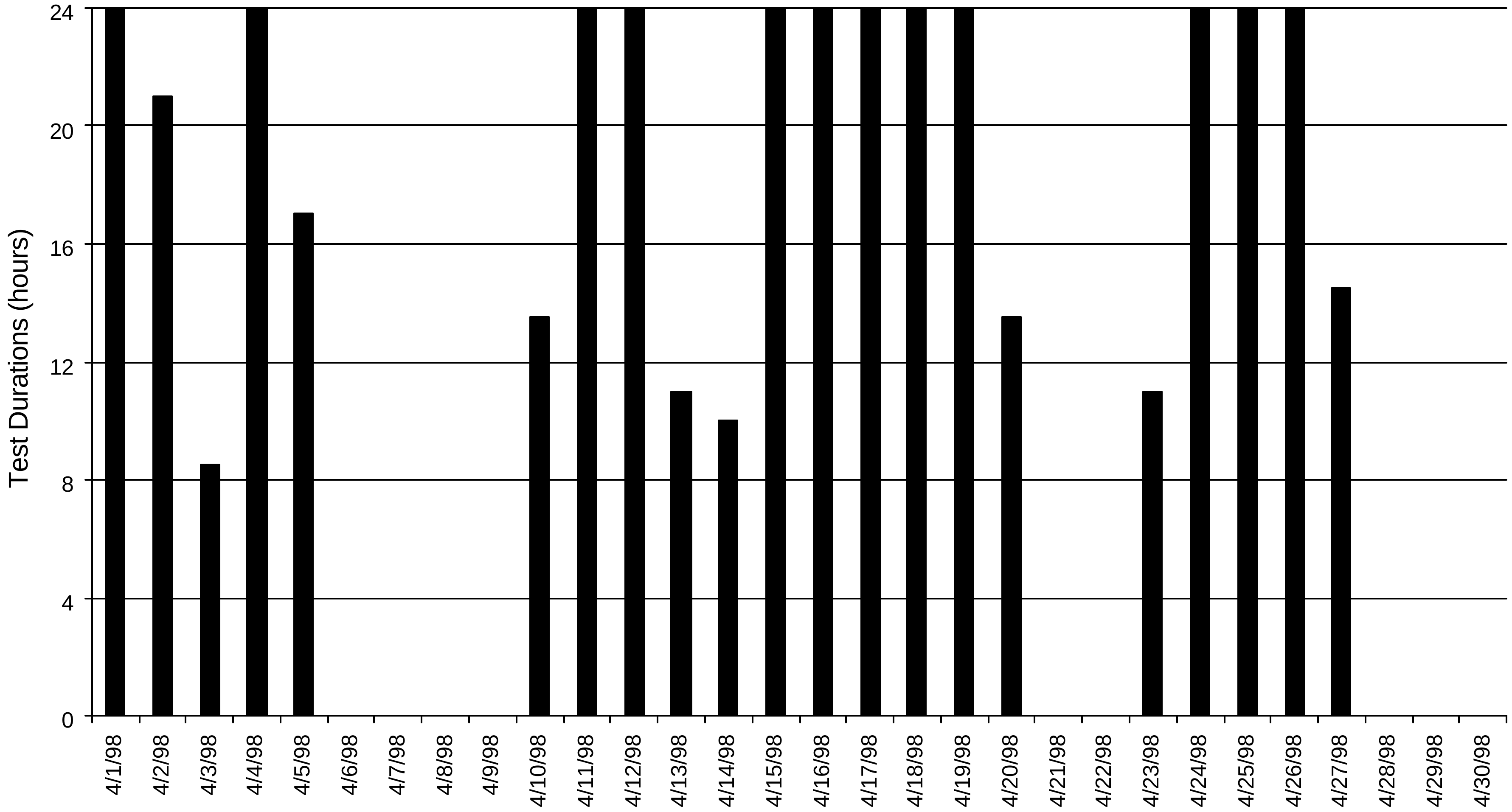
ROM coal from Seam 6 and Seam 3 was fired during the first three tests. Blended coal tests, using Seam 4 ROM and Seam 4 waste coal, were initiated on April 23. Two reduced load (40 MW gross) blended coal tests were conducted instead of the initially proposed combustor performance characterization test series. Boiler feed problems and a concurrent incorrect pulverizer classifier setting (which resulted in coarser than specified coal) delayed the combustor performance characterization test series until May.

In general, the combustor performance was very good. Overall slag coverage on the gas-side surfaces was excellent while burning both ROM and blended coal, with all areas covered by a uniformly thick, molten slag layer, without any bare regions.

Slag quantity and quality were very good when operating at full or part load, while burning ROM coal or blended coal with a minimum higher heating value of 7,000 Btu/lb. The drag chain flights were three-quarters full and few clinkers were observed on the drag chain during the test. Two different coal sizes were inadvertently evaluated during this time period, forty percent through 200 mesh (courser than specified) and sixty to seventy percent through 200 mesh. Significant deterioration in slag characteristics occurred at reduced load (30 to 40 MW gross), when burning blended coal sized so that forty percent passed through 200 mesh.

Combustor operation without oil ignitors was excellent while firing either ROM coal or blended coal. No performance or flame stability degradation was noted after removing the ignitors from service. Coal flames were very stable even at precombustor and slagging combustor stoichiometries down to 0.65 and 0.77, respectively.

As noted prior to April, occasional rapid increases in boiler duty with corresponding decreases in furnace O_2 and increases in furnace carbon monoxide occurred approximately once every ten to twelve hours during test operations. These excursions were theorized to be caused by coal (particularly Seam 6 coal) accumulating in the pulverizers and then entering the furnace as a slug. They continued to occur during the early part of April. In almost all cases, the excursions occurred when pressure drop across a mill decreased. Mill pressure drop would gradually increase and then suddenly decrease as boiler duty increased and furnace exit gas oxygen concentration decreased. Slag characteristics during the mill pressure drop variations lends credence to this theory. Specifically, when the mill pressure drop was high, the slag quantity appeared to be less than normally expected and there was more fly ash than usual. This implies a finer coal and is consistent with the theory that the mill classifier was packed allowing only smaller coal particles to exit the mill. When the mill pressure drop decreased, slag quantity increased.



Test Durations (hours)
0
4
8
12
16
20
24
4/1/98
4/2/98
4/3/98
4/4/98
4/5/98
4/6/98
4/7/98
4/8/98
4/9/98
4/10/98
4/11/98
4/12/98
4/13/98
4/14/98
4/15/98
4/16/98
4/17/98
4/18/98
4/19/98
4/20/98
4/21/98
4/22/98
4/23/98
4/24/98
4/25/98
4/26/98
4/27/98
4/28/98
4/29/98
4/30/98

Date	Test Durations (hours)
4/1/98	24
4/2/98	21
4/3/98	8.5
4/4/98	24
4/5/98	17
4/6/98	0
4/7/98	0
4/8/98	0
4/9/98	0
4/10/98	13.5
4/11/98	24
4/12/98	24
4/13/98	11
4/14/98	10
4/15/98	24
4/16/98	24
4/17/98	24
4/18/98	24
4/19/98	24
4/20/98	13.5
4/21/98	0
4/22/98	0
4/23/98	11
4/24/98	24
4/25/98	24
4/26/98	24
4/27/98	14.5
4/28/98	0
4/29/98	0
4/30/98	0

Mill pressure drop excursions were less pronounced after setting the classifier to ninety-five percent open to deliver coarser coal. The resulting coarser coal (forty percent through 200 mesh) was not acceptable for operation at part load. At the end of May, the classifier was reset to seventy-five percent open to provide an estimated sixty percent through 200 mesh coal size.

Slag recovery was measured at reduced load (40 MW gross) with ROM Seam 4 coal. The slag ash from the combustor and bottom ash from the furnace were accumulated in the silo over 15.5 hours of relatively steady-state operation and then transferred to a Usibelli dump truck having a load cell. The amount of slag ash removed (39.7 tons) indicated that approximately eighty-three percent of the coal ash was recovered as slag, assuming ten percent ash in the ROM coal (which is a somewhat high estimate), so no correction was made for the moisture content of the slag. The slag removal efficiency, resulting from a low precombustor exit velocity (less than 250 ft/sec), which typically reduces slag recovery, was higher than expected for this reduced load test.

Precombustor slag accumulation was again observed during the initial blended coal tests conducted at the end of April. The first experience with blended coal occurred unexpectedly, during the test with ROM Seam 3 coal, between April 14 and April 20, when the coal higher heating value varied from 6,300 to 8,000 Btu/lb. For the first sixty hours of this test, coal higher heating value varied from 6,500 to 7,600 Btu/lb and there was no indication of precombustor slag accumulation. However, following an online adjustment in the mill classifier setting from sixty to seventy percent open and several hours of continuous operation with a coal higher heating value less than 6,500 Btu/lb, the precombustor chamber pressure began to increase, indicating slag accumulation near the exit of the precombustor into the slag combustor. The effect of decreased higher heating value was compounded by a corresponding decrease in thermal input since the coal flow rate was not increased when the coal higher heating value decreased. It is important to note that combustion controls to automatically adjust for changes in higher heating value were not fully implemented in April.

It had been anticipated that during operation with blended coal, the coal split between the precombustor and slagging combustor would need to be changed to either increase or decrease the percentage of total coal flow to the precombustor. Specifically, to continue to operate the precombustor in a slagging mode with blended coal, the coal flow to the precombustor would need to be increased from thirty-eight to forty-three percent. In order to operate the precombustor in a non-slagging mode, the coal flow to the precombustor would need to be reduced to thirty percent, thus reducing the precombustor exit temperature (i.e., inlet to the slagging stage) below the ash fusion temperature. The desired rate or setpoint of coal flow to both precombustors was to be increased to forty percent. Inadvertently, it was only increased on Combustor B and the coal flow to Combustor A remained at thirty-eight percent. Therefore, both the slagging and non-slagging modes of operation were evaluated for effects of slag accumulation during the combustor characterization test series in May.

There was little, if any, apparent difference in NO_X emission while burning blended coal versus burning ROM coal. In all cases, during full load operation, at a slagging combustor stoichiometry of 0.85, while burning either ROM or blended coal, the NO_X emission readings were consistently below the environmental permit requirement of 0.35 pounds per million Btu, and typically in the range of 0.29 to 0.31 pounds per million Btu. When the slagging combustor stoichiometry was reduced to 0.80, the NO_X emission was 0.23 pounds per million Btu, while burning either ROM or blended coal.

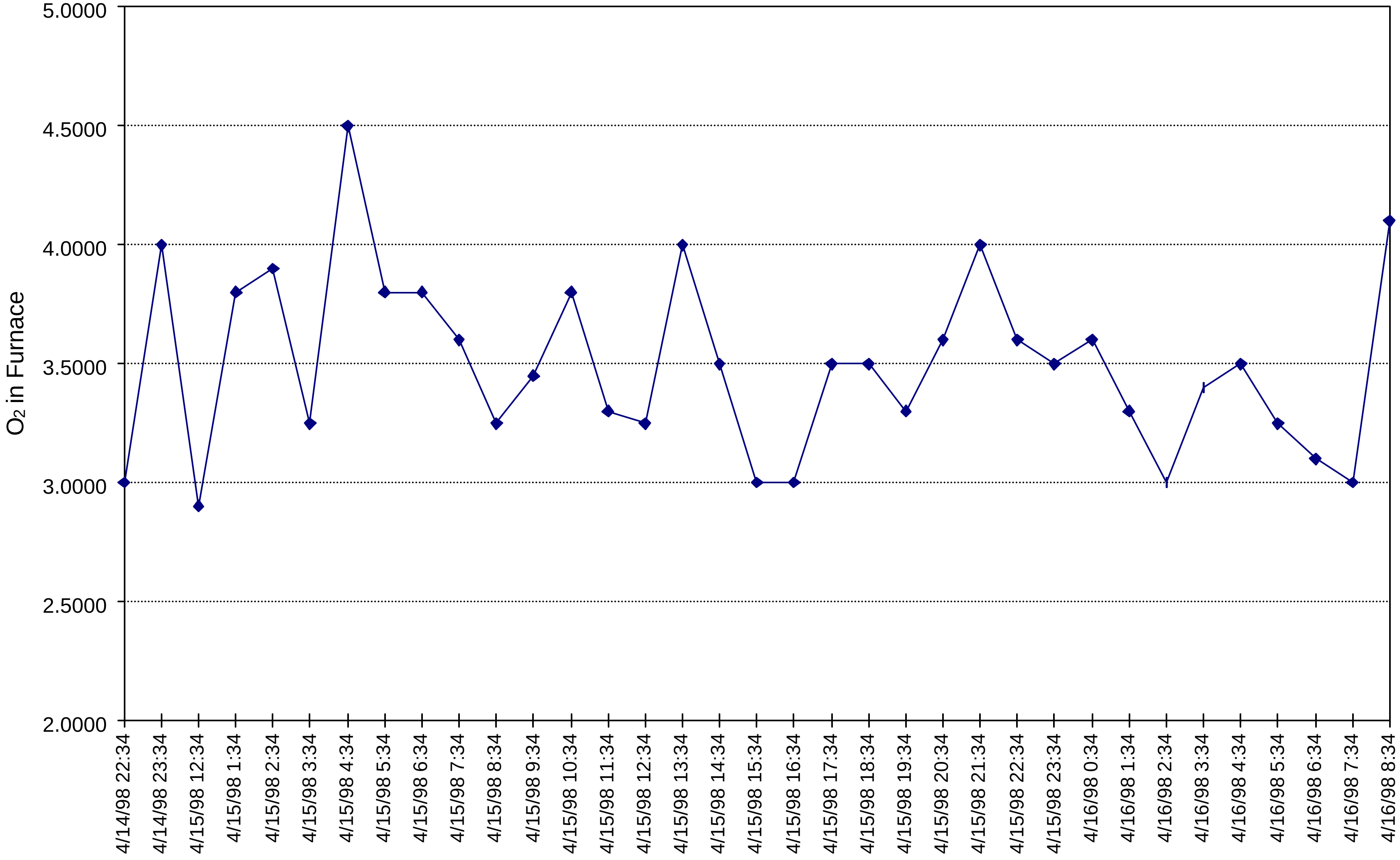
The SO_2 measurements recorded upstream of the SDA indicated approximately twenty to thirty-five percent removal in the furnace.

Figures 4.6.2, 4.6.3 and 4.6.4 show the O_2, NO_X, and SO_2 emission trends over a thirty-four hour period starting on April 14.

Server> odms01_mon
Start> 23-june-98 08:00
Interval> 06:35

		Furnace O_2 (%)	Stack SO_2 (ppm)	NO_X (lb/MBtu)
35	4/14/98 22:34	3.0000	2.0000	0.2600
34	4/14/98 23:34	4.0000	1.5000	0.2400
33	4/15/98 12:34	2.9000	2.0000	0.2875
32	4/15/98 1:34	3.8000	0.0000	
31	4/15/98 2:34	3.9000	2.9000	0.2725
30	4/15/98 3:34	3.2500	7.5000	0.2500
29	4/15/98 4:34	4.5000	3.7500	0.2500
28	4/15/98 5:34	3.8000	3.0000	0.2500
27	4/15/98 6:34	3.8000	4.0000	0.2675
26	4/15/98 7:34	3.6000	7.7500	0.2475
25	4/15/98 8:34	3.2500	4.0000	0.2680
24	4/15/98 9:34	3.4500	4.5000	0.2500
23	4/15/98 10:34	3.8000	9.7500	0.2675
22	4/15/98 11:34	3.3000	4.2500	0.2225
21	4/15/98 12:34	3.2500	2.2500	0.2150
20	4/15/98 13:34	4.0000	2.4000	0.2375
19	4/15/98 14:34	3.5000	4.2500	0.2300
18	4/15/98 15:34	3.0000	9.0000	0.2400
17	4/15/98 16:34	3.0000	7.2500	0.2050
16	4/15/98 17:34	3.5000	5.7500	0.2150
15	4/15/98 18:34	3.5000	10.5000	0.2050
14	4/15/98 19:34	3.3000	7.5	0.2225
13	4/15/98 20:34	3.6000	2.6000	0.2500
12	4/15/98 21:34	4.0000	2.5000	0.2425
11	4/15/98 22:34	3.6000	5.7500	0.2225
10	4/15/98 23:34	3.5000	3.2500	0.2275
9	4/16/98 0:34	3.6000	7.5000	0.2250

8	4/16/98 1:34	3.3000	4.2500	0.2075
7	4/16/98 2:34	3.0000	1.7500	0.2075
6	4/16/98 3:34	3.4000	3.5000	0.2400
5	4/16/98 4:34	3.5000	2.5000	0.2375
4	4/16/98 5:34	3.2500	2.9000	0.205
3	4/16/98 6:34	3.1000	2.7500	0.2100
2	4/16/98 7:34	3.0000	4.5000	0.2350
1	4/16/98 8:34	4.1000	2.7500	0.2200


O2 in Furnace
5.0000
4.5000
4.0000
3.5000
3.0000
2.5000
2.0000
4/14/98 22:34
4/14/98 23:34
4/15/98 12:34
4/15/98 1:34
4/15/98 2:34
4/15/98 3:34
4/15/98 4:34
4/15/98 5:34
4/15/98 6:34
4/15/98 7:34
4/15/98 8:34
4/15/98 9:34
4/15/98 10:34
4/15/98 11:34
4/15/98 12:34
4/15/98 13:34
4/15/98 14:34
4/15/98 15:34
4/15/98 16:34
4/15/98 17:34
4/15/98 18:34
4/15/98 19:34
4/15/98 20:34
4/15/98 21:34
4/15/98 22:34
4/15/98 23:34
4/16/98 0:34
4/16/98 1:34
4/16/98 2:34
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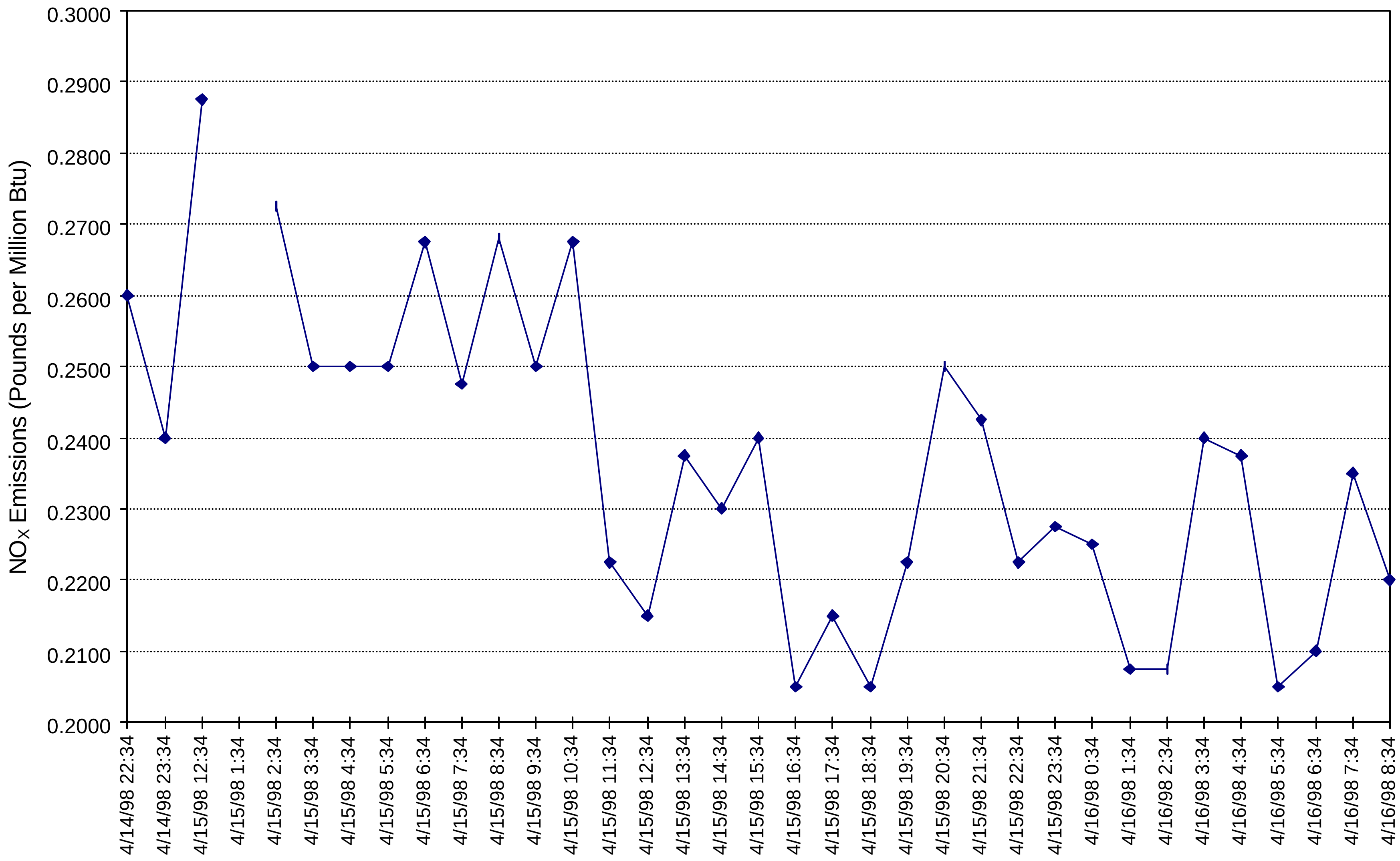
4/16/98 7:34
4/16/98 8:34


NOx Emissions (Pounds per Million Btu)
0.3000
0.2900
0.2800
0.2700
0.2600
0.2500
0.2400
0.2300
0.2200
0.2100
0.2000
4/14/98 22:34
4/14/98 23:34
4/15/98 12:34
4/15/98 1:34
4/15/98 2:34
4/15/98 3:34
4/15/98 4:34
4/15/98 5:34
4/15/98 6:34
4/15/98 7:34
4/15/98 8:34
4/15/98 9:34
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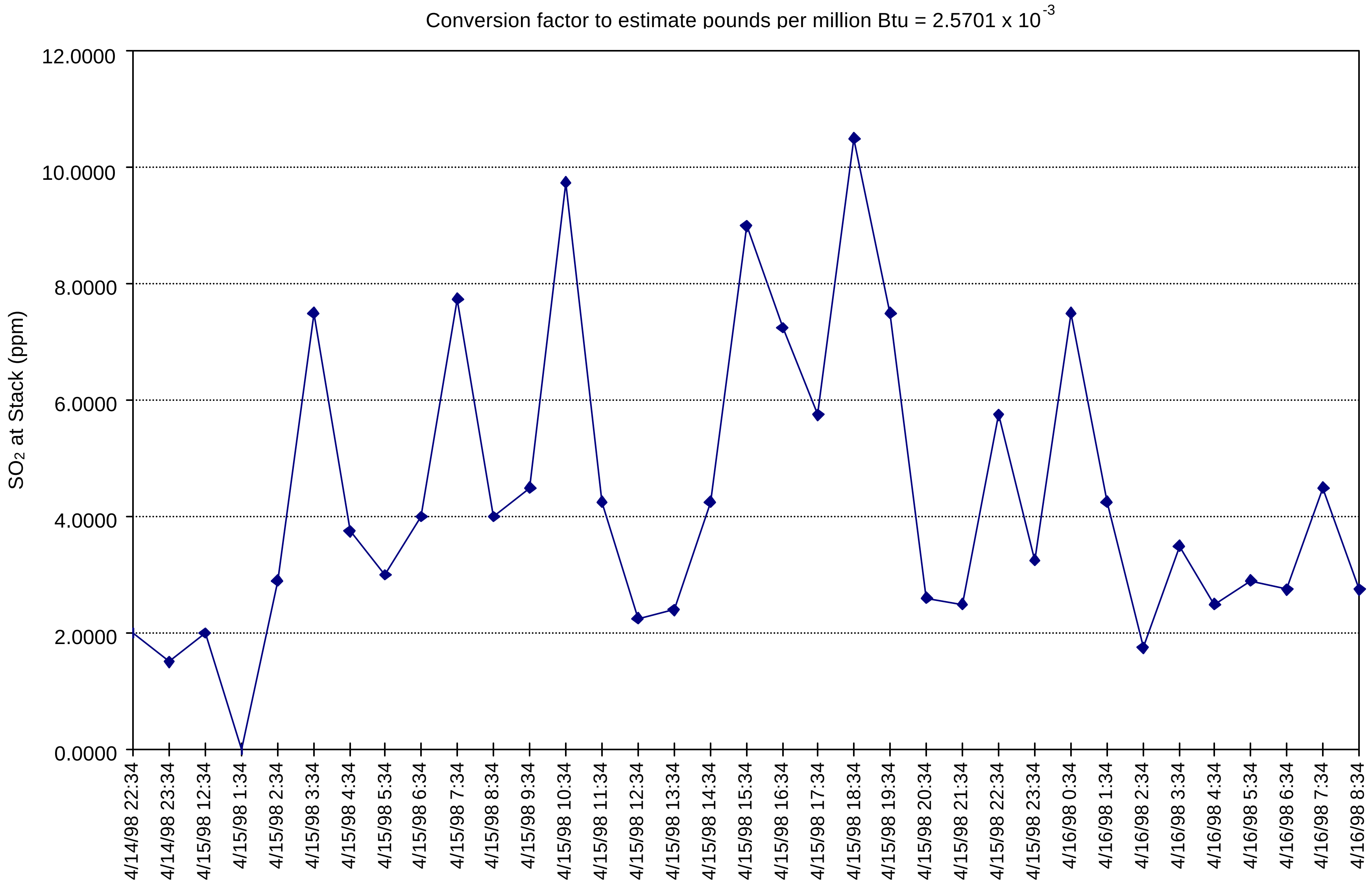
4/16/98 7:34
4/16/98 8:34



Conversion factor to estimate pounds per million Btu = 2.5701 x 10^{-3}

4.7 MAY COMBUSTOR OPERATION

As part of the combustor characterization test program, a sampling program was initiated during May. Samples of coal, limestone, slag, bottom ash and fly ash were taken during steady-state portions of the test program. Typically, four types of coal samples were taken:

1) A sample from the region of the HCCP coal from the pile being loaded into the hopper for that particular test
2) A blended sample from multiple samples taken at uniform intervals, from the automatic coal belt sampler, during the entire duration of the coal loading
3) A sample from each coal feeder during a steady-state portion of the test
4) A sample of pulverized coal taken from the mill exhauster discharge coal line to each combustor, using an isokinetic probe

As a rule, two coal samples were analyzed for each test, a proximate analysis on each coal feeder sample and a sieve analysis from each isokinetic sample. The slag samples, bottom ash samples, fly ash samples and limestone samples were taken once each test. These samples were stored for future analysis. The coal sample analysis indicated a large variability in the coal properties from test to test, as well as from Combustor A to Combustor B. For example, the analysis of the coal feeder samples (from test PERF-S4-4 on May 15) indicated a higher heating value of 5,199 Btu/lb for the coal in Feeder A and a higher heating value of 6,722 Btu/lb for the coal in Feeder B. During this period of time, the inferred higher heating value, based on steam output, was 6,600 Btu/lb. For this example, the slagging combustor stoichiometry in Combustor A was 1.0 and 0.76 in Combustor B, while the overall stoichiometry setpoint was 0.80 for both combustors. Although this is an extreme example of the mismatch in the higher heating value observed between the two combustors, it was not uncommon to have a 500 Btu/lb mismatch, which corresponds to stoichiometry variation of approximately 0.06. For example, if one combustor was at a stoichiometry of 0.78, the other combustor would be at a stoichiometry of 0.84 for the same stoichiometry setpoint, which affects NO_X emission and slag recovery. The coal sieve analysis results during May were typically fifty to seventy percent through 200 mesh.

Figures 4.7.1, 4.7.2 and 4.12.3 show coal burn time and NO_x and SO_2 emissions, respectively. Seven tests were conducted during May, accumulating 339 hours of coal burn time. The majority of the tests lasted from twelve to twenty-four hours. Eighty-one of the 339 hours were conducted at reduced load because of various facility problems including feedwater pump outage, atomizer pluggage and poor slag ash drag chain performance. These tests were conducted with blended 6,900 Btu/lb coal, ground to fifty to sixty percent through 200 mesh.

The primary objective of the test operations in May was to determine the normal combustor operating envelope and performance characteristics with blended coal. Four key combustor operating parameters, coal flow split to the precombustor, precombustor stoichiometry, precombustor exit velocity and slagging combustor stoichiometry, were varied. The overall combustor characterization test matrix is shown back in Table 4.2.1, which provides a summary of the test objectives, operating conditions and combustor performance parameters for each test performed. The test durations reported in the table only include periods of applicable steady-state operation. In many cases, the combustion system was not shut down between tests. Test conditions were simply changed during operation to correspond to the new operating conditions. The Seam 4 performance coal blend tests were completed in May.

	5/1/98		5/2/98		5/3/98		5/4/98		5/5/98		5/6/98		5/7
Hour	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx
0:00	0.475	0.249	0.133	0.249	0.475	0.249	0.429	0.249	0.358	0.249	0.000	0.000	0.000
1:00	0.475	0.249	0.133	0.249			0.440	0.249	0.352	0.249	0.000	0.000	0.000
2:00	0.475	0.249	0.151	0.249	0.471	0.249	0.449	0.249	0.383	0.249	0.000	0.000	0.000
3:00	0.476	0.249	0.186	0.249	0.464	0.249	0.449	0.249	0.348	0.249	0.000	0.000	0.000
4:00	0.475	0.249	0.168	0.249	0.475	0.249	0.420	0.249	0.343	0.249	0.000	0.000	0.000
5:00	0.475	0.249	0.189	0.249	0.475	0.249	0.445	0.249	0.333	0.249	0.000	0.000	0.000
6:00	0.366	0.249	0.294	0.249	0.476	0.249	0.371	0.249	0.322	0.249	0.000	0.000	0.000
7:00	0.401	0.249	0.130	0.249	0.475	0.249	0.414	0.249	0.312	0.249	0.000	0.000	0.000
8:00			0.150	0.249	0.460	0.249	0.465	0.249	0.312	0.249	0.000	0.000	0.000
9:00	0.412	0.249	0.168	0.249	0.455	0.249	0.439	0.249			0.000	0.000	0.000
10:00	0.412	0.249	0.299	0.249	0.476	0.249	0.449	0.249	0.354	0.249	0.000	0.000	0.000
11:00	0.412	0.249	0.367	0.249			0.370	0.249	0.354	0.249	0.000	0.000	0.000
12:00	0.414	0.249	0.476	0.249	0.433	0.249			0.354	0.249	0.000	0.000	0.000
13:00	0.387	0.249	0.476	0.000			0.360	0.249	0.354	0.249	0.000	0.000	0.000
14:00	0.409	0.249	0.475	0.249	0.450	0.249			0.354	0.249	0.000	0.000	0.000
15:00	0.394	0.249	0.475	0.249	0.448	0.249	0.327	0.249	0.354	0.249	0.000	0.000	0.000
16:00	0.475	0.249	0.475	0.249	0.461	0.249	0.361	0.249	0.354	0.249	0.000	0.000	0.000
17:00	0.476	0.208	0.475	0.249	0.441	0.249	0.384	0.249	0.000	0.000	0.000	0.000	0.000
18:00	0.357	0.249	0.475	0.249	0.448	0.249	0.382	0.249	0.000	0.000	0.000	0.000	0.000
19:00	0.473	0.249	0.475	0.249	0.435	0.249	0.391	0.249	0.000	0.000	0.000	0.000	0.000
20:00	0.350	0.249	0.475	0.249	0.459	0.249	0.385	0.249	0.000	0.000	0.000	0.000	0.000
21:00	0.476	0.149	0.411	0.249	0.463	0.249	0.369	0.249	0.000	0.000	0.000	0.000	0.000
22:00	0.133	0.249	0.412	0.249	0.475	0.249	0.345	0.249	0.000	0.000	0.000	0.000	0.000
23:00	0.133	0.249	0.476	0.249	0.462	0.249	0.348	0.249	0.000	0.000	0.000	0.000	0.000
NOx Daily Average lb/mmBtu	**0.406**		**0.331**		**0.461**		**0.400**		**0.241**		**0.000**		**0.000**
SO_2 Daily Average lb/mmBtu		**0.243**		**0.239**		**0.249**		**0.249**		**0.173**		**0.000**	

/98	5/8/98		5/9/98		5/10/98		5/11/98		5/12/98		5/13/98		5/14
SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.152
0.000	0.000	0.000											0.112
0.000	0.000	0.000											0.149
0.000	0.000	0.000											0.273
0.000	0.000	0.000											0.476
0.000	0.000	0.000											0.476
0.000	0.000	0.000											0.476
0.000	0.000	0.000											0.476
0.000	0.000	0.000											0.476
0.000	0.000	0.000											
0.000	0.000	0.000											0.476
0.000	0.000	0.000											0.476
0.000													0.449
0.000													0.459
0.000													0.475
0.000													
0.000											0.265	0.249	0.472
0.000													0.475
0.000											0.443	0.249	0.475
0.000											0.443	0.249	0.475
0.000											0.248	0.249	0.475
0.000											0.277	0.249	0.447
0.000											0.280	0.249	0.408
0.000											0.454	0.249	0.476
	0.000		**0.000**		**0.000**		**0.000**		**0.000**		**0.301**		**0.414**
0.000		**0.000**		**0.000**		**0.000**		**0.000**		**0.000**		**0.218**	

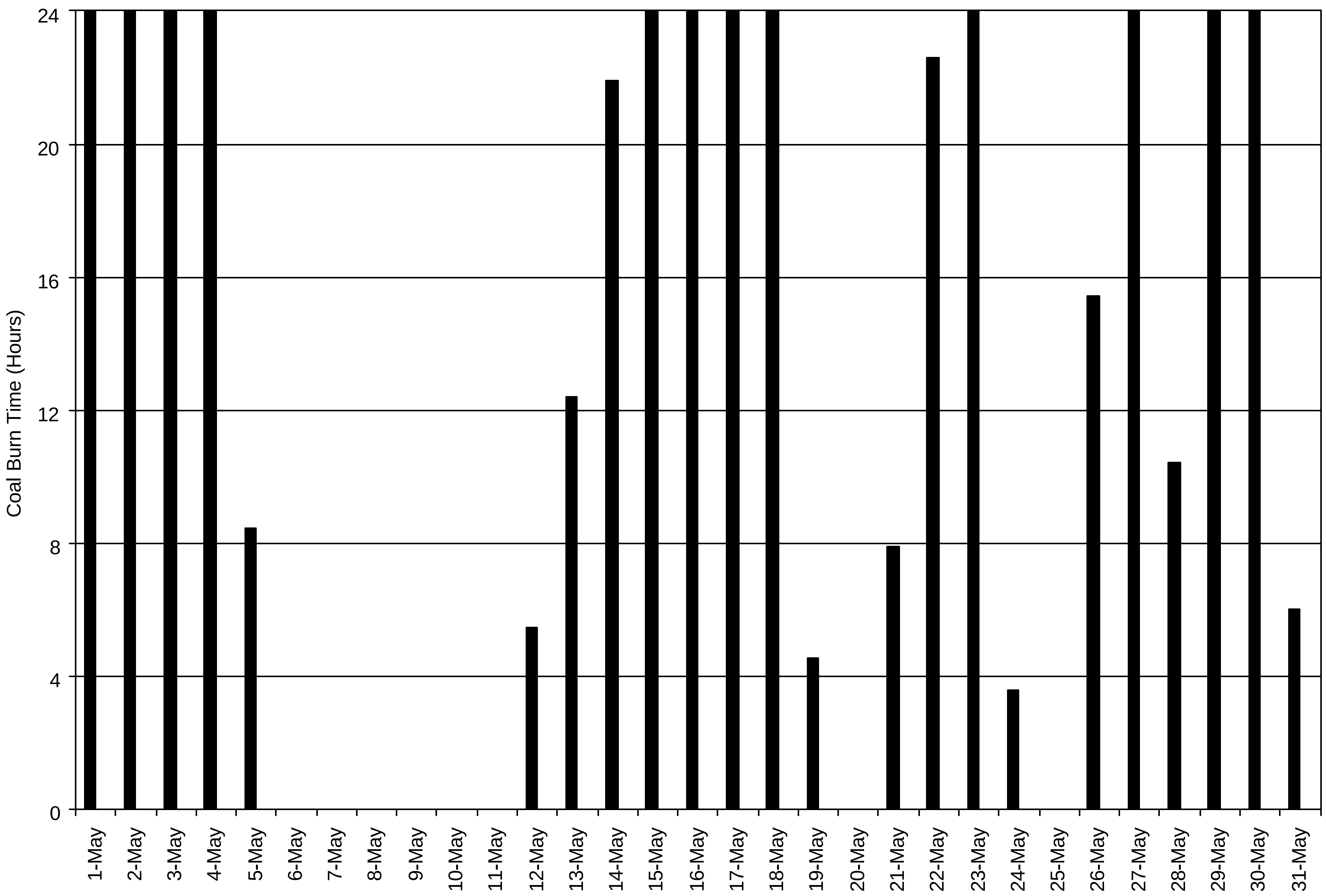
4/98	5/15/98		5/16/98		5/17/98		5/18/98		5/19/98		5/20/98		5/21
SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx
0.249	0.475	0.249	0.290	0.026	0.219	0.245	0.234	0.193					
0.249	0.475	0.249	0.297	0.099	0.214	0.228	0.254	0.249					
0.249	0.475	0.249	0.299	0.249	0.199	0.215	0.248	0.249					
0.249	0.476	0.249	0.348	0.076	0.210	0.170	0.242	0.247					
0.249	0.475	0.249	0.475	0.048	0.213	0.202	0.231	0.249					
0.000	0.475	0.249	0.256	0.173	0.277	0.164	0.227	0.249					
0.000	0.461	0.249	0.417	0.142	0.350	0.135	0.227	0.249					
0.000	0.370	0.249	0.312	0.128	0.428	0.249	0.227	0.249					
0.000	0.352	0.249	0.306	0.181	0.393	0.240	0.227	0.249					
0.000	0.396	0.249	0.423	0.105	0.475	0.249	0.227	0.249					
0.000			0.281	0.065	0.475	0.211	0.227	0.249					
0.000	0.339	0.249	0.209	0.092	0.475	0.049	0.227	0.249					
0.000	0.301	0.249	0.179	0.060	0.475	0.093	0.227	0.249					
0.000	0.288	0.249	0.297	0.120	0.475	0.105	0.227	0.249					
0.000	0.302	0.249	0.211	0.213	0.397	0.228	0.227	0.249					
	0.256	0.249			0.391	0.249	0.000	0.000					
0.000	0.278	0.249	0.215	0.249	0.329	0.249	0.000	0.000					
0.249	0.231	0.249			0.475	0.249							
0.249	0.217	0.249	0.203	0.177	0.475	0.249							
0.249	0.221	0.249	0.201	0.176	0.475	0.249							
0.249	0.236	0.249	0.223	0.246	0.247	0.249							
0.249	0.279	0.210	0.209	0.243	0.248	0.249							
0.249	0.430	0.111	0.211	0.160	0.229	0.249							
0.249	0.250	0.033	0.228	0.242	0.246	0.249							
	0.350		**0.277**		**0.350**		**0.205**		**0.000**		**0.000**		**0.000**
0.130		**0.232**		**0.149**		**0.209**		**0.216**		**0.000**		**0.000**	

/98	5/22/98		5/23/98		5/24/98		5/25/98		5/26/98		5/27/98		5/2
SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx
		0.249	0.320	0.249	0.250	0.249	0.358	0.249			0.475	0.142	
		0.249	0.306	0.249	0.335	0.249	0.358	0.249			0.475	0.249	0.297
		0.249	0.285	0.249	0.393	0.249	0.358	0.249			0.475	0.128	0.287
		0.249	0.276	0.249	0.374	0.249	0.358	0.249			0.475	0.079	0.293
		0.249	0.268	0.249	0.358	0.249	0.358	0.249			0.475	0.079	0.301
		0.249	0.255	0.249	0.358	0.249	0.358	0.249			0.475	0.059	0.290
		0.249	0.237	0.249	0.358	0.249	0.358	0.249			0.475	0.058	0.300
		0.249	0.247	0.249	0.358	0.249	0.358	0.249			0.475	0.038	
	0.273	0.249	0.247	0.249	0.358	0.249	0.359	0.249			0.475	0.020	0.316
	0.327	0.249	0.264	0.249	0.358	0.249					0.476	0.034	0.334
	0.305	0.249	0.247	0.249	0.358	0.249					0.476	0.023	0.328
	0.284	0.249	0.242	0.249	0.358	0.249					0.396	0.035	0.328
	0.299	0.249	0.259	0.249	0.358	0.249					0.342	0.077	0.389
	0.222	0.249			0.358	0.249					0.345	0.098	0.205
	0.263	0.249	0.263	0.249	0.358	0.249					0.357	0.091	0.278
	0.266	0.249	0.267	0.249	0.358	0.249					0.306	0.117	0.346
	0.269	0.249	0.248	0.249	0.358	0.249					0.346	0.068	0.412
	0.326	0.249	0.263	0.249	0.358	0.249							0.476
	0.475	0.000	0.301	0.249	0.358	0.249					0.315	0.085	0.399
	0.475	0.048	0.249	0.249	0.358	0.249					0.301	0.073	0.259
	0.440	0.249	0.254	0.249	0.358	0.249					0.330	0.093	0.288
	0.385	0.249	0.266	0.249	0.358	0.249					0.300	0.120	0.281
	0.276	0.249	0.243	0.249	0.358	0.249			0.475	0.220	0.327	0.115	0.269
	0.305	0.249	0.241	0.249	0.358	0.249			0.475	0.213	0.307	0.145	0.261
	0.324		**0.263**		**0.355**		**0.358**		**0.475**		**0.400**		**0.315**
0.000		**0.230**		**0.249**		**0.249**		**0.249**		**0.217**		**0.088**	

3/98	5/29/98		5/30/98		5/31/98	
SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2
	0.265	0.197	0.309	0.249	0.391	0.249
0.090			0.341	0.249	0.377	0.249
0.092	0.289	0.213	0.306	0.249	0.378	0.249
0.078			0.325	0.249	0.475	0.249
0.135	0.278	0.221	0.309	0.176	0.475	0.249
0.172	0.307	0.192	0.285	0.127	0.473	0.249
0.150	0.308	0.163	0.288	0.124	0.246	0.249
	0.306	0.249	0.312	0.097	0.246	0.249
0.217	0.293	0.249			0.246	0.249
0.234	0.292	0.249	0.315	0.040	0.246	0.249
0.249	0.292	0.249	0.303	0.249	0.246	0.249
0.204	0.311	0.249	0.315	0.249	0.246	0.249
0.044	0.310	0.249	0.308	0.249	0.246	0.249
0.249	0.309	0.249	0.290	0.249	0.246	0.249
0.249	0.299	0.249	0.316	0.249	0.246	0.249
0.249	0.290	0.249	0.314	0.249	0.246	0.249
0.018	0.295	0.249	0.390	0.249	0.246	0.249
0.070					0.246	0.249
0.204	0.299	0.249	0.353	0.249	0.246	0.249
0.249	0.271	0.249	0.384	0.249	0.246	0.249
0.151	0.286	0.249	0.350	0.249	0.246	0.249
0.164	0.283	0.249	0.367	0.249	0.246	0.249
0.249	0.274	0.249	0.362	0.249	0.246	0.249
0.164	0.283	0.249	0.367	0.249	0.246	0.249
	0.292		**0.328**		**0.292**	
0.167		**0.237**		**0.218**		**0.249**

Date	NOx lb/mmBtu	SO_2 lb/mmBtu		Burn Time	Date	on/off	Time	Burn time (Hr/min)	to minutes	Hours
1-May	0.406	0.243	1-May	24	30-Apr	on	1420			
2-May	0.331	0.239	2-May	24	5-May	off	827			
3-May	0.461	0.249	3-May	24	12-May	on	850			
4-May	0.400	0.249	4-May	24		off	1237	3.47	227	
5-May	0.241	0.173	5-May	8.45		on	1840			
6-May	0.000	0.000	6-May	0		off	1923	0.43	43	
7-May	0.000	0.000	7-May	0		on	2009			
8-May	0.000	0.000	8-May	0		off	2100	0.59	59	5.483333
9-May	0.000	0.000	9-May	0	13-May	on	150			
10-May	0.000	0.000	10-May	0		off	730	5.4	340	
11-May	0.000	0.000	11-May	0		on	1434			
12-May	0.000	0.000	12-May	5.483333		off	1830	3.56	236	
13-May	0.301	0.218	13-May	12.4		on	1940			
14-May	0.414	0.130	14-May	21.9		off	2218	2.48	168	12.4
15-May	0.350	0.232	15-May	24	14-May	on	206	21.54	1314	21.9
16-May	0.277	0.149	16-May	24	19-May	off	433	4.33	273	4.55
17-May	0.350	0.209	17-May	24	21-May	on	1606	7.54	474	7.9
18-May	0.205	0.216	18-May	24	22-May	off	1120	11.2	680	
19-May	0.000	0.000	19-May	4.55		on	1244	11.16	676	22.6
20-May	0.000	0.000	20-May	0	24-May	off	334	3.34	214	3.566667
21-	0.000	0.000	21-May	7.9	26-May	on	1527	15.27	927	15.45

May									
22-May	0.324	0.230	22-May	22.6	28-May off	1145	11.45	705	
23-May	0.263	0.249	23-May	24	on	1333	10.27	627	10.45
24-May	0.355	0.249	24-May	3.566667	31-May off	600	6	360	6
25-May	0.358	0.249	25-May	0					
26-May	0.475	0.217	26-May	15.45					
27-May	0.400	0.088	27-May	24					
28-May	0.315	0.167	28-May	10.45					
29-May	0.292	0.237	29-May	24					
30-May	0.328	0.218	30-May	24					
31-May	0.292	0.249	31-May	6					


Coal Burn Time (Hours)
0
4
8
12
16
20
24
1-May
2-May
3-May
4-May
5-May
6-May
7-May
8-May
9-May
10-May
11-May
12-May
13-May
14-May
15-May
16-May
17-May
18-May
19-May
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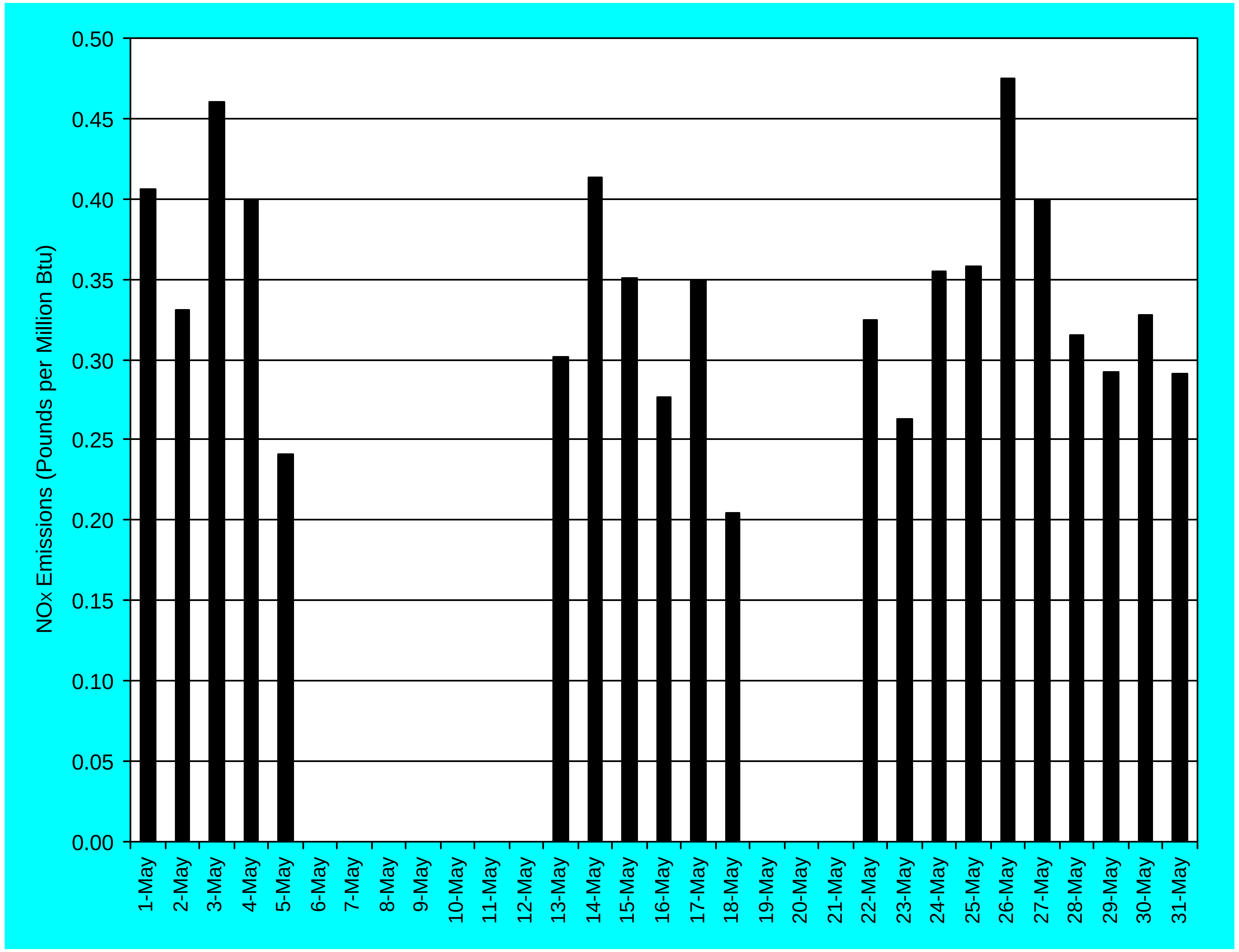
28-May
29-May
30-May
31-May


NOx Emissions (Pounds per Million Btu)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1-May
2-May
3-May
4-May
5-May
6-May
7-May
8-May
9-May
10-May
11-May
12-May
13-May
14-May
15-May
16-May
17-May
18-May
19-May
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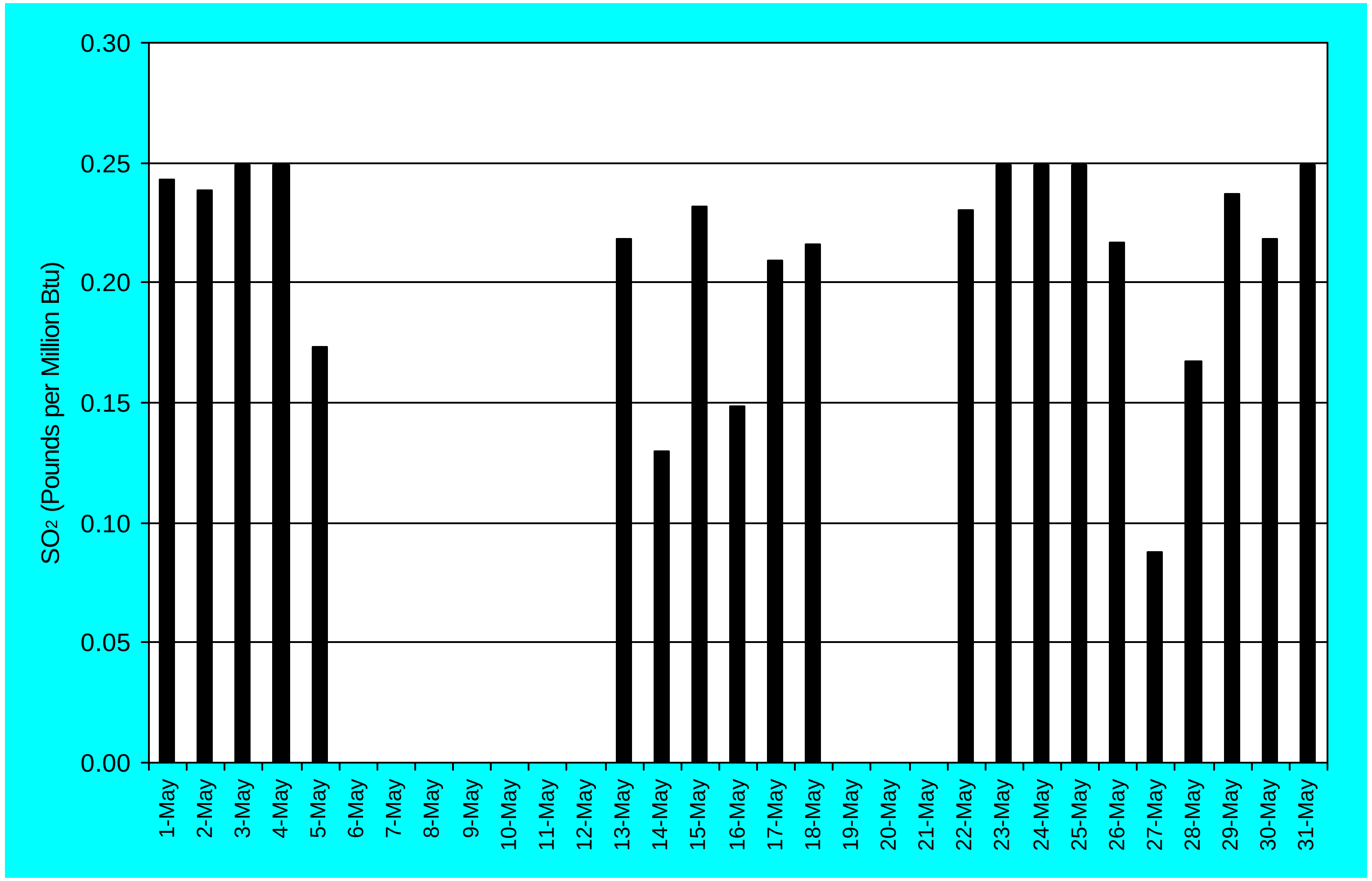
28-May
29-May
30-May
31-May


SO2 (Pounds per Million Btu)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1-May
2-May
3-May
4-May
5-May
6-May
7-May
8-May
9-May
10-May
11-May
12-May
13-May
14-May
15-May
16-May
17-May
18-May
19-May
20-May
21-May
22-May
23-May
24-May
25-May
26-May
27-May
28-May
29-May
30-May
31-May

PRECOMBUSTOR COAL SPLIT AND PRECOMBUSTOR STOICHIOMETRY

The proportion of total coal flow burned in the precombustor (referred to as precombustor coal split) and precombustor stoichiometry was varied and its effects on precombustor slagging and NO_X emission were evaluated.

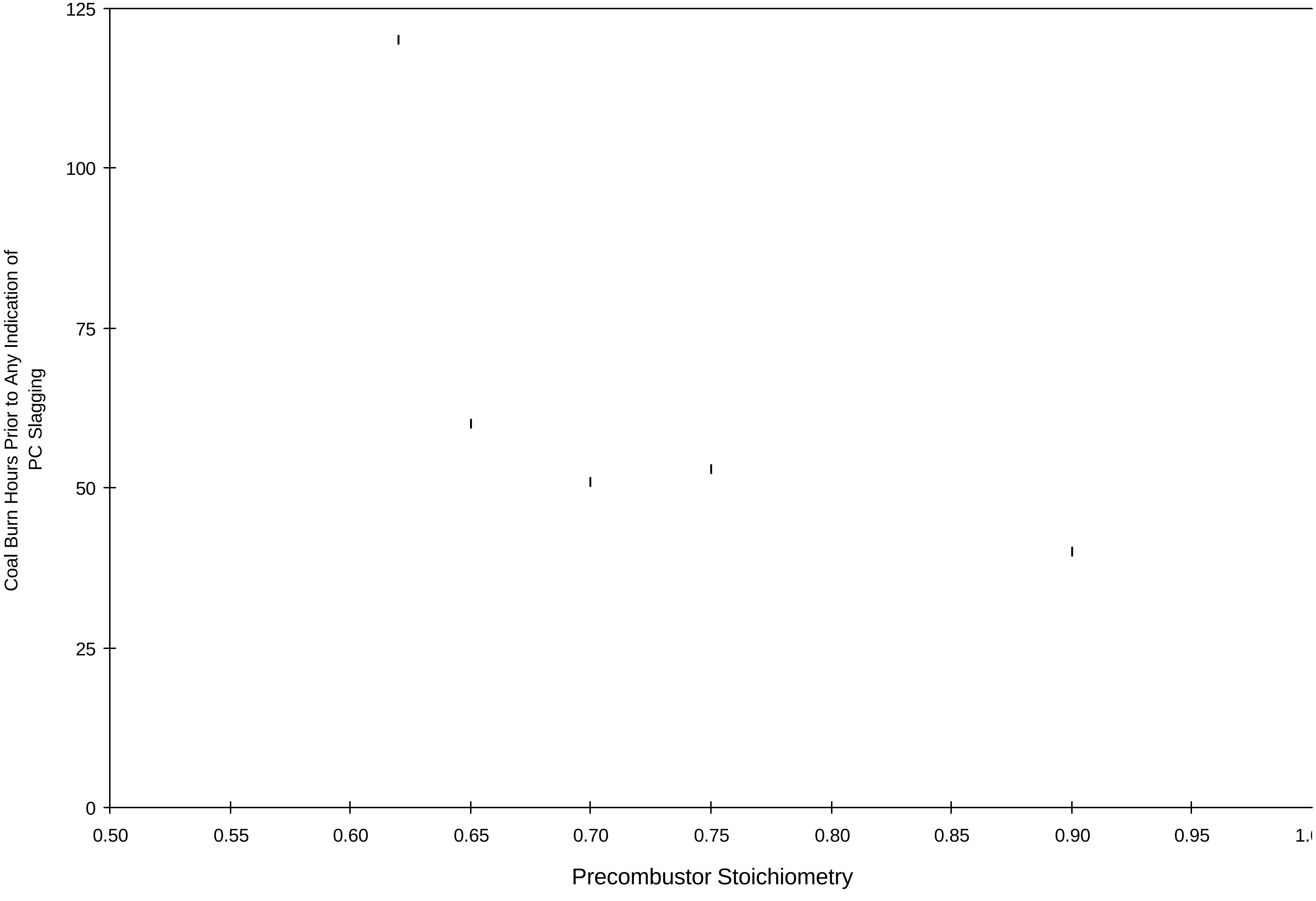
As precombustor coal split increases, its exit temperature increases and, conversely, as the precombustor coal split decreases, its exit temperature decreases. The operating range for the precombustor coal split is thirty to forty-four percent. Four different precombustor coal splits were evaluated, thirty-two percent, thirty-eight percent, forty percent and forty-three percent. For the majority of tests conducted, the precombustor coal split for Combustor A was different than that for Combustor B. Specifically, for Combustor A, the coal flow split to the precombustor was typically thirty-eight percent of the total coal flow (same as used during the previous ROM tests); whereas, for Combustor B, the coal flow split to the precombustor was forty-three percent of the total coal flow. For both precombustor coal split ratios, the precombustor stoichiometry was varied over a wide range, from 0.65 to 1.00.

In general, post-test inspection revealed slagging conditions in both combustors had no strong dependence on precombustor coal split variation between thirty-eight and forty-three percent. During the majority of these tests, online indication of precombustor slag accumulation was typically observed approximately forty to sixty hours after starting to fire coal. Lowering precombustor stoichiometry typically increased the duration of coal burn time prior to indications of precombustor slag accumulation. Precombustor coal split to both precombustors was reduced to thirty-two percent and precombustor stoichiometry was varied between 0.60 to 0.70 at the end of May. Lower precombustor coal split and lower precombustor stoichiometry (0.60) appeared to minimize slag accumulation in the precombustor. This trend is shown graphically in Figure 4.7.4. Data for precombustor stoichiometry greater than 0.65 were with a precombustor coal split of thirty-eight to forty-three percent. The data point with precombustor stoichiometry less than 0.65 was at a precombustor coal split of thirty percent. It should be noted that this test, at a precombustor stoichiometry less than 0.65, was shut down at 110 hours total coal burn, prior to any indication of precombustor chamber pressure increase. The 120 hour duration indicated on the plot is an estimate.

For a slagging combustor stoichiometry of 0.84, the analytical model predicted 0.33 pounds per million Btu NO_X emission with a forty-three percent precombustor coal split and 0.24 pounds per million Btu with a thirty percent precombustor coal split. This trend was not observed.

Precombustor stoichiometry was varied from 0.60 to 1.00. The objective of operating at the lower precombustor stoichiometry was to minimize slag formation in the precombustor combustion can and, therefore, slag accumulation in the precombustor. The objective of operating at the higher precombustor stoichiometry was twofold. The first objective was to operate at a higher temperature within the precombustor combustion chamber to create liquid slag flow. The second objective was to minimize the cold (770° F) mix annulus secondary air flow that appeared to be freezing the slag flowing out of the precombustor chamber where it interfaced with the secondary air flowing from the annular area outside the end of the precombustor combustion chamber. At the higher precombustor stoichiometry, the slag flow was very liquid; however, a cold slag curtain (i.e., slag growth) continued to form at the exit of the combustion chamber where the slag encountered the cold mix annulus secondary air flow. This flow could not be reduced below a minimum level of 30,000 lb/hr because of combustion logic control interlocks on minimum air flow. Lower precombustor stoichiometry reduced slag formation within the precombustor combustion chamber and, therefore, slag accumulation within the precombustor exit also diminished.

PHI-PC	Coal burn time prior to PC slag
0.65	60
0.70	51
0.75	53
0.90	40
0.62	120


125
100
75
50
25
0
Coal Burn Hours Prior to Any Indication of PC Slagging
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.
Precombustor Stoichiometry

PRECOMBUSTOR EXIT VELOCITY

Precombustor exit velocity strongly affects slag characteristics and slag recovery and, to a lesser extent, it affects NO_X emission. The exit velocity was controlled by varying the position of the precombustor swirl dampers for the majority of tests performed in May. The swirl dampers were set in a fixed position, so precombustor exit velocity at full load varied as a function of slagging combustor stoichiometry. In general, calculated precombustor exit velocity, based on the swirl damper position, was 240 to 350 ft/sec. However, because of slag accumulation at the exit of the precombustor, the actual precombustor exit velocity was much higher than this toward the ends of the tests. For all tests performed with the precombustor exit velocity above approximately 265 ft/sec, the approximately weekly post-test inspections revealed excellent slagging combustor slag coverage. The slag was thin and black with a smooth surface, indicating it had been very molten and had uniform thickness. There were insufficient tests conducted at similar operating conditions to specifically determine the effect of precombustor exit velocity on slag recovery. For precombustor exit velocities between 240 and 350 ft/sec, slag recovery varied from sixty to 120 percent as shown in Figure 4.7.5. There is a relatively large error band on these values since the coal ash content varied throughout the test. An overall average ash content of fifteen percent was assumed to determine the slag recovery for this test.

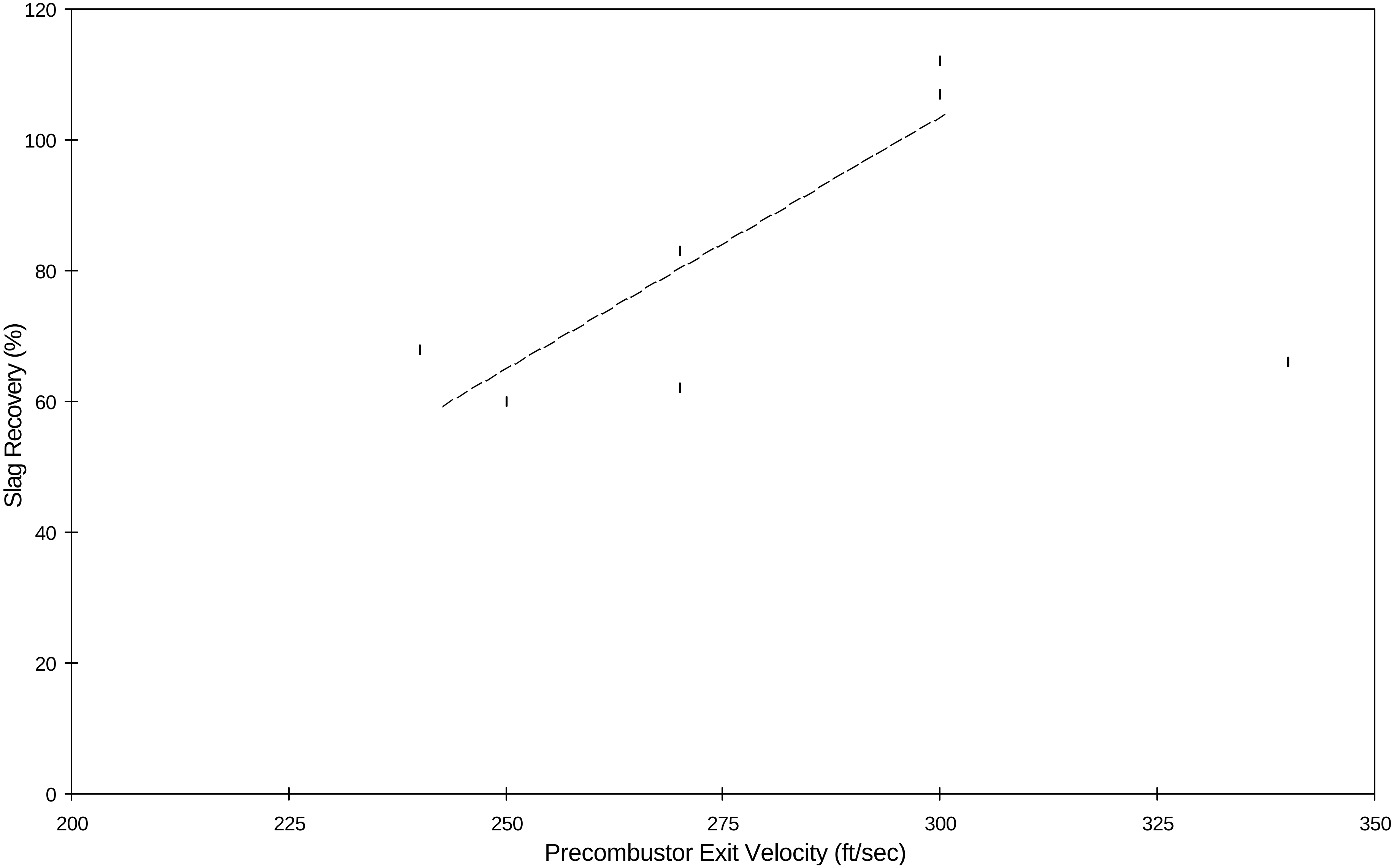
There were two indications that NO_X emission decreased as precombustor exit velocity was increased. First, a comparison of the NO_X emission for two separate tests that were conducted at the same slagging combustor stoichiometry, but with different precombustor exit velocities, indicated that the NO_X emission was consistently lower for the tests conducted with the higher precombustor exit velocity (see Figure 4.7.6). Secondly, it was noted that the NO_X emission tended to be lower during the latter portion of tests when the precombustor exit velocity increased because of slag accumulation. At the end of May, one test was conducted with lower precombustor exit velocity (approximately 250 ft/sec). This appeared to degrade slag characteristics as revealed by a large molten slag accumulation in the base of the head end section and by sixty percent slag recovery.

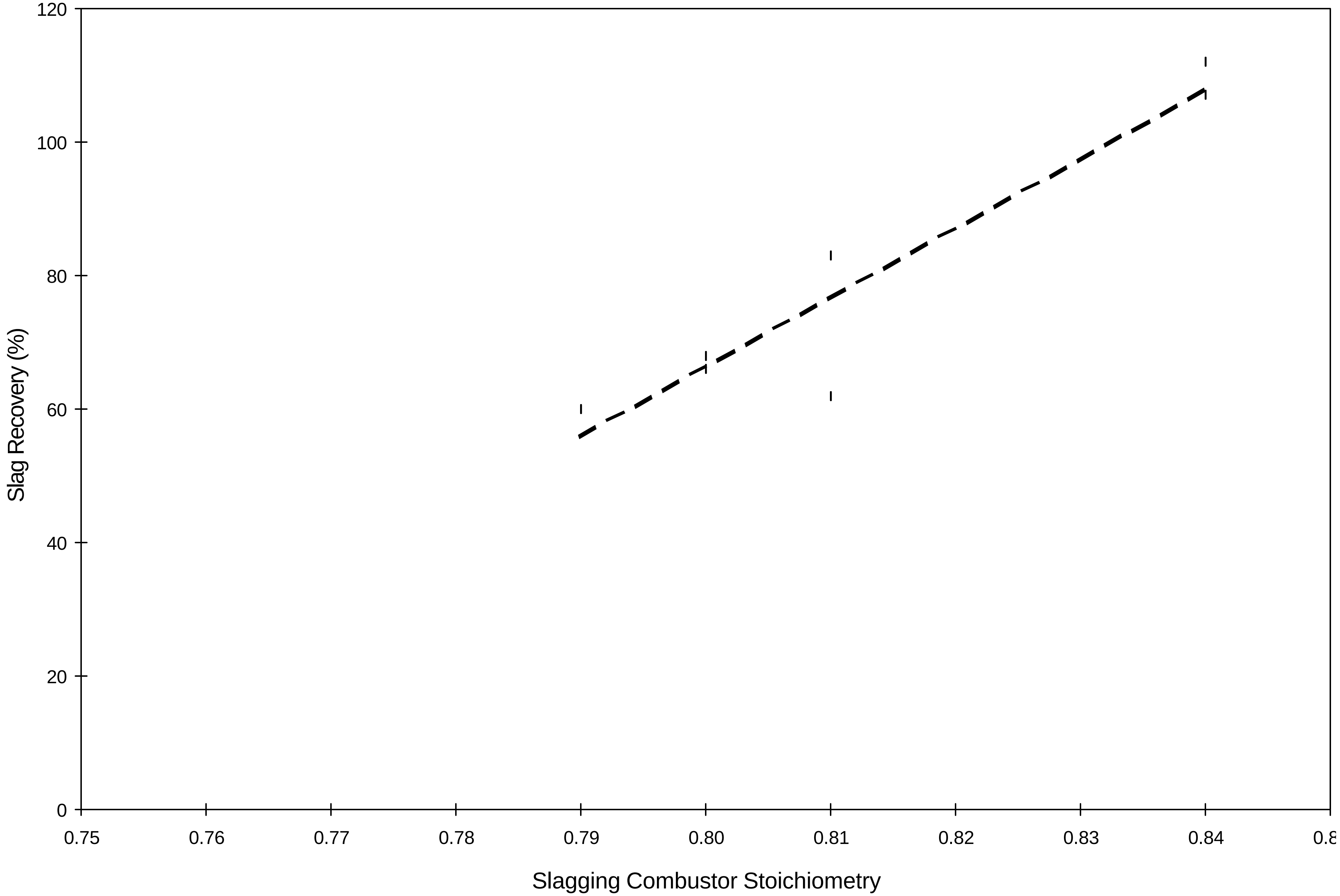
SLAGGING COMBUSTOR STOICHIOMETRY

Slagging combustor stoichiometry affects slag characteristics, slag recovery and NO_X emission. Slagging combustor stoichiometry was varied over a rather narrow range of 0.76 to 0.84. Quality and quantity of the slag on the drag chain, slag recovery and NO_X emission were evaluated. There was little, if any effect on the slag quality or quantity. The slag on the drag chain was consistently good quality (small molten balls or chunks and no clinkers were observed). In general, slag recovery increased as the slagging combustor stoichiometry was increased. This trend is shown in Figure 4.7.7.

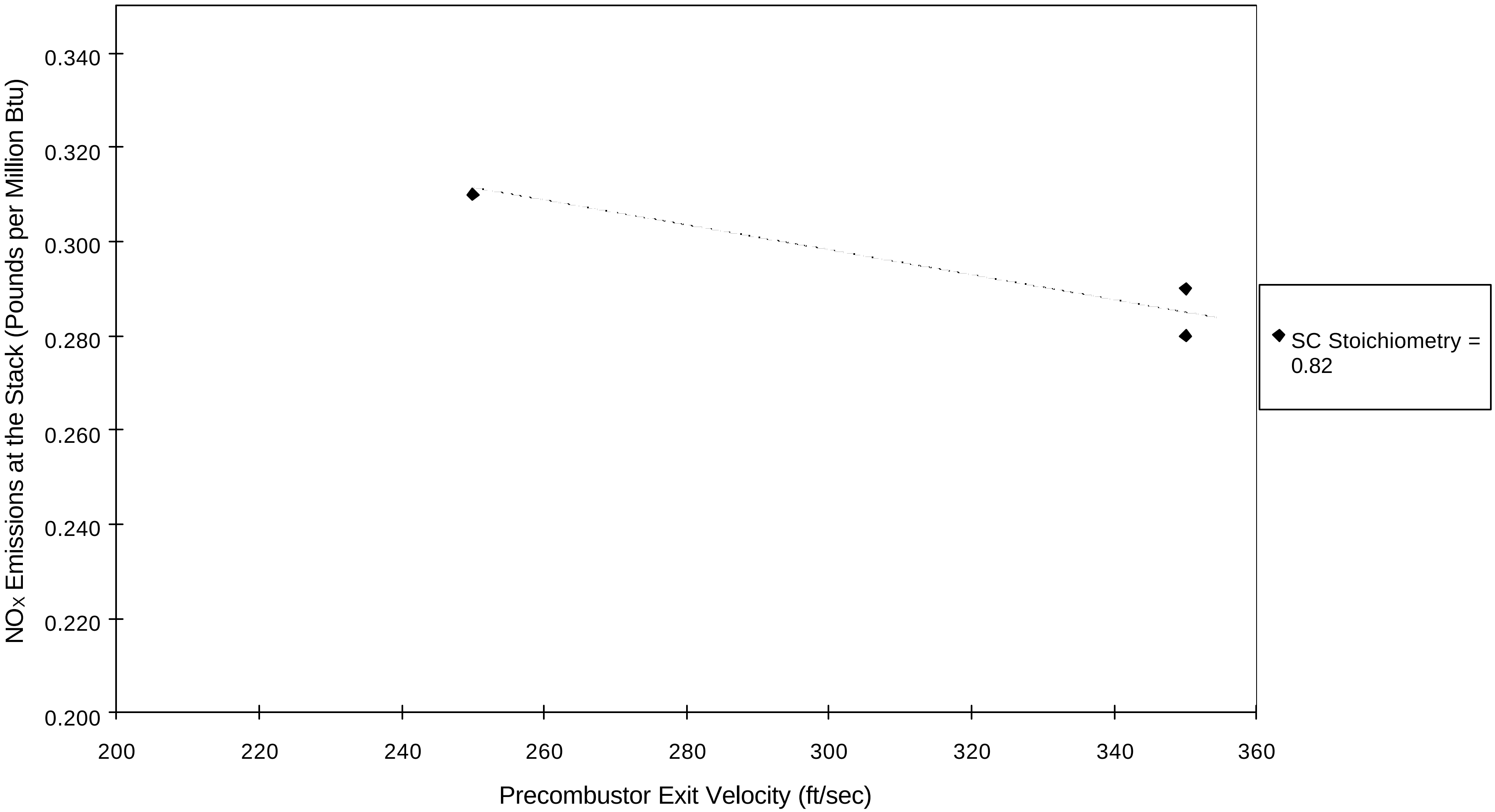
NO_X emission varied significantly as a function of slagging combustor stoichiometry. Figure 4.7.8 shows NO_X emission as a function of slagging combustor stoichiometry for the tests conducted in May. Each data point represents a twenty-four hour average value for NO_X emission and slagging combustor stoichiometry during a relatively steady-state portion of each test. NO_X emission decreased from 0.45 to 0.22 pounds per million Btu as the slagging combustor stoichiometry decreased from 0.85 to 0.80. Figure 4.7.9 compares this empirical trend with analytical predictions at a suggested precombustor exit velocity of 350 ft/sec. The empirical data is indicated as a dashed line. The individual data points correspond to NO_X emission values averaged over a twelve to twenty-four hour time period during four separate tests conducted in May with an approximately 770° F secondary air and 320 to 365 ft/second estimated precombustor exit velocity.

Test No	PHI-SC	Velocity	Ash%	SR%	
PERF-S4-2	0.84	300	15	112	
PERF-S4-3	0.84	300	15	107	
PERF-S4-1	0.81	270	15	62	
PERF-S4-3	0.81	270	15	83	
PERF-S4-8	0.80	240	15	68	
ROM-S4-1	0.79	250	8.5	60	
PERF-S4-7	0.80	340	15	66	(note: PHI-PC = 1)


120
100
80
60
40
20
0
Slag Recovery (%)
200
225
250
275
300
325
350
Precombustor Exit Velocity (ft/sec)



120
100
80
60
40
20
0
Slag Recovery (%)
0.75
0.76
0.77
0.78
0.79
0.80
0.81
0.82
0.83
0.84
0.8
Slagging Combustor Stoichiometry


0.340
0.320
0.300
0.280
0.260
0.240
0.220
0.200
200
220
240
260
280
300
320
340
360
NO_X Emissions at the Stack (Pounds per Million Btu)
Precombustor Exit Velocity (ft/sec)
◆ SC Stoichiometry = 0.82

SC Stoichiometry = 0.82

	SC Stoichiometry = 0.82
200	
210	
220	
230	
240	
250	0.310
260	
270	
280	
290	
300	
310	
320	
330	
340	
350	0.280
350	0.290
360	

Test Date	Test No	PHI-sc	Nox	Velocity	PC Coal Split	Btu/lb
3-May	PERF-S4-2	0.850	0.460	250	A:38%, B:43%	6750
4-May	PERF-S4-3	0.850	0.437	250	A:38%, B:43%	6880
15-May	PERF-S4-4	0.840	0.340	330	A:38%, B:43%	6700
15-May	PERF-S4-4	0.820	0.290	350	A:38%, B:43%	7100
15-May	PERF-S4-4	0.820	0.280	350	A:38%, B:43%	6900
15-May	PERF-S4-4	0.800	0.220	380	A:38%, B:43%	7000
16-May	PERF-S4-7	0.800	0.220	380	A:38%, B:43%	7000
22-May	PERF-S4-1	0.815	0.280	300	A:32%, B:32%	7000
23-May	PERF-S4-3	0.810	0.265	300	A:32%, B:32%	6980
27-May	PERF-S4-3	0.820	0.310	250	A:32%, B:32%	7000

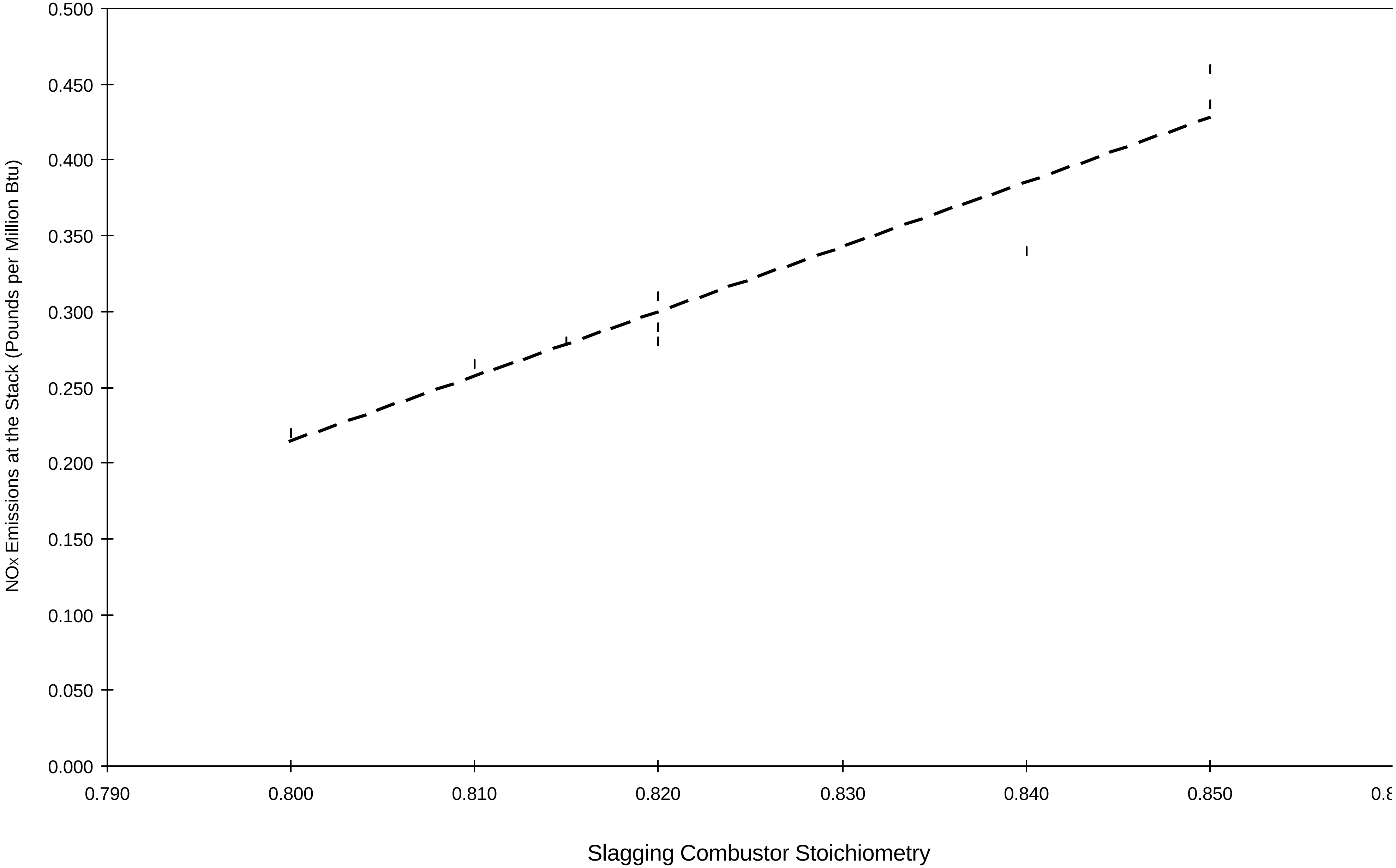
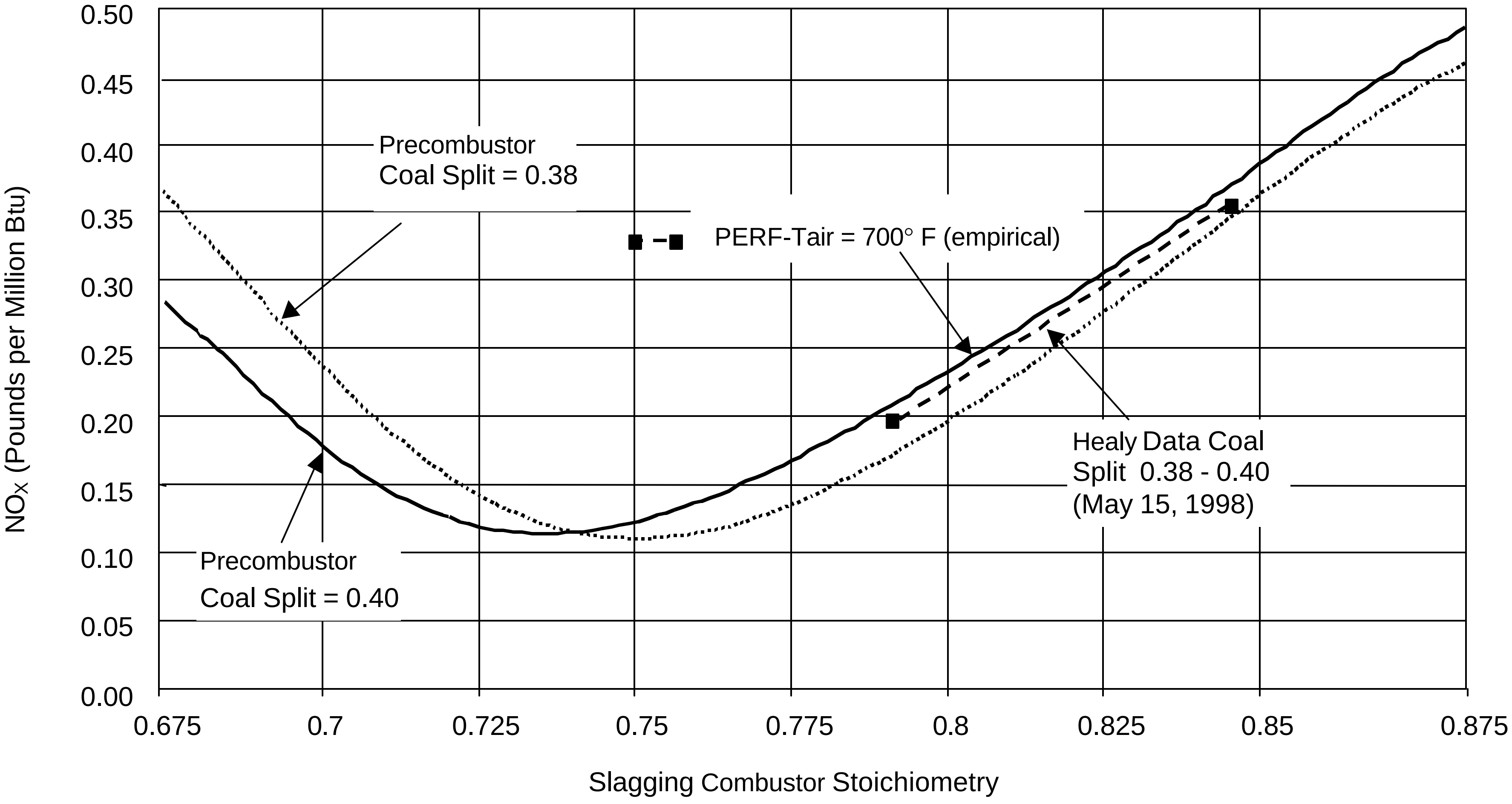

NOx Emissions at the Stack (Pounds per Million Btu)
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.790
0.800
0.810
0.820
0.830
0.840
0.850
0.8
Slagging Combustor Stoichiometry

Figure 4.7.9 – Comparison of Analytical Predictions and Empirical Data for NO_X Emission



In summary, the combustor performance during May was very good. Key performance results were:

- Overall slag coverage on the gas-side surfaces was excellent while burning blended coal, with all areas covered by a uniformly thick molten slag layer, without any bare regions.
- Slag characteristics, both quantity and quality of slag, were very good when burning blended coal with a 7,000 Btu/lb ± 200 Btu/lb higher heating value. The drag chain flights were three-quarters full and few clinkers were observed on the drag chain during the test.
- Combustor operation without oil ignitors was excellent. There was no detrimental impact noted on either performance or flame stability after removing the ignitors from service. Coal flames were very stable even at precombustor and slagging combustor stoichiometry levels down to 0.61 and 0.77, respectively.
- Indications of slag accumulation in the precombustor were typically observed following sixty hours of coal burn operation. By reducing the precombustor coal split to thirty percent and the precombustor stoichiometry to 0.61, over 110 hours of coal burn operation were completed without any online indications (i.e., precombustor chamber pressure increase) of excessive precombustor slag accumulation.
- NO_X emission values at the stack were very good. Specifically, for a slagging combustor stoichiometry setpoint of 0.80, NO_X emission was typically 0.19 to 0.24 pounds per million Btu, with a twenty-four hour average of 0.22, well below the air quality permit level of 0.35 pounds per million Btu.
- Carbon monoxide measurements in the furnace were in the range of 2 to 30 ppm, with typical values less than 10 ppm. These values corresponded to a stack O_2 concentration ranging from 3.3 to 3.8 percent.
- SO_2 measurements recorded upstream of the SDA indicated approximately thirteen to thirty-one percent SO_2 removal for a Ca/S ratio of 2.0 to 5.0, respectively.

4.8 JUNE COMBUSTOR OPERATION

The primary objectives in June were to complete an independent source test and implement two additional plant operating modes, turbine follow mode and coordinated control mode. Prior to June, the only automated mode of operation used had been the inlet pressure control (IPC) mode. In this mode, the throttle valves are modulated to maintain a throttle valve inlet pressure setpoint. Therefore, when fuel heat input to the furnace increases, the inlet pressure to the throttle valve increases causing a feedback signal to modulate the throttle valve further open until throttle valve inlet pressure decreases to its setpoint value. This would cause power output to increase. The plant operator is responsible for setting the coal feed rate from the coal silos into the pulverizers as appropriate to obtain desired unit output. The first additional operating mode, the turbine follow mode, acts the same as the IPC mode except that the operator provides a power output setpoint in addition to the throttle valve inlet pressure setpoint and the coal feeders automatically vary fuel flow to maintain that power output setpoint. The second additional operating mode, the coordinated control mode, also modulates the throttle valve and fuel flow automatically and is primarily for steady-state operation. The throttle valve is modulated to control power output and is also influenced by throttle valve inlet pressure when it deviates from its setpoint by more than ± 23 psi. The fuel flow is also modulated to maintain a power output setpoint and is slightly influenced by throttle inlet pressure. Implementation of the turbine follow mode and coordinated control mode was accomplished. A planned maintenance and repair shutdown occurred between June 1 and June 8. Then, between June 9 and June 26, one continuous test accumulated 384 hours of coal firing. During the first fourteen days of this test, the independent emissions source test was completed and the plant turbine follow and coordinated modes of plant operation were implemented, while firing 7,800 Btu/lb (average) ROM coal. Then blended coal was burned for the final four days. The test was terminated on June 26 because of a trip on high furnace pressure, probably (in retrospect) a slag fall.

There were two secondary objectives in June. The first was to complete the baseline Seam 4 ROM full load test, which was part of the combustor performance test matrix (test ROM-S4-4). The second objective was to evaluate the effect of blended coal on combustion system performance by blending in incrementally increasing percentages of waste coal to achieve heating values down to 7,000 Btu/lb, while observing the effects of additional waste coal on slagging behavior and on NO_X and SO_2 emissions. The first of these objectives, the baseline Seam 4 ROM test, was successfully completed concurrent with the source test. Unfortunately, incremental increases of waste coal did not occur. Instead, fifty-five percent waste coal was blended with ROM coal and the higher heating value decreased to a range of 6,500 to 6,700 Btu/lb for the last several days of the test.

Figure 4.8.1 shows the daily coal burn duration during June. Combustion system related items performed during the outage from June 1 to June 8 included inspection of the dipper skirt, inspection and repair, as required, of the precombustor mill air ports and installation of new swirl damper actuators. Test operations were reinitiated on June 8 with a short test comprised of several hours of oil fired operation, followed by a short period of coal fired operation (approximately six hours), followed by oil fired operation. This test sequence was performed in order to roll the turbine off of the turning gear with high boiler pressure. Coal firing was reinitiated on June 9 and continued without interruption until the high furnace pressure trip on June 26. Post-test inspection and preparations for the next test were performed from June 26 through June 30.

Average NO_X emission during the fourteen day period was 0.232 pounds per million Btu, with a standard deviation of 0.010, well below the air quality permit level of 0.35 pounds per million Btu.

	Coal Burn Time (hours)
1-Jun	0
2-Jun	0
3-Jun	0
4-Jun	0
5-Jun	0
6-Jun	0
7-Jun	0
8-Jun	0
9-Jun	12
10-Jun	24
11-Jun	24
12-Jun	24
13-Jun	24
14-Jun	24
15-Jun	24
16-Jun	24
17-Jun	24
18-Jun	24
20-Jun	24
21-Jun	24
22-Jun	24
23-Jun	24
24-Jun	24
25-Jun	24
26-Jun	12
27-Jun	0
28-Jun	0
29-Jun	0
30-Jun	0

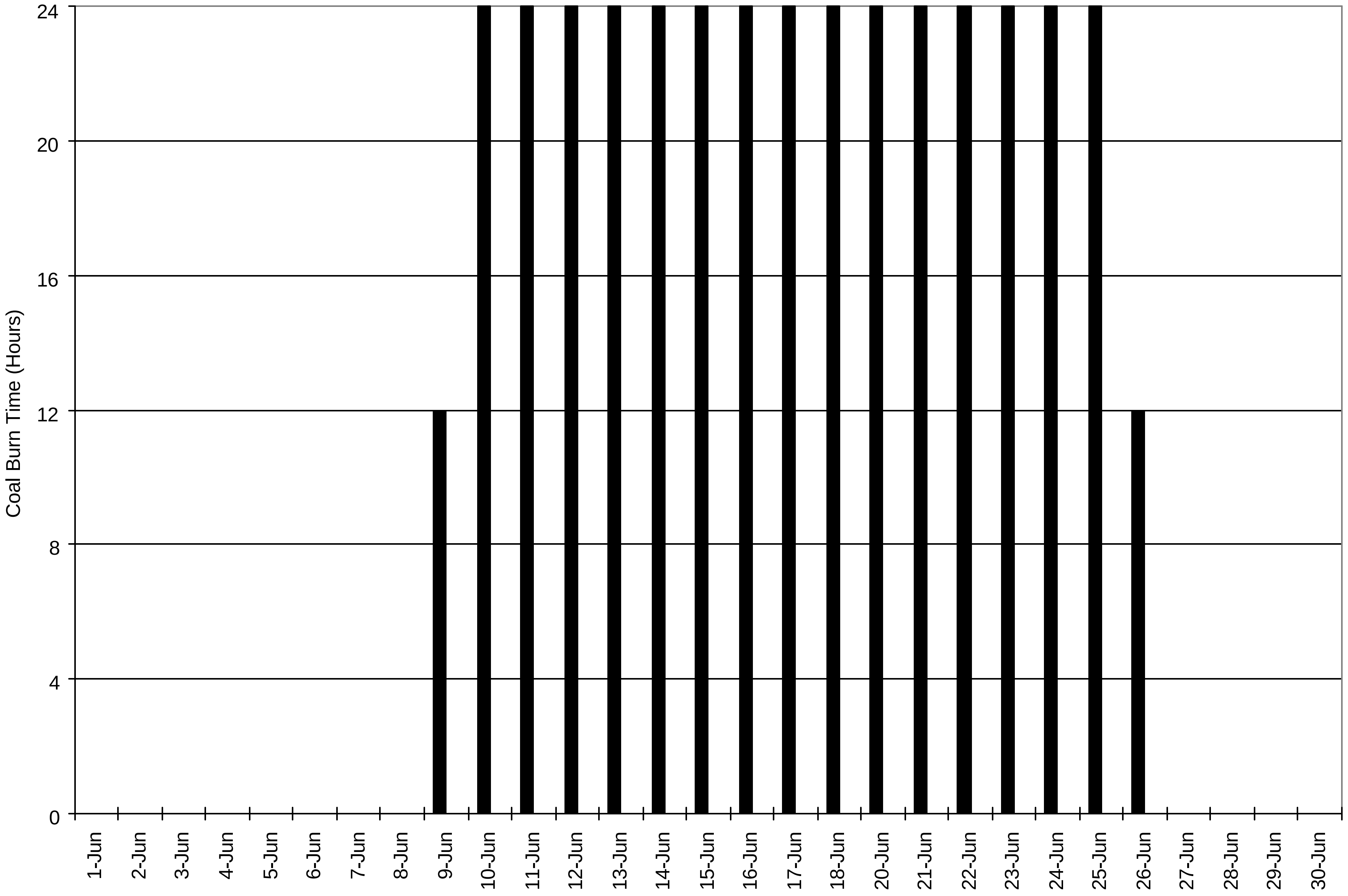

Coal Burn Time (Hours)
24
20
16
12
8
4
0
1-Jun
2-Jun
3-Jun
4-Jun
5-Jun
6-Jun
7-Jun
8-Jun
9-Jun
10-Jun
11-Jun
12-Jun
13-Jun
14-Jun
15-Jun
16-Jun
17-Jun
18-Jun
20-Jun
21-Jun
22-Jun
23-Jun
24-Jun
25-Jun
26-Jun
27-Jun
28-Jun
29-Jun
30-Jun

Figure 4.8.2 shows average NO_X and SO_2 emissions during the fourteen days of continuous operation. These emission levels were independently verified during the source test.

Furnace carbon monoxide levels were typically less than 1 ppm at 3.5 percent O_2 throughout the fourteen-day period of continuous operation. This is also well below the goal of 200 ppm. Figure 4.8.3 shows carbon monoxide emission and furnace O_2 concentration during the fourteen days of operation.

Slag was rejected from the slag tank in small granules. There were no clinkers. The slag rejection rate was estimated at sixty percent, lower than the goal of seventy percent, but consistent with the anticipated slag rejection at lower precombustor exit velocities. For this test, the precombustor exit velocity was 250 ft/sec rather than the normal 320 to 360 ft/sec. Sixty percent slag recovery with a 250 ft/sec precombustor exit velocity is consistent with analytical predictions and with the empirical correlation of slag recovery as a function of tangential velocity.

SO_2 removal in the furnace was estimated as fifteen percent, better than analytically predicted for low sulfur coal (0.22 percent) with a Ca/S ratio less than 2.0. Stack SO_2 emission averaged 0.05 pounds per million Btu for the fourteen day period, compared to the air quality permit level of 0.1 pounds per million Btu.

There was no evidence of unacceptable slag accumulation within the precombustor, during the fourteen days of continuous operation. The average higher heating value was 7,800 Btu/lb and Precombustor A chamber pressure was 13.2 inches ± 2 inches water gauge. Figure 4.8.4 shows precombustor chamber pressure during the fourteen day test period. Precombustor B chamber pressure was not as consistent as Precombustor A chamber pressure. Its pressure at the end of the fourteen day period was seven inches wg higher than the pressure at the beginning of the test (i.e., from 10.4 inches water gauge to seventeen inches water gauge over the fourteen-day period). During a four day period in the middle of the test, it was noted that the chamber pressure in Precombustor B increased by several inches of water. However, this pressure dropped back down to normal chamber pressure for the last day of the test, while still burning 7,800 Btu/lb ROM coal. This long duration operation with no evidence of unacceptable precombustor slag accumulation demonstrated that the precombustor slagging behavior is a function of coal quality, rather than being solely intrinsic to the precombustor design configuration. The difference in performance between Precombustors A and B may have resulted from damage to the Precombustor B mix annulus (not discovered in June).

Following two weeks of successful continuous operation with ROM coal, fifty-five percent waste coal was blended with the ROM coal and the test operations continued. The objective of this portion of the test had been to slowly blend in waste coal to achieve average higher heating values of 7,750, 7,500, 7,250, and then 7,000 Btu/lb, for forty-eight hours at each higher heating value, in order to evaluate the specific effect of waste coal on the combustion system performance in terms of slagging and fouling characteristics, and NO_X and SO_2 emissions. However, because of the inability to compensate for variations in ROM and waste coal higher heating values, the higher heating value dropped to 6,700 Btu/lb. Therefore, the objective of this portion of the test was not achieved. Results with the low heating value blended coal were similar to previous tests with low heating value coal in terms of slagging and fouling characteristics and NO_X emission. However, the SO_2 emission at the stack was significantly lower than those achieved during previous tests with low heating value blended coal. This improvement in SO_2 removal in the SDA was attributed to lower operating temperatures in the SDA and better limestone.

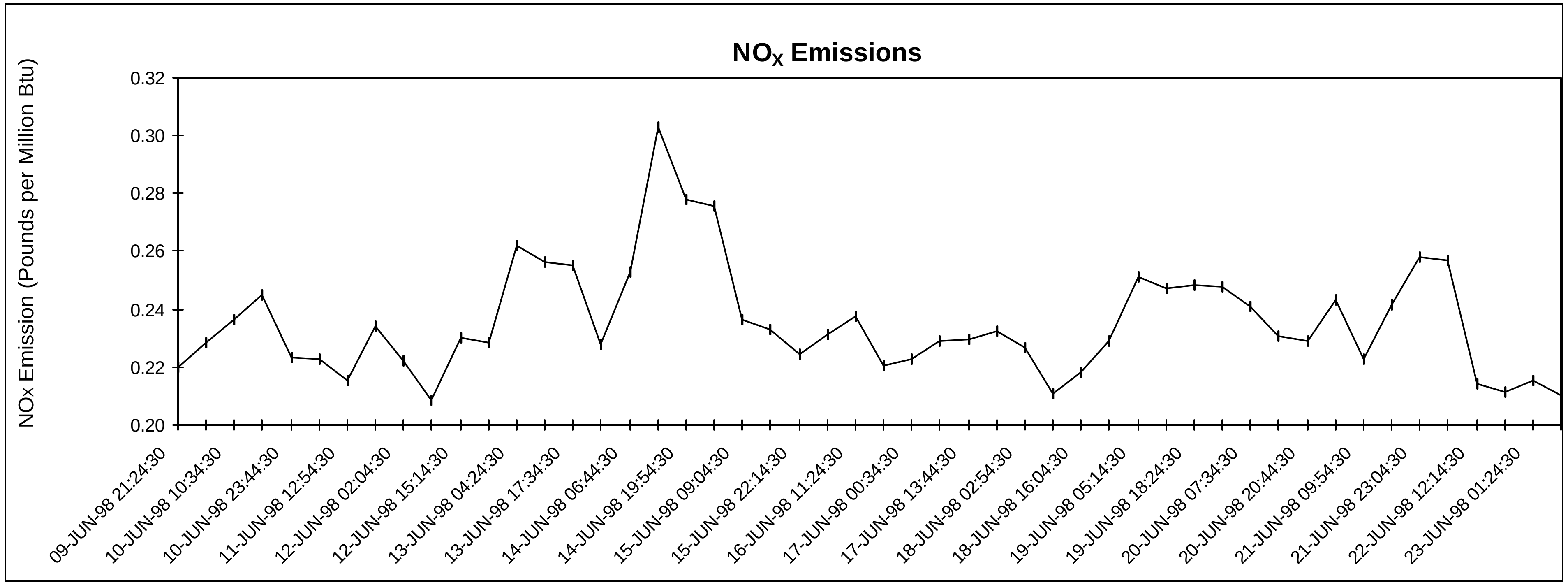
Server> odms01_mon
Start> 23-Jun-98 8:00
Interval> 6:35

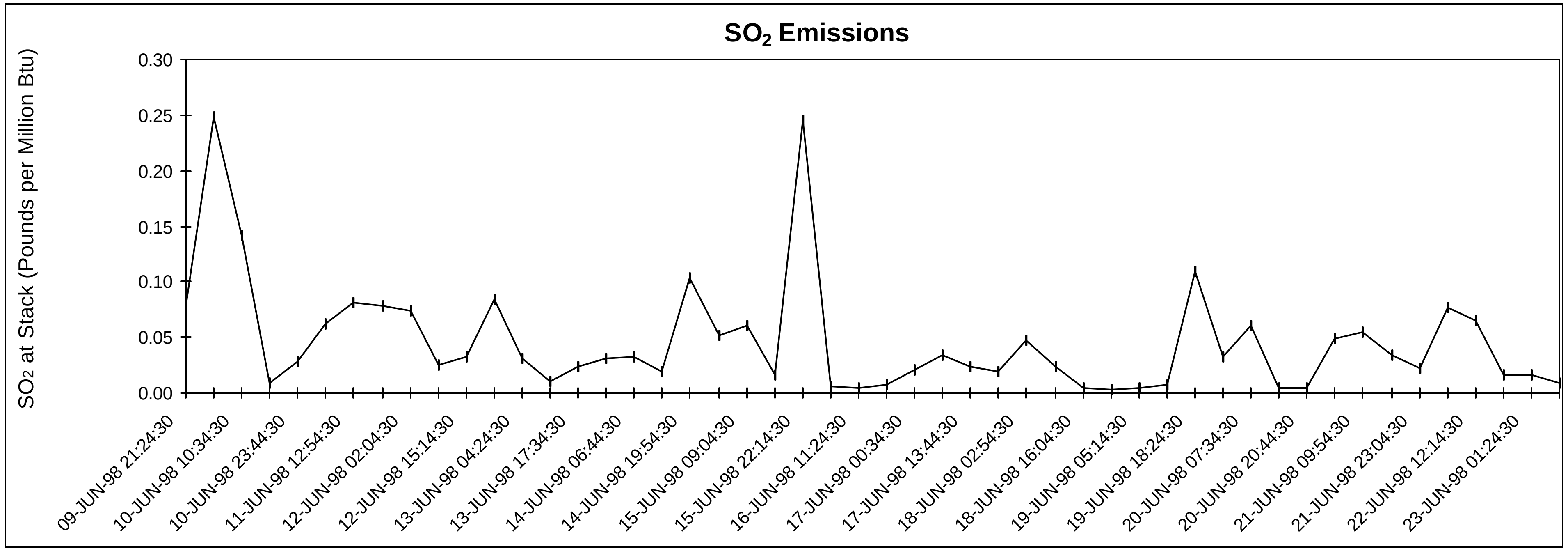
		2gm-jt03 value time	hhv-btu value time	2fg-at02a value time	2fg-at02b value time	2fg-at03a value time	2fg-at03b value time	2fg-at17 value time	2fg-ur22a value time	2fg-ur22b value time	2fg-ur22c value time	2fg-ur22e value time	2lh-pt69a value time	2lh-pt69b value time	2lh-st27 value time
50	09-JUN-98 21:24:30	59.95	7790.23	3.48	-3.66	1.50	1269.35	156.90	5.81	0.08	0.22	1.90	15.99	16.98	14.29
49	10-JUN-98 03:59:30	60.22	7855.17	3.31	-3.65	1.53	1269.39	163.12	126.25	0.25	0.23	0.49	12.56	13.96	9.26
48	10-JUN-98 10:34:30	60.74	7801.73	3.89	-3.66	1.77	1269.31	165.54	1.21	0.14	0.24	3.60	12.39	14.00	9.32
47	10-JUN-98 17:09:30	60.11	7657.92	3.65	-3.66	1.78	1269.47	165.60	3.86	0.01	0.24	2.22	10.57	12.44	6.95
46	10-JUN-98 23:44:30	60.35	7822.18	2.73	-3.67	1.76	1269.39	166.80	11.96	0.03	0.22	2.10	10.31	12.31	7.79
45	11-JUN-98 06:19:30	60.02	7883.59	3.70	-3.59	1.25	1269.31	157.04	24.88	0.06	0.22	2.41	9.92	12.56	7.80
44	11-JUN-98 12:54:30	59.97	7835.63	3.63	-3.58	1.28	1269.40	160.71	33.29	0.08	0.22	2.19	11.46	13.89	10.02
43	11-JUN-98 19:29:30	60.04	7578.82	3.79	-3.58	1.26	1269.16	170.36	32.22	0.08	0.23	2.59	11.04	13.68	10.07
42	12-JUN-98 02:04:30	60.68	7695.02	3.25	-3.56	1.01	1269.08	179.57	32.00	0.07	0.22	2.67	10.66	12.83	9.72
41	12-JUN-98 08:39:30	60.29	7727.85	3.55	-3.55	0.78	1269.32	138.54	12.76	0.02	0.21	3.24	14.93	14.09	16.22
40	12-JUN-98 15:14:30	61.31	7985.06	3.05	-3.57	1.00	1269.18	161.23	11.84	0.03	0.23	2.83	11.26	13.84	10.50
39	12-JUN-98 21:49:30	60.38	7720.29	3.62	-3.57	1.00	1269.09	175.62	34.94	0.08	0.23	2.09	12.29	15.16	10.28
38	13-JUN-98 04:24:30	59.64	7776.42	3.23	-3.55	0.75	1269.24	169.82	8.03	0.03	0.26	3.79	10.43	14.97	10.66
37	13-JUN-98 10:59:30	62.13	8105.14	3.15	-3.55	0.62	1269.26	149.37	3.90	0.01	0.26	3.56	10.11	14.05	10.97

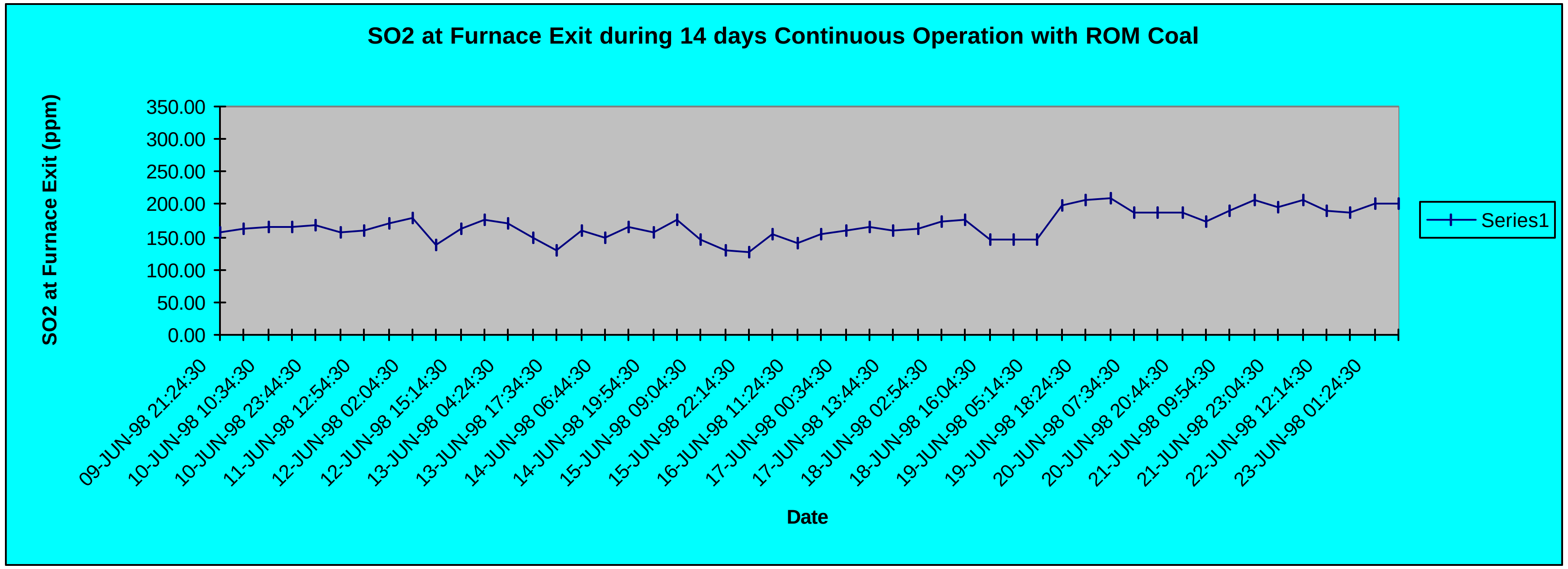
36	13-JUN-98 17:34:30	59.22	7813.10	4.16	-3.57	1.01	1269.17	130.24	9.58	0.02	0.26	2.00	11.09	14.53	10.64
35	14-JUN-98 00:09:30	62.35	8768.08	3.28	-3.55	0.77	1269.07	161.03	13.84	0.03	0.23	2.24	10.98	14.42	11.07
34	14-JUN-98 06:44:30	60.02	7957.94	3.61	-3.53	0.52	1269.15	149.04	12.71	0.03	0.25	2.28	11.25	13.00	11.02
33	14-JUN-98 13:19:30	60.27	7912.94	3.39	-3.55	0.77	1269.26	164.29	7.94	0.02	0.30	2.57	8.15	11.99	6.94
32	14-JUN-98 19:54:30	60.31	7931.00	3.80	-3.57	1.00	1269.17	155.93	47.88	0.10	0.28	1.36	9.57	10.93	5.55
31	15-JUN-98 02:29:30	59.97	7978.38	3.13	-3.55	0.78	1269.20	175.54	24.95	0.05	0.28	2.44	7.06	11.71	5.82
30	15-JUN-98 09:04:30	60.52	8010.42	3.68	-3.55	0.75	1269.26	144.77	24.95	0.06	0.24	0.04	13.05	15.56	15.10
29	15-JUN-98 15:39:30	59.38	7819.88	3.61	13.69	0.75	1.73	129.30	7.21	0.02	0.23	2.59	13.34	13.63	14.75
28	15-JUN-98 22:14:30	59.89	7919.43	3.60	4.08	0.78	1.75	126.25	107.55	0.25	0.22	0.26	12.56	15.13	14.70
27	16-JUN-98 04:49:30	59.59	7858.07	3.77	3.94	0.50	1.47	155.37	2.56	0.01	0.23	1.83	11.37	12.07	8.00
26	16-JUN-98 11:24:30	59.22	7779.66	3.82	4.45	0.77	3.97	141.14	1.60	0.00	0.24	3.32	10.31	11.38	8.24
25	16-JUN-98 17:59:30	59.01	7766.83	3.76	3.45	0.84	12.77	153.66	2.79	0.01	0.22	3.82	10.13	11.47	7.87
24	17-JUN-98 00:34:30	60.83	8069.75	3.46	3.60	0.75	20.47	160.96	8.73	0.02	0.22	3.73	9.74	11.94	8.70
23	17-JUN-98 07:09:30	59.72	7882.77	3.97	4.12	0.52	30.49	164.84	13.46	0.03	0.23	3.53	9.23	11.62	8.33
22	17-JUN-98 13:44:30	59.28	7791.07	3.52	3.44	0.76	33.73	159.01	8.47	0.02	0.23	4.13	11.97	13.78	12.43
21	17-JUN-98 20:19:30	60.45	7934.77	3.32	3.13	1.01	36.52	162.30	8.79	0.02	0.23	4.23	9.47	12.24	10.41
20	18-JUN-98 02:54:30	59.80	7704.50	3.54	3.50	0.77	35.93	174.63	19.52	0.05	0.23	4.79	9.96	11.78	10.30
19	18-JUN-98 09:29:30	59.82	7697.61	3.24	2.76	0.75	37.22	175.93	11.07	0.02	0.21	4.73	9.44	11.13	10.03

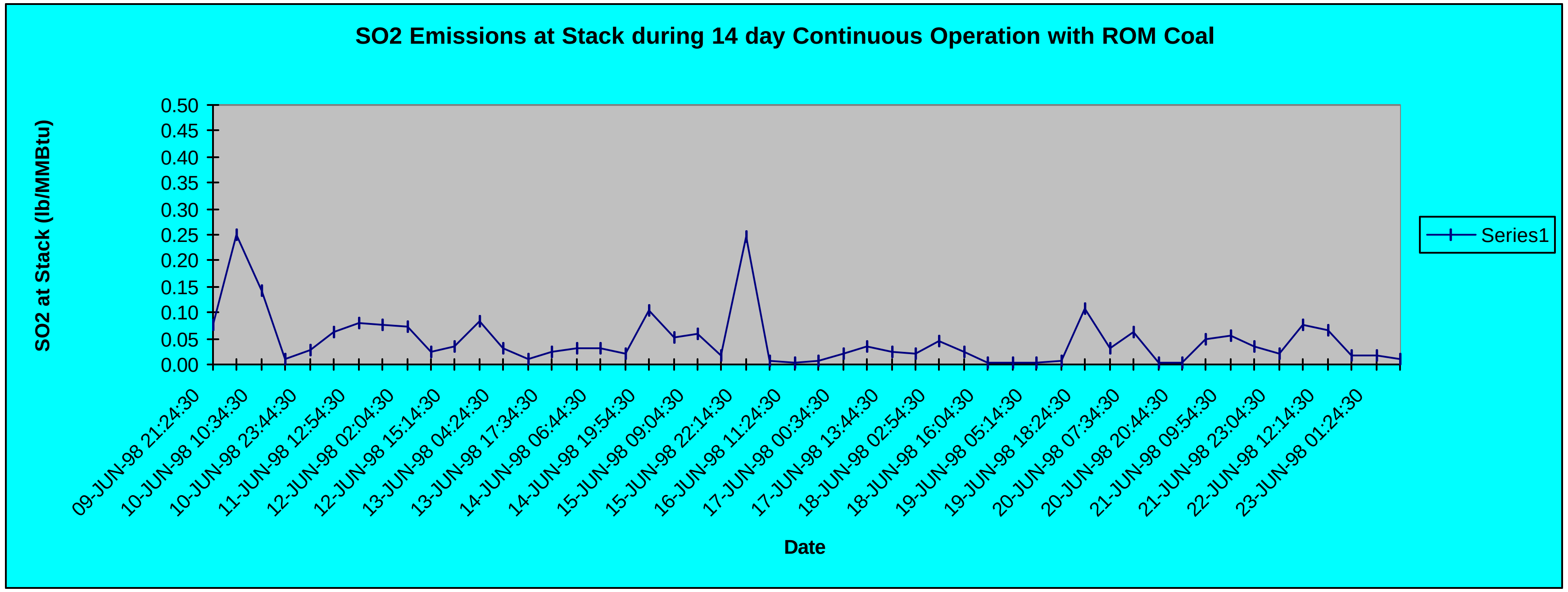
18	18-JUN-98 16:04:30	57.99	7582.38	3.84	3.08	1.27	40.22	146.17	2.10	0.01	0.22	4.13	9.47	12.00	10.90
17	18-JUN-98 22:39:30	60.65	8082.11	2.62	2.73	1.53	40.60	146.18	1.06	0.00	0.23	4.79	8.46	13.71	10.12
16	19-JUN-98 05:14:30	60.38	7989.46	3.73	3.12	0.90	40.08	145.55	1.75	0.00	0.25	4.35	9.50	13.21	10.27
15	19-JUN-98 11:49:30	60.45	8099.20	3.66	2.98	0.76	39.72	197.39	3.09	0.01	0.25	5.78	9.48	13.55	10.50
14	19-JUN-98 18:24:30	60.30	8075.10	3.49	2.72	0.78	40.70	205.75	48.50	0.11	0.25	4.41	10.67	14.63	14.13
13	20-JUN-98 00:59:30	59.92	7983.12	3.28	3.12	0.78	40.08	209.91	12.56	0.03	0.25	5.65	11.95	14.97	14.08
12	20-JUN-98 07:34:30	59.96	7854.58	3.52	3.62	0.78	39.60	188.66	25.06	0.06	0.24	4.49	12.80	13.18	13.64
11	20-JUN-98 14:09:30	60.14	7705.21	3.43	2.66	0.78	39.47	188.25	2.27	0.01	0.23	5.79	11.66	12.73	13.64
10	20-JUN-98 20:44:30	60.36	7821.06	3.09	3.11	0.76	38.97	188.04	2.41	0.00	0.23	6.72	11.53	14.43	13.24
9	21-JUN-98 03:19:30	59.67	7666.30	3.73	3.36	0.50	39.11	173.79	20.58	0.05	0.24	5.28	10.81	12.83	14.05
8	21-JUN-98 09:54:30	59.81	7757.98	3.85	3.22	0.51	39.40	190.76	23.84	0.06	0.22	4.70	15.76	13.33	21.38
7	21-JUN-98 16:29:30	60.30	7805.89	3.74	3.20	0.50	39.87	206.61	14.40	0.03	0.24	5.40	11.13	12.43	13.32
6	21-JUN-98 23:04:30	61.31	7937.50	3.07	3.13	0.40	39.12	194.48	9.67	0.02	0.26	4.78	10.15	13.35	13.47
5	22-JUN-98 05:39:30	59.80	7761.65	3.78	3.47	0.25	39.73	206.16	33.35	0.08	0.26	4.67	11.16	13.05	14.04
4	22-JUN-98 12:14:30	59.88	7582.78	3.70	3.42	0.32	38.61	190.93	28.63	0.07	0.21	5.74	13.42	15.62	17.14
3	22-JUN-98 18:49:30	60.15	8036.29	3.40	2.93	0.50	39.22	188.11	7.23	0.02	0.21	5.46	14.63	17.58	16.78
2	23-JUN-98 01:24:30	60.19	7701.65	3.44	3.38	0.78	39.60	202.48	5.63	0.02	0.22	5.48	15.35	15.93	15.79
1	6/23/98 7:59	60.17	7932.75	3.64	3.92	0.25	37.72	200.54	3.40	0.01	0.21	6.53	14.73	16.17	16.85

AVERAGE	60.14	7864.13	3.51	0.64	0.87	551.64	168.68	18.44	0.05	0.24	3.59	11.30	13.52	11.54
ST DEV	0.70	190.36	0.30	3.93	0.38	616.94	21.71	23.73		0.02	1.60	1.97	1.52	3.31


NOX Emissions
NOX Emission (Pounds per Million Btu)
0.32
0.30
0.28
0.26
0.24
0.22
0.20
09-JUN-98 21:24:30
10-JUN-98 10:34:30
10-JUN-98 23:44:30
11-JUN-98 12:54:30
12-JUN-98 02:04:30
12-JUN-98 15:14:30
13-JUN-98 04:24:30
13-JUN-98 17:34:30
14-JUN-98 06:44:30
14-JUN-98 19:54:30
15-JUN-98 09:04:30
15-JUN-98 22:14:30
16-JUN-98 11:24:30
17-JUN-98 00:34:30
17-JUN-98 13:44:30
18-JUN-98 02:54:30
18-JUN-98 16:04:30
19-JUN-98 05:14:30
19-JUN-98 18:24:30
20-JUN-98 07:34:30
20-JUN-98 20:44:30
21-JUN-98 09:54:30
21-JUN-98 23:04:30
22-JUN-98 12:14:30
23-JUN-98 01:24:30


SO₂ Emissions
SO₂ at Stack (Pounds per Million Btu)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
09-JUN-98 21:24:30
10-JUN-98 10:34:30
10-JUN-98 23:44:30
11-JUN-98 12:54:30
12-JUN-98 02:04:30
12-JUN-98 15:14:30
13-JUN-98 04:24:30
13-JUN-98 17:34:30
14-JUN-98 06:44:30
14-JUN-98 19:54:30
15-JUN-98 09:04:30
15-JUN-98 22:14:30
16-JUN-98 11:24:30
17-JUN-98 00:34:30
17-JUN-98 13:44:30
18-JUN-98 02:54:30
18-JUN-98 16:04:30
19-JUN-98 05:14:30
19-JUN-98 18:24:30
20-JUN-98 07:34:30
20-JUN-98 20:44:30
21-JUN-98 09:54:30
21-JUN-98 23:04:30
22-JUN-98 12:14:30
23-JUN-98 01:24:30


SO2 at Furnace Exit during 14 days Continuous Operation with ROM Coal

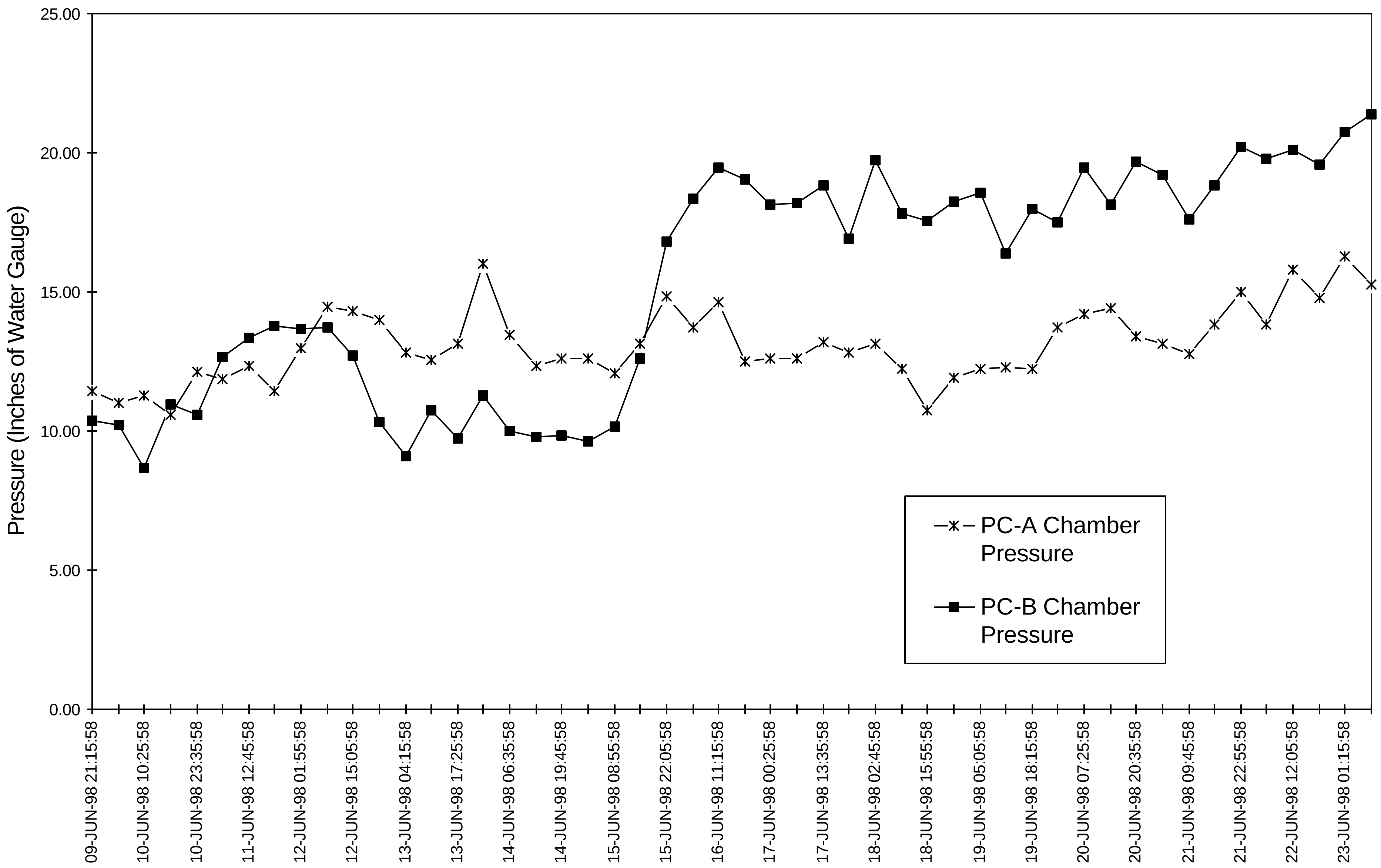


SO2 Emissions at Stack during 14 day Continuous Operation with ROM Coal

Server> odms01_mon
Start> 23-june-98 08:00
Interval> 06:35

		2GM-JT03 VALUE TIME	2BC-PT04A VALUE TIME	2BC-PT04B VALUE TIME	2CN-TE80A VALUE TIME	2CN-TE80B VALUE TIME	2CN-TE77A VALUE TIME	2CN-TE77B VALUE TIME	2PCA-STMRY VALUE TIME	2PCB-STMRY VALUE TIME
50	09-JUN-98 21:15:58	59.95	11.42	10.36	122.36	130.57	96.94	95.37	0.57	0.61
49	10-JUN-98 03:50:58	60.22	10.99	10.21	118.62	127.29	93.47	93.71	0.58	0.62
48	10-JUN-98 10:25:58	60.74	11.26	8.69	115.02	123.05	94.13	92.08	0.58	0.62
47	10-JUN-98 17:00:58	60.11	10.56	10.95	114.74	121.42	94.52	94.14	0.58	0.63
46	10-JUN-98 23:35:58	60.35	12.13	10.60	115.69	119.17	94.11	95.00	0.57	0.59
45	11-JUN-98 06:10:58	60.02	11.86	12.66	112.10	120.05	91.65	92.55	0.57	0.59
44	11-JUN-98 12:45:58	59.97	12.32	13.38	109.85	115.39	91.73	94.86	0.57	0.62
43	11-JUN-98 19:20:58	60.04	11.42	13.77	109.81	115.08	94.11	94.11	0.58	0.59
42	12-JUN-98 01:55:58	60.68	12.97	13.66	108.41	113.09	93.01	93.25	0.58	0.61
41	12-JUN-98 08:30:58	60.29	14.45	13.70	108.53	110.80	92.59	91.85	0.59	0.62
40	12-JUN-98 15:05:58	61.31	14.32	12.71	109.56	109.45	95.42	94.00	0.58	0.61
39	12-JUN-98 21:40:58	60.38	13.97	10.33	112.39	115.69	95.42	95.90	0.58	0.62
38	13-JUN-98 04:15:58	59.64	12.80	9.10	107.46	111.70	92.82	93.22	0.58	0.60
37	13-JUN-98 10:50:58	62.13	12.53	10.73	106.89	111.43	92.92	93.31	0.59	0.62
36	13-JUN-98 17:25:58	59.22	13.13	9.73	108.85	110.51	94.82	95.21	0.55	0.61
35	14-JUN-98 00:00:58	62.35	16.01	11.30	108.90	111.63	96.40	96.55	0.58	0.60
34	14-JUN-98 06:35:58	60.02	13.44	10.02	107.85	109.24	93.47	93.98	0.56	0.60
33	14-JUN-98 13:10:58	60.27	12.34	9.81	105.86	106.72	92.96	93.34	0.57	0.60
32	14-JUN-98 19:45:58	60.31	12.63	9.85	106.37	109.81	94.36	94.58	0.57	0.61
31	15-JUN-98 02:20:58	59.97	12.59	9.62	103.75	108.36	92.92	93.47	0.58	0.64
30	15-JUN-98 08:55:58	60.52	12.09	10.16	100.73	109.54	91.66	92.15	0.59	0.62
29	15-JUN-98 15:30:58	59.38	13.12	12.61	101.44	110.49	92.90	92.86	0.57	0.61
28	15-JUN-98 22:05:58	59.89	14.83	16.81	103.39	114.76	94.66	95.26	0.57	0.60
27	16-JUN-98 04:40:58	59.59	13.74	18.34	100.96	114.53	94.95	93.39	0.59	0.62
26	16-JUN-98 11:15:58	59.22	14.65	19.46	102.06	114.90	92.96	93.21	0.59	0.62
25	16-JUN-98 17:50:58	59.01	12.50	19.03	103.99	114.86	95.17	96.17	0.58	0.60

24	17-JUN-98 00:25:58	60.83	12.61	18.12	106.64	113.69	96.31	96.70	0.58	0.62
23	17-JUN-98 07:00:58	59.72	12.61	18.20	100.62	112.42	93.09	95.11	0.57	0.61
22	17-JUN-98 13:35:58	59.28	13.19	18.83	102.85	112.22	94.72	95.22	0.58	0.61
21	17-JUN-98 20:10:58	60.45	12.82	16.89	105.77	113.07	99.19	97.70	0.56	0.61
20	18-JUN-98 02:45:58	59.80	13.11	19.71	104.19	111.57	98.47	96.38	0.58	0.61
19	18-JUN-98 09:20:58	59.82	12.23	17.80	102.19	111.58	94.25	95.03	0.59	0.62
18	18-JUN-98 15:55:58	57.99	10.74	17.55	106.92	117.73	97.69	98.50	0.57	0.60
17	18-JUN-98 22:30:58	60.65	11.92	18.24	108.66	116.55	99.85	100.29	0.58	0.62
16	19-JUN-98 05:05:58	60.38	12.23	18.59	105.72	113.10	97.21	98.34	0.58	0.62
15	19-JUN-98 11:40:58	60.45	12.27	16.40	103.24	110.54	95.65	95.10	0.58	0.61
14	19-JUN-98 18:15:58	60.30	12.22	18.00	104.31	113.45	96.72	97.16	0.56	0.62
13	20-JUN-98 00:50:58	59.92	13.73	17.52	103.39	111.37	97.21	95.66	0.57	0.61
12	20-JUN-98 07:25:58	59.96	14.22	19.48	100.70	106.52	96.10	95.89	0.58	0.61
11	20-JUN-98 14:00:58	60.14	14.40	18.13	102.08	107.45	94.36	94.70	0.58	0.63
10	20-JUN-98 20:35:58	60.36	13.41	19.70	101.67	110.81	94.22	94.42	0.58	0.63
9	21-JUN-98 03:10:58	59.67	13.16	19.20	100.64	108.54	93.45	94.00	0.57	0.62
8	21-JUN-98 09:45:58	59.81	12.78	17.63	98.25	109.11	91.82	92.14	0.59	0.61
7	21-JUN-98 16:20:58	60.30	13.84	18.82	98.85	108.65	93.86	93.18	0.59	0.61
6	21-JUN-98 22:55:58	61.31	14.97	20.19	99.59	108.59	92.80	93.01	0.58	0.63
5	22-JUN-98 05:30:58	59.80	13.82	19.81	96.60	104.31	90.28	90.55	0.57	0.61
4	22-JUN-98 12:05:58	59.88	15.78	20.09	96.09	102.73	89.72	89.95	0.59	0.63
3	22-JUN-98 18:40:58	60.15	14.79	19.58	97.58	107.25	92.27	92.70	0.56	0.61
2	23-JUN-98 01:15:58	60.19	16.29	20.73	99.09	107.26	92.78	93.16	0.59	0.62
1	23-JUN-98 07:50:58	60.17	15.24	21.37	98.15	108.50	90.69	93.72	0.57	0.62
	AVERAGE	60.05	13.47	18.80	101.57	109.85	94.67	94.75	0.58	0.62
	STDEV	0.63	1.41	1.15	3.48	3.78	2.77	2.67	0.01	0.01


Pressure (Inches of Water Gauge)
25.00
20.00
15.00
10.00
5.00
0.00
09-JUN-98 21:15:58
10-JUN-98 10:25:58
10-JUN-98 23:35:58
11-JUN-98 12:45:58
12-JUN-98 01:55:58
12-JUN-98 15:05:58
13-JUN-98 04:15:58
13-JUN-98 17:25:58
14-JUN-98 06:35:58
14-JUN-98 19:45:58
15-JUN-98 08:55:58
15-JUN-98 22:05:58
16-JUN-98 11:15:58
17-JUN-98 00:25:58
17-JUN-98 13:35:58
18-JUN-98 02:45:58
18-JUN-98 15:55:58
19-JUN-98 05:05:58
19-JUN-98 18:15:58
20-JUN-98 07:25:58
20-JUN-98 20:35:58
21-JUN-98 09:45:58
21-JUN-98 22:55:58
22-JUN-98 12:05:58
23-JUN-98 01:15:58
PC-A Chamber Pressure
PC-B Chamber Pressure

Four sets of pulverized coal samples were taken from the coal lines using an isokinetic probe during the ROM portion of the test. The sieve analysis results indicated that the ROM coal was coarser than the performance coal for the same classifier setting. Average coal size varied from thirty-six to fifty-eight percent through 200 mesh, with an average of forty-seven percent through 200 mesh.

In summary, combustor performance results were:

- Fourteen days of continuous operation occurred with no indications of unacceptable precombustor slag accumulation, while burning coal with an inferred higher heating value of 7,800 Btu/lb.
- During the fourteen days of continuous operation, the slagging combustor stoichiometry setpoint was 0.80. The average NO_X emission was 0.24 pounds per million Btu with a standard deviation of 0.02. This is well below the air quality permit level of 0.35 pounds per million Btu.
- Carbon monoxide concentration measurements in the furnace ranged from 0.25 to 1.78 ppm and averaged 0.87 ppm, while the stack O_2 concentration was 3.3 to 3.8 percent.
- SO_2 measurements recorded upstream of the SDA indicated approximately fifteen percent removal, for a Ca/S ratio of approximately 1.5 to 2.0.

4.9 JULY COMBUSTOR OPERATION

The primary objective of the test operations conducted in July was to resolve the problem of excessive slag accumulation within the precombustor that occurred when firing blended coal with a higher heating value less than 7,400 Btu/lb. As noted before, the extent of slag accumulation has varied from test to test, as well as from one combustor to the other. Based on the post-test observations of the slag formation, as well as the variation in slag accumulation from one combustor to the other, the cause of the excess slag accumulation was attributed to two conditions. The first was the freezing of the slag exiting the precombustor combustion chamber where the mix annulus secondary air (770° F) was injected. The second condition was wide variations in the actual precombustor stoichiometry, caused by variations in the coal higher heating value in one combustor versus the other. The test effort focused on resolving the first item.

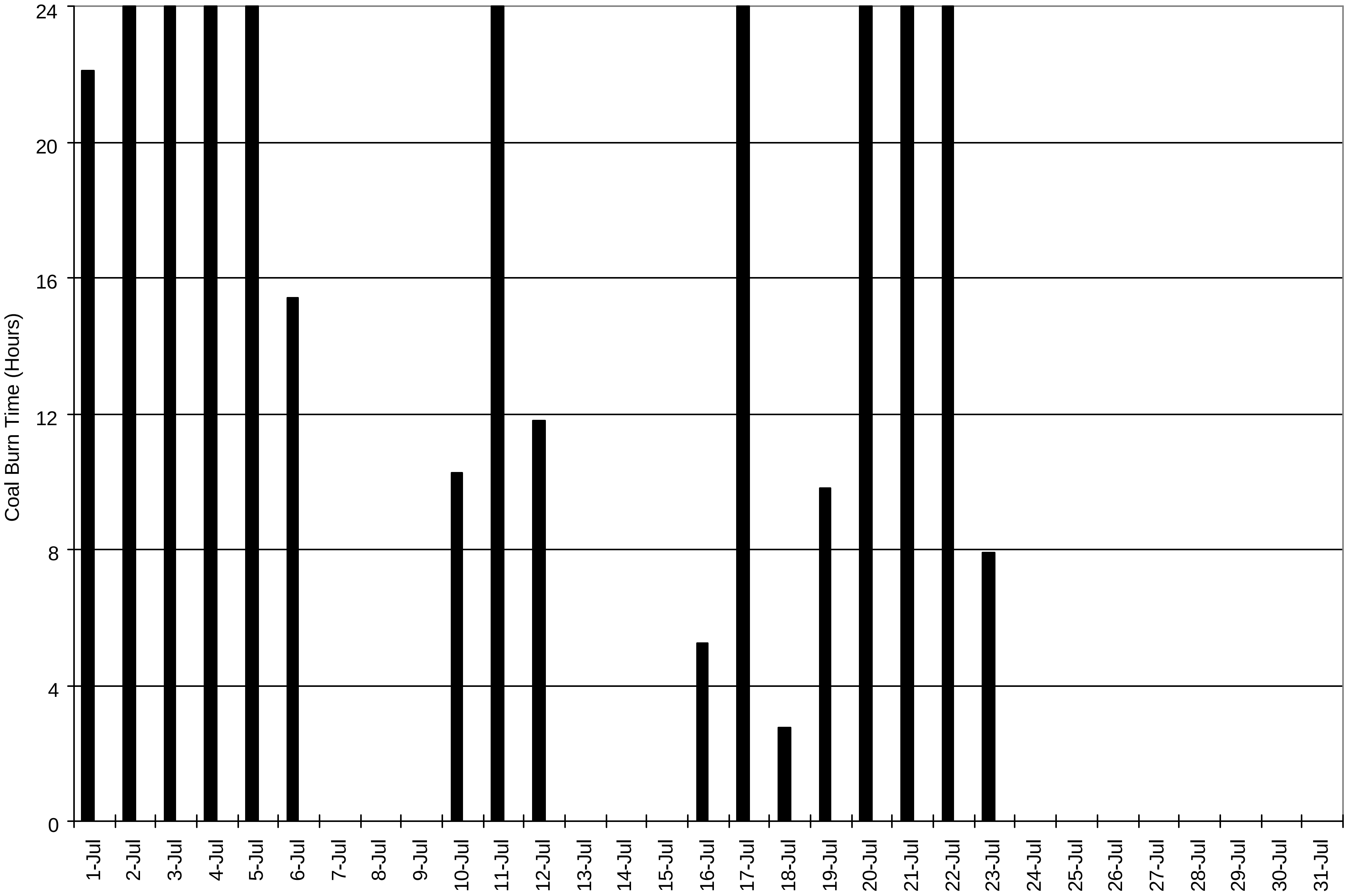
Previous attempts to minimize slag accumulation within the precombustor had focused on operational changes to reduce slag formation within the precombustor combustion chamber, such as operating at a lower precombustor stoichiometric ratio and by maintaining the precombustor exit temperature either below the melting temperature (2,200° F) of the slag ash or above the T_{250} (2,800° F) of the slag ash. Although these conditions could be maintained for a period of time varying from one to four days, the changing coal quality characteristics, excessively low heating value coal and/or high T_{250} ash eventually caused slag accumulation within the precombustor. Therefore, the focus during July was on the hardware configuration changes that would provide a broader operating envelope more forgiving of coal quality variations and/or lower heating value coal. Figures 4.9.1, 4.9.2 and 4.9.3 show coal burn time and NO_X and SO_2 emissions, respectively. The numbers used in these figures are estimates based on the operator's log for this period, because all of the test data prior to July 10 had been corrupted when space had been made on the hard drive to store additional test data.

The original mix annulus configuration is shown in Figure 4.9.4. During July, three different precombustor mix annulus configurations were evaluated in an effort to change the mixing characteristics of the precombustor combustion chamber combustion products and the secondary air.

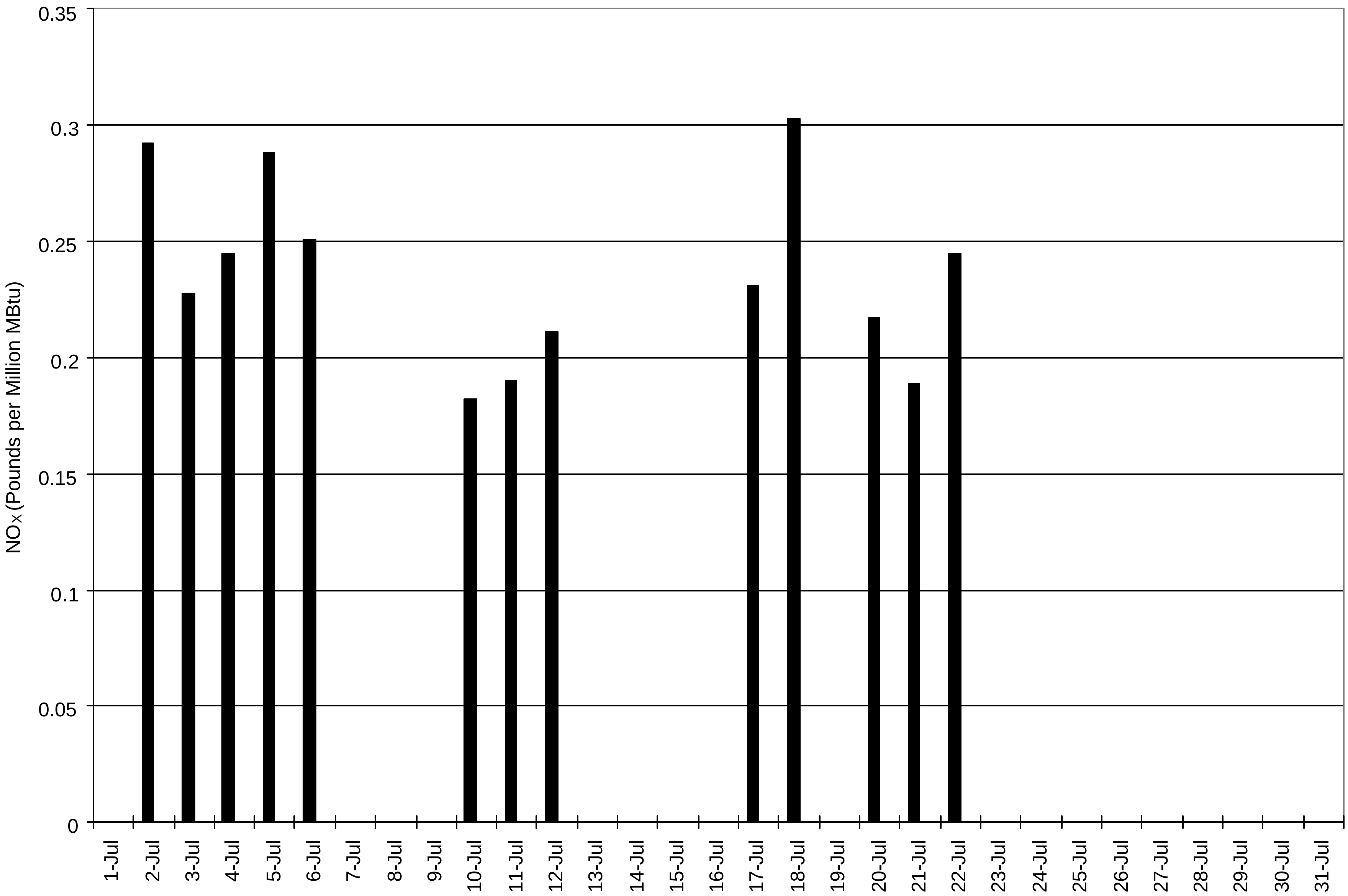
1. A non-mixing configuration, shown in Figures 4.9.5 and 4.9.6, which maintained the existing mix annulus secondary air annular configuration, but reduced the annular open area by seventy-five percent by blocking off the top and bottom cross-sectional area. This change provided high velocity air (approximately 240 ft/sec) along the side walls of the precombustor transition section that, by design, did not mix with the precombustor combustion chamber combustion products until downstream of the swirl dampers, within the precombustor tangential exit.
2. A mixing configuration, shown in Figures 4.9.7 and 4.9.8, that directed the mix annulus secondary air through fourteen short radius 90° elbows into the center of the precombustor immediately downstream of the precombustor combustion chamber. This change provided high velocity jets (approximately 190 ft/sec) immediately downstream of the chamber that would penetrate and mix with the precombustor chamber combustion products within the precombustor transition section.
3. Same as Configuration 2 above, however the number of elbows was reduced from fourteen to twelve by blocking off the top two elbows as shown in Figure 4.9.9.

In addition to the hardware configuration changes, two different operating regimes were evaluated in July. The first was a low precombustor stoichiometry of 0.58 and a low

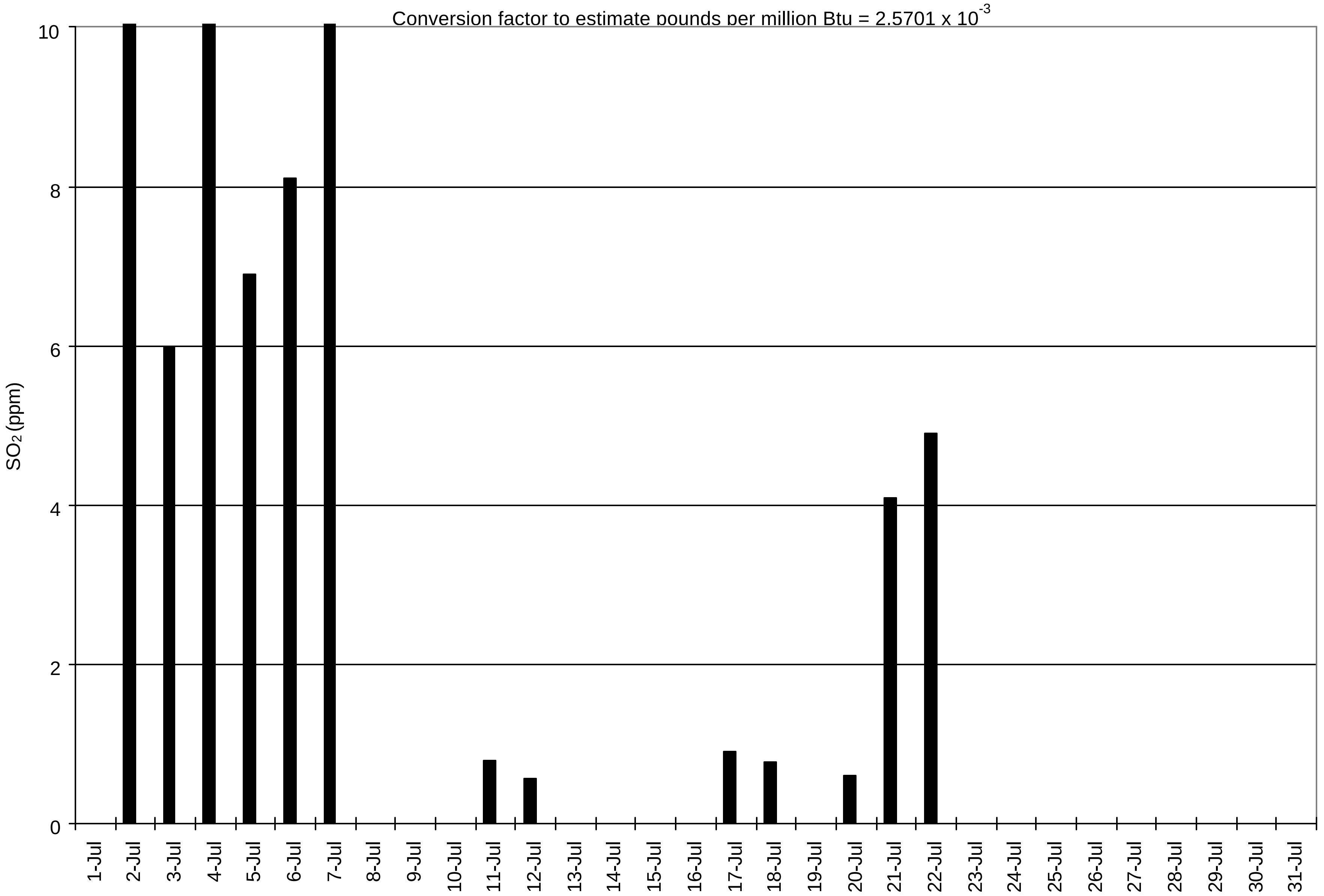
	Coal Burn Time (hours)
1-Jul	22.13333
2-Jul	24
3-Jul	24
4-Jul	24
5-Jul	24
6-Jul	15.45
7-Jul	0
8-Jul	0
9-Jul	0
10-Jul	10.25
11-Jul	24
12-Jul	11.8
13-Jul	0
14-Jul	0
15-Jul	0
16-Jul	5.233333
17-Jul	24
18-Jul	2.75
19-Jul	9.8
20-Jul	24
21-Jul	24
22-Jul	24
23-Jul	7.933333
24-Jul	0
25-Jul	0
26-Jul	0
27-Jul	0
28-Jul	0
29-Jul	0
30-Jul	0
31-Jul	0


Coal Burn Time (Hours)
0
4
8
12
16
20
24
1-Jul
2-Jul
3-Jul
4-Jul
5-Jul
6-Jul
7-Jul
8-Jul
9-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
16-Jul
17-Jul
18-Jul
19-Jul
20-Jul
21-Jul
22-Jul
23-Jul
24-Jul
25-Jul
26-Jul
27-Jul
28-Jul
29-Jul
30-Jul
31-Jul

	Coal Burn Time (hours)
1-Jul	0
2-Jul	0.292
3-Jul	0.228
4-Jul	0.245
5-Jul	0.288
6-Jul	0.251
7-Jul	0
8-Jul	0
9-Jul	0
10-Jul	0.182
11-Jul	0.19
12-Jul	0.211
13-Jul	0
14-Jul	0
15-Jul	0
16-Jul	0
17-Jul	0.231
18-Jul	0.303
19-Jul	0
20-Jul	0.217
21-Jul	0.189
22-Jul	0.245
23-Jul	0
24-Jul	0
25-Jul	0
26-Jul	0
27-Jul	0
28-Jul	0
29-Jul	0
30-Jul	0
31-Jul	0


NOX (Pounds per Million MBtu)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1-Jul
2-Jul
3-Jul
4-Jul
5-Jul
6-Jul
7-Jul
8-Jul
9-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
16-Jul
17-Jul
18-Jul
19-Jul
20-Jul
21-Jul
22-Jul
23-Jul
24-Jul
25-Jul
26-Jul
27-Jul
28-Jul
29-Jul
30-Jul
31-Jul

1-Jul	0
2-Jul	14.9
3-Jul	6
4-Jul	24.1
5-Jul	6.9
6-Jul	8.1
7-Jul	28.875
8-Jul	0
9-Jul	0
10-Jul	0
11-Jul	0.8
12-Jul	0.56
13-Jul	0
14-Jul	0
15-Jul	0
16-Jul	0
17-Jul	0.9
18-Jul	0.77
19-Jul	0
20-Jul	0.6
21-Jul	4.1
22-Jul	4.9
23-Jul	0
24-Jul	0
25-Jul	0
26-Jul	0
27-Jul	0
28-Jul	0
29-Jul	0
30-Jul	0
31-Jul	0



Conversion factor to estimate pounds per million Btu = 2.5701 x 10^-3
SO₂ (ppm)
0
2
4
6
8
10
1-Jul
2-Jul
3-Jul
4-Jul
5-Jul
6-Jul
7-Jul
8-Jul
9-Jul
10-Jul
11-Jul
12-Jul
13-Jul
14-Jul
15-Jul
16-Jul
17-Jul
18-Jul
19-Jul
20-Jul
21-Jul
22-Jul
23-Jul
24-Jul
25-Jul
26-Jul
27-Jul
28-Jul
29-Jul
30-Jul
31-Jul

Figure 4.9.4 – Detailed Cross Section of Original Mix Annulus Configuration

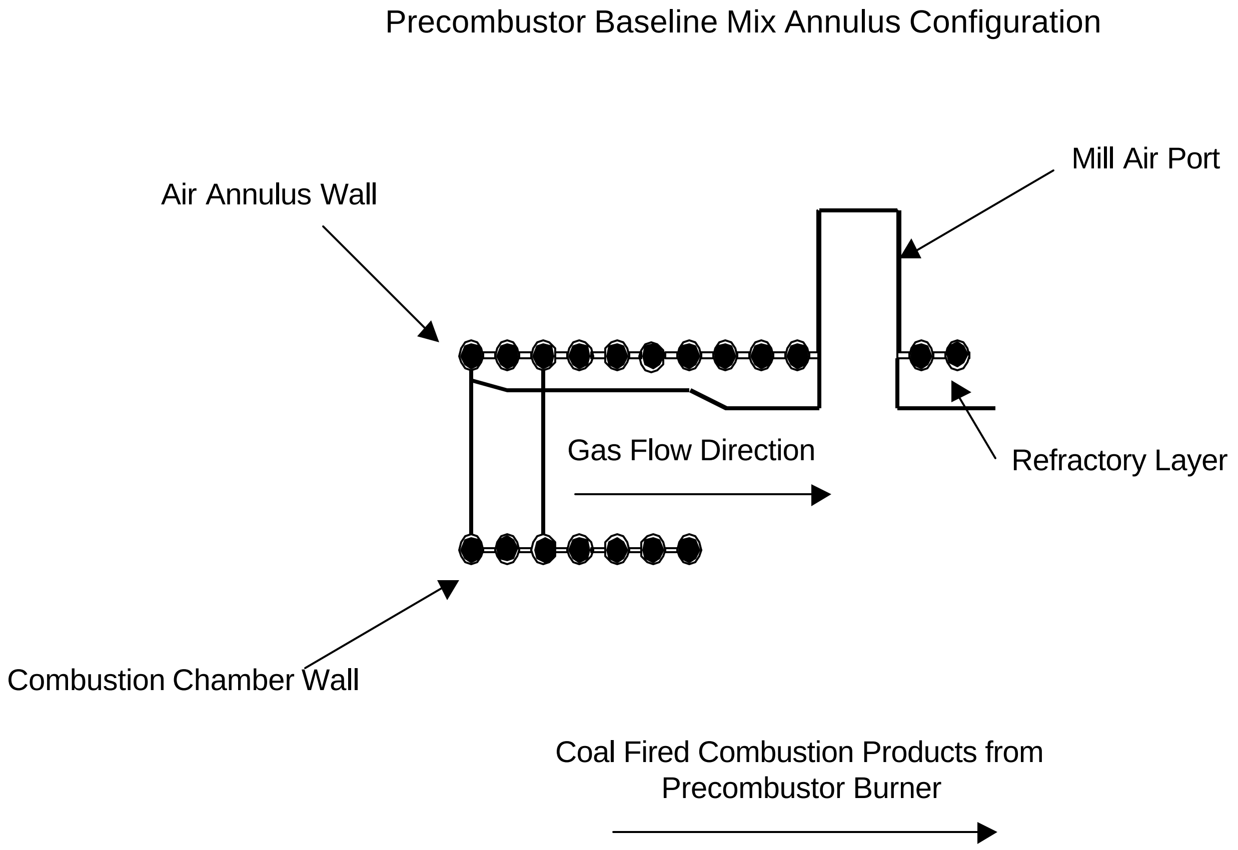


Figure 4.9.5 – Schematic of Non-Mixing Precombustor Mix Annulus Configuration

High Velocity Axial Injection of Mix Annulus Air on Side Walls

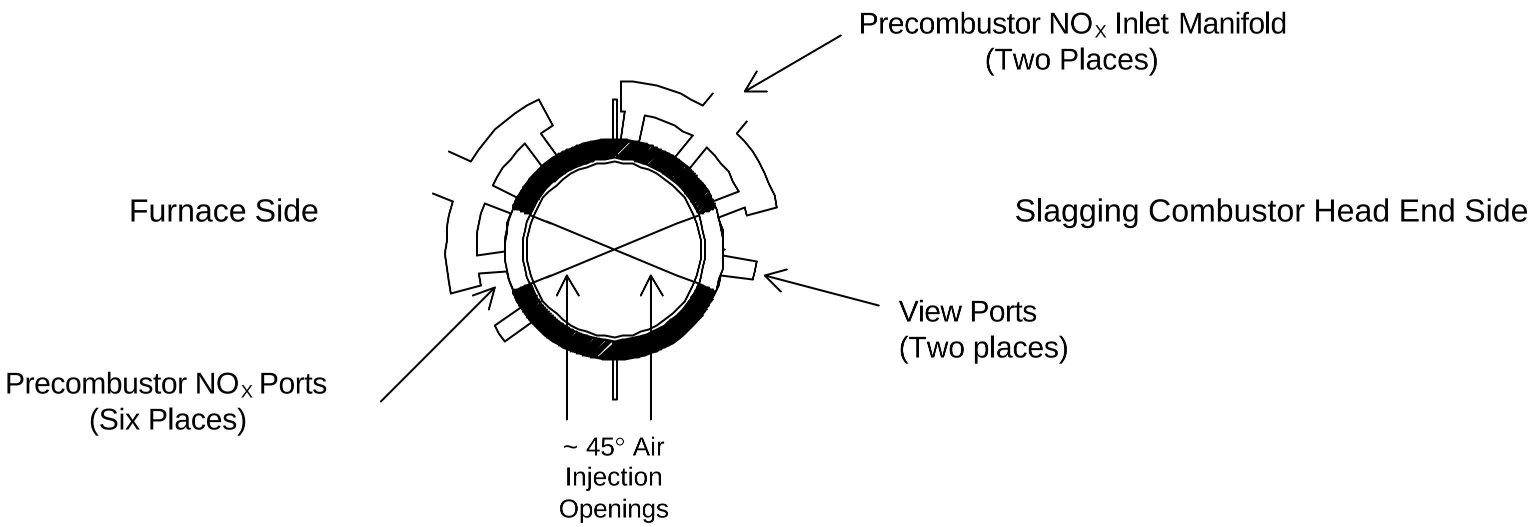


Figure 4.9.6 – Detailed Cross Section of Non-Mixing Precombustor Mix Annulus Configuration

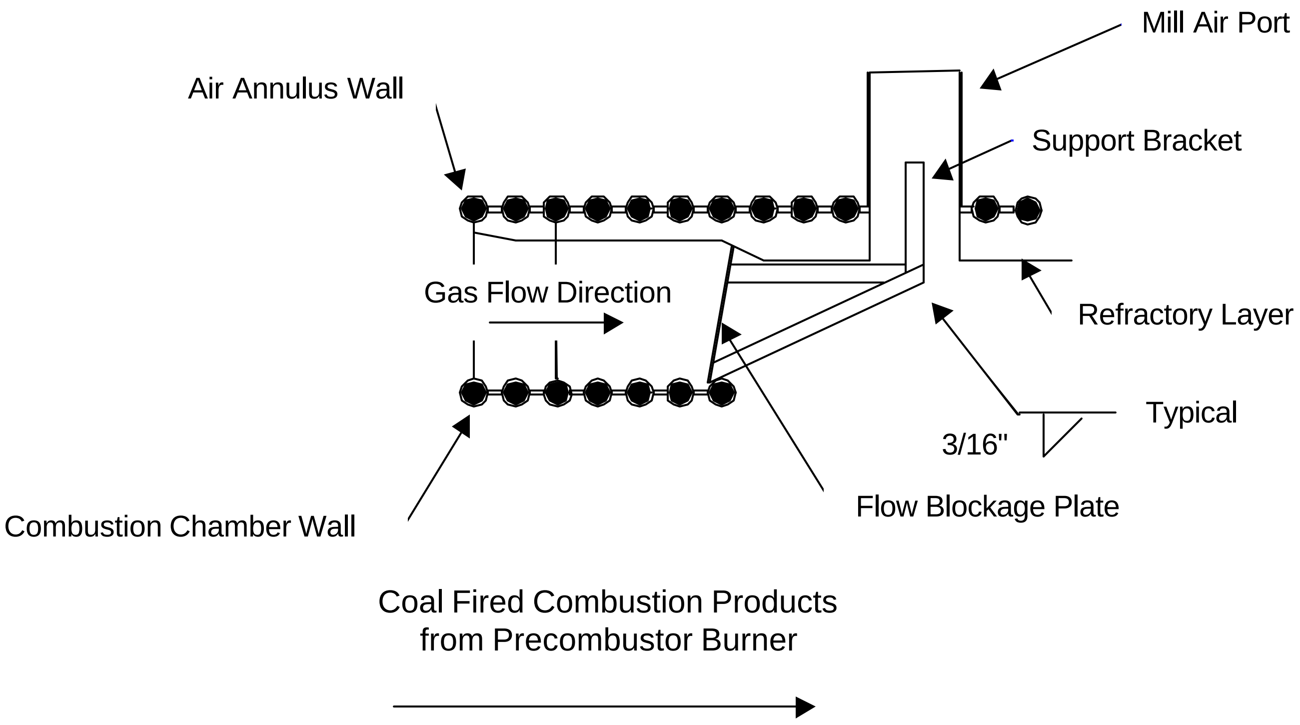
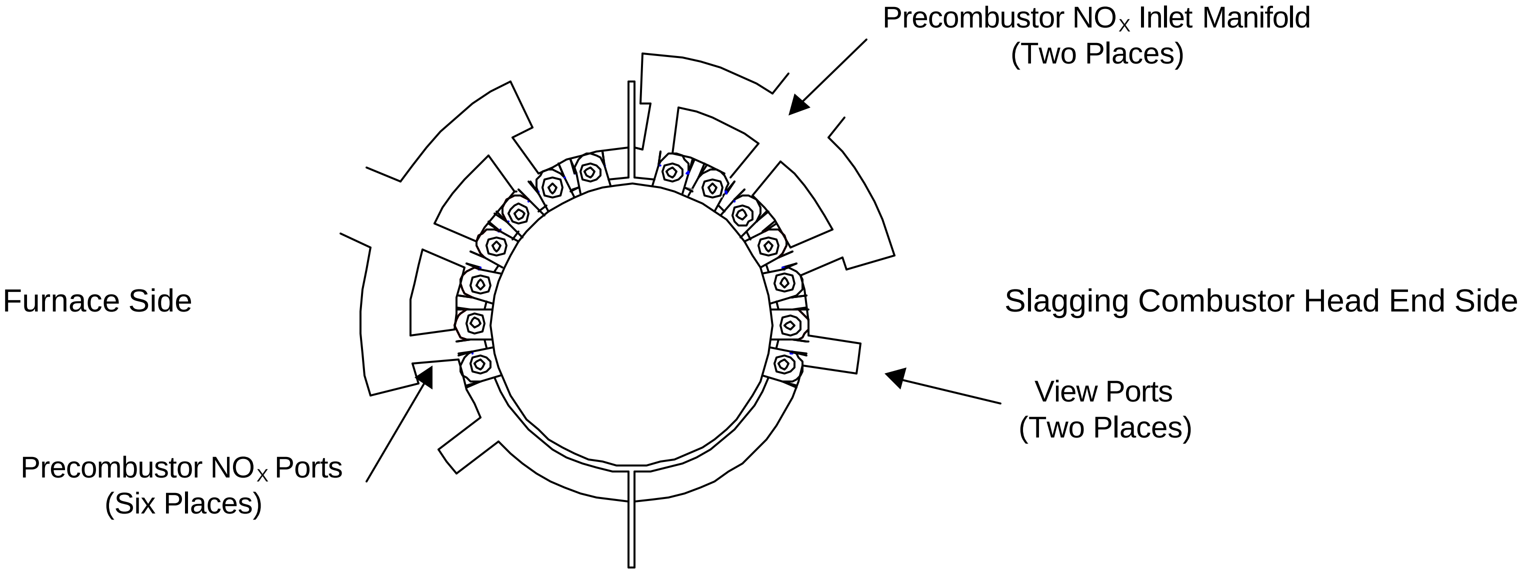


Figure 4.9.7 – Schematic of Fourteen Port Precombustor Mix Annulus Elbow Configuration



Note: ☆ refers to a closed mix air injection port

⬡ refers to an open mix air injection port

Figure 4.9.8 – Detailed Cross Section of Fourteen Port Precombustor Mix Annulus Elbow Configuration

Precombustor Mix Air Injection Layout

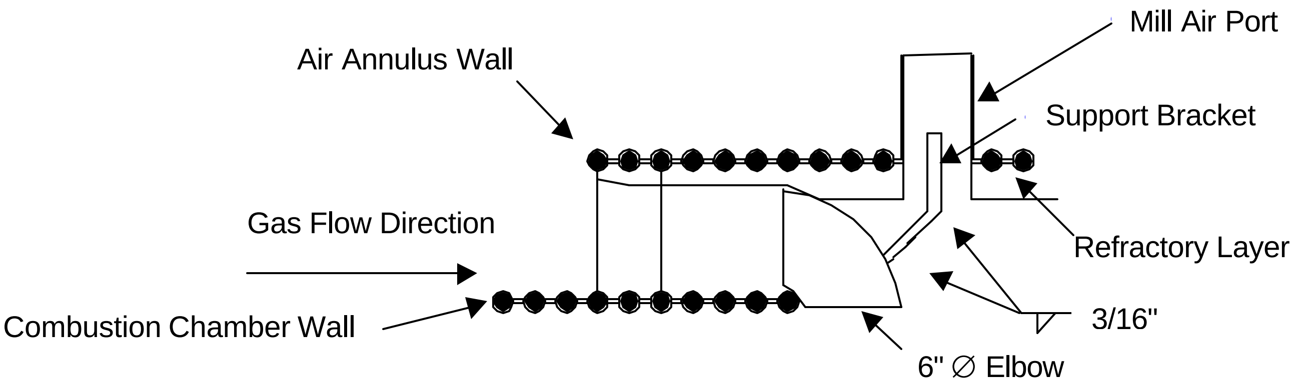
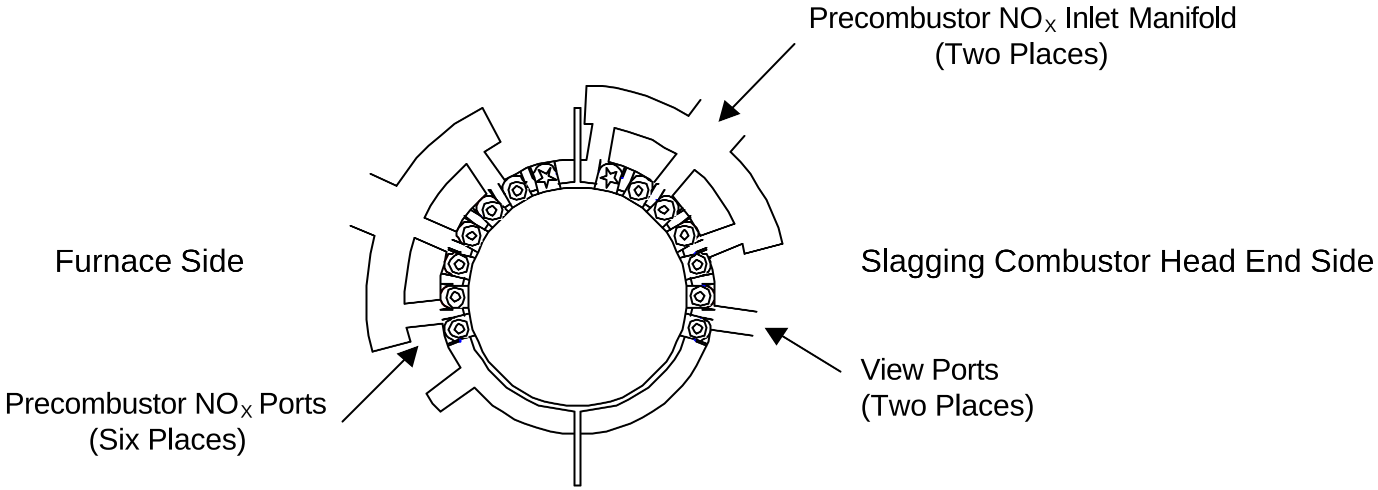


Figure 4.9.9 – Schematic of Twelve Port Precombustor Mix Annulus Elbow Configuration



Note: ☆ refers to a closed mix air injection port

◎ refers to an open mix air injection port precombustor coal split (thirty percent), in order to maintain precombustor temperatures below the slag ash melting temperature (2,200° F). This was the operating condition during the evaluation of Configurations 1 and 2. The second operating regime was a high precombustor stoichiometry and a high precombustor coal split, in order to maintain the precombustor temperatures above the slag ash T_{250} (2,800° F). This was the operating condition during the evaluation of Configuration 3.

The test durations varied from twenty-four to 140 hours, depending on the length of time required to evaluate effects of the hardware configuration and operating condition changes on the precombustor slagging and fouling characteristics. Table 4.9.10 provides a summary of the individual test configurations, test operating conditions and test results for each test performed. All tests were conducted with blended coal. The inferred higher heating value of the coal (based on steam generation and assumed boiler efficiency) varied from 6,700 to 7,300 Btu/lb.

The following paragraphs summarize the results from this test series.

ORIGINAL MIX ANNULUS CONFIGURATION

For the original mix annulus configuration, the optimum operating conditions were a low precombustor coal split (approximately thirty percent) and a low precombustor chamber stoichiometry (0.59). These conditions resulted in reduced slag formation within the precombustor and, therefore, extended precombustor operation without excessive slag accumulation. Unfortunately, because of unknown and changing coal quality within each combustor, it was not possible to maintain close control over the stoichiometry and eventually operating conditions occurred that resulted in unacceptable slag accumulation within the tangential inlet to the slagging combustor and/or combustion chamber of the precombustor. One hundred and forty hours of continuous coal burn time without unacceptable slag accumulation was achieved on Combustor B, while operating under these conditions.

NON-MIXING MIX ANNULUS CONFIGURATION

As discussed above, the non-mixing mix annulus configuration was achieved by blocking off seventy-five percent of the total annular opening of the mix annulus and leaving only 45° arcs open on each side of the mix annulus as shown in Figures 4.9.5 and 4.9.6. A mix annulus flow rate of 82,000 lb/hr provided a mix annulus secondary air injection velocity of approximately 240 ft/sec. This increase in velocity resulted in delaying the mixing of the mix annulus air flow with the precombustor combustion products until it encountered the swirl dampers at the precombustor exit. The single test of this configuration was conducted with a 0.59 precombustor stoichiometry and a thirty percent precombustor coal split to achieve a precombustor exit temperature below 2,300° F. Only Combustor A was operated. Within twenty-four hours, the precombustor chamber pressure increased significantly (over twelve inches of water gauge), indicating a significant blockage of the precombustor exit from excessive slag accumulation. The test was terminated following forty hours of total coal flow, to inspect the precombustor slag accumulation. Post-test inspection revealed significant slag accumulation within the precombustor exit section extending approximately two feet into the slagging stage chamber. It is postulated that the slag accumulation was initiated immediately downstream of the swirl dampers, where the secondary air and precombustor combustion products mixed, and the slag extension into the slagging stage resulted from convective cooling by the unmixed cold (770° F) secondary air. Based on the results of this non-mixing test, a decision was made to improve the mixing of the secondary air and combustion products and to move the mixing location further upstream within the precombustor.

Table 4.9.10 – July 1998 Test Activities

			Operating Conditions		Results	
Test Number	Test Start Date	Gross MW	Velocity of Mix Air Injection, ft/sec	Stoich Ratio PC (can)	Stack SO_2 (ppm)	PC Fouling Comments
	Duration at Test Conditions	Inferred Coal HHV (Btu/lb)	T Exit (° F)	Stoich Ratio SC (baffle)	Stack NO_X (lb/MBtu)	Post Test Inspection Notes
	Reported Data Interval	Coal Flow Rate (klb/hr)	V Exit (ft/s)		Slag Recovery (%)	
PERF-S4-1A-7500	7/1	58 - 61	not reported	0.58	2-16	PC A chamber pressure increased 8" wc w/in initial 30 hrs. PC B chamber pressure did not increase during the first 72 hrs, but later indicated slag sloughing behavior w/periodic increases and decreases in pressure.
	140 hrs	6500-8000	~2300	0.80 - 0.83	0.21 - 0.31	PC B had only limited amount of slag accumulation in tangential inlet; typical slag fan extending from combustion chamber into transition section, PC A was not inspected prior to slag removal.
	No data recorded. ODMS hard drive full	not reported	not reported		not reported	
PERF-S4-1-7000 Non-Mixing	7/10	28	260	0.60	1	PC A chamber pressure increased total of 17" wc w/in 30 hrs.
	31 hrs	6,780	2,352	0.80	0.19	PC A operation only. Non-mixing configuration led to the most unusual PC slag accumulation to date, PC slag accumulation extending into slagging combustor.
	7/10 (23:58) - 7/11 (23:58)	44.9	305			
	continuous	27	220	0.60	1	
		6,700	2,364	0.73	0.18	
	7/11(23:58) - 7/12 (07:30)	42.5	289		57%	
PERF-S3-1B-7000 14 Mixing Elbows	7/16/98	29	175-220	0.57	1	PC A chamber pressure increased 8" wc during initial 13 hrs.
	20 hrs	7,000	2,348	0.80	0.22	Very little slag within tangential air inlet. Slag accumulation is directly downstream of combustion chamber where air jets from elbows impinge on slag curtain; curtain is directed downstream and inward toward PC centerline.
	7/17 (5:29) - 7/17 (23:52)	45.8	315		92%	
PERF-S3-2-7000 13 Mixing Elbows	7/19/98	29	139	0.90	4	PC A chamber pressure increased 12" wc during initial 40 hrs. Then slag accumulation apparently reached a self-limiting condition. No further net chamber pressure increase during the next 43 hrs.
	87 hrs	7,080	2,347	0.80	0.20	Tangential air inlet is clear of any slag accumulation. Molten river of slag on bottom. Slag fan attached to top and furnace side of PC can, covering the upper portion of the can outlet.
	7/19 (20:49) - 7/20 (23:58)	46.2	317			
	continuous	28	110	1.00	7	
		6,901	2,346	0.80	0.22	
	7/20 (23:58) - 7/21 (23:58)	46.3	318			
	continuous	29	94	1.00	9	
		7,168	2,346	0.80	0.26	
	7/21 (23:58) - 7/22 (23:53)	46.3	318			
	continuous	29	79	0.98	15	
		7,325	2,346	0.80	0.26	
	7/22 (23:53) - 7/23 (05:52)	46.3	318		72%	

Table 4.9.10 – July 1998 Test Activities

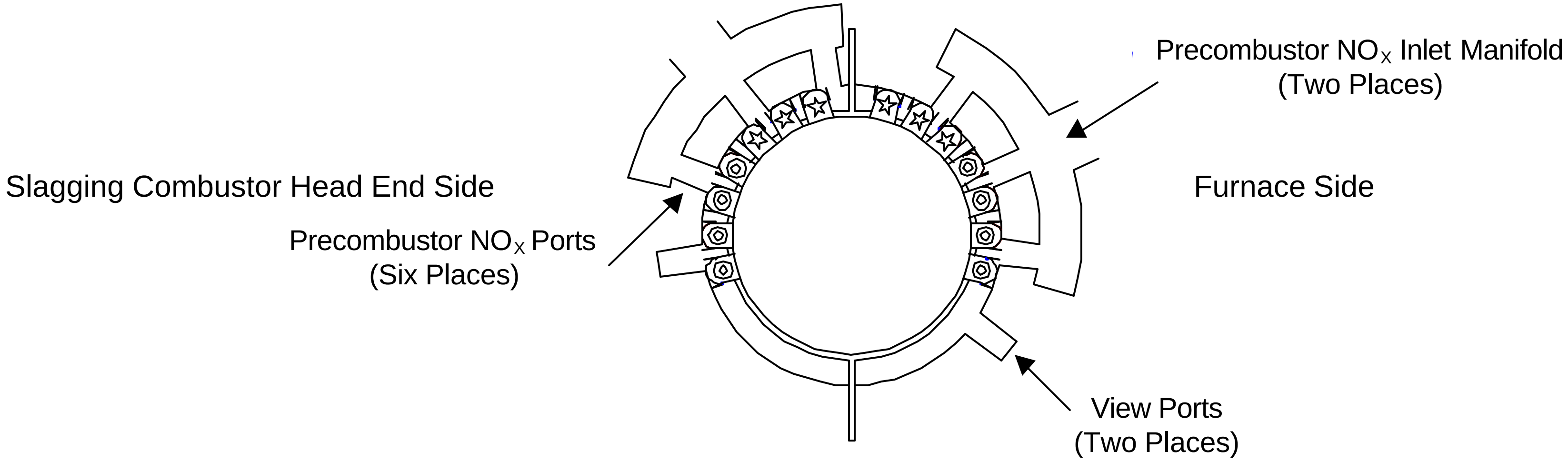
MIXING ELBOW MIX ANNULUS CONFIGURATION: NON-SLAGGING

The mixing configuration for the mix annulus secondary air was achieved as shown in Figures 4.9.7 and 4.9.8 by installing fourteen short radius 90° elbows immediately downstream of the precombustor combustion chamber to jet the mix annulus secondary air centripetally into the core flow of the precombustor combustion products. The high velocity, discrete air jets created by the elbows were to penetrate the core flow of the precombustor combustion products and promote active mixing immediately downstream of the precombustor combustion chamber. Only Combustor A was operated for this series of tests. The initial test in this configuration was conducted with a 0.59 precombustor stoichiometry and a thirty percent precombustor coal split to achieve a precombustor exit temperature below 2,300° F. The precombustor was inspected following twenty-four hours of coal firing. Post-test inspection indicated that there was no slag accumulation within the precombustor tangential exit. A slag fan, with a configuration approximately four inches thick and two feet long (as roughly illustrated in Figure 4.9.11), attached to the downstream end of the precombustor combustion chamber and extended inward towards the centerline of the precombustor and bent over the secondary air jets. The fan was heaviest towards the top and east (head end) side of the combustion chamber. Based on the results of this test, a decision was made to increase the precombustor stoichiometric ratio from 0.59 to 0.85, so that the slag fan extending from the chamber would be thinner and more easily sheared off (and/or penetrated by the secondary air jets). The precombustor coal split was increased from thirty to forty-one percent, in order to raise the precombustor exit temperature. In addition, since the new operating conditions would reduce the precombustor mix annulus secondary air flow rate, the two topmost elbows installed in the mix annulus were blocked off, in order to maintain the air jet velocity while operating at the reduced secondary air flow rate.

MIXING ELBOW MIX ANNULUS CONFIGURATION: SLAGGING

As noted above, the second iteration of the mixing configuration for the secondary air mix annulus was identical to the original 90° elbow configuration, with the exception that the two topmost elbows were blocked off (Figure 4.9.9), resulting in a total of twelve elbows and a mix annulus secondary air injection velocity of approximately 120 ft/sec. It should be noted that post-test inspection revealed that only one of the elbows remained plugged for the duration of the test and, therefore, the final configuration was thirteen elbows, which corresponds to an air injection velocity of approximately 106 ft/sec. Only Combustor A was operated for this series of tests. The initial operating conditions in this configuration was conducted with a precombustor stoichiometry of 0.85 and a forty-one percent precombustor coal split, to achieve a thinner slag layer at the exit of the precombustor chamber and a precombustor exit temperature above 2,800° F. Based on visual inspections through the precombustor view port, a slag fan began to form at the exit of the precombustor combustion chamber following approximately thirty hours of coal burn time. Online indications of precombustor chamber pressure indicated slag formation (i.e., increase in chamber pressure) followed by slag sloughing (i.e., decrease in chamber pressure) for the next ten hours, resulting in an overall gradual increase in the chamber pressure after forty hours of coal burn time. Then, the precombustor stoichiometry was increased to 1.0 and the precombustor coal split was increased to forty-three percent. The precombustor chamber pressure held relatively constant, with occasional increases and decreases in response to coal higher heating value changes and/or operational changes, over the next forty hours until the test was shut down for a planned plant outage. The precombustor was inspected following approximately eighty-eight hours of coal firing. There was no slag accumulation within the precombustor tangential exit. There was a slag fan, approximately one to two inches thick and two feet long, extending from the top and furnace side of the downstream end of the precombustor combustion chamber. One of the two elbows that had been deliberately blocked

Figure 4.9.12 – Schematic of Eight Port Precombustor Mix Annulus Elbow Configuration

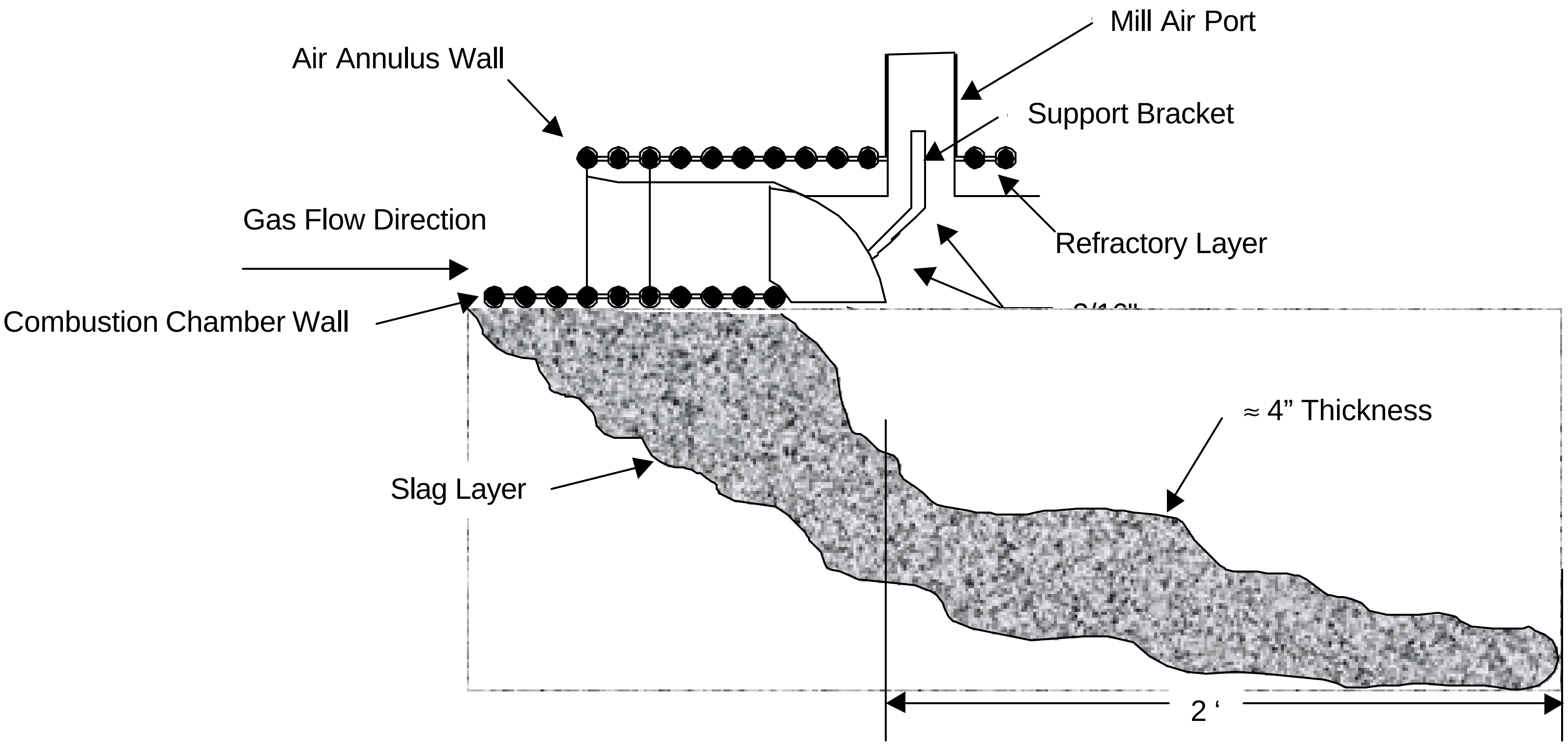


Note: ☆ refers to a closed mix air injection port

◎ refers to an open mix air injection port

Figure 4.9.11 – Detailed Cross Section of Fourteen Port Precombustor Mix Annulus Elbow Configuration

Precombustor Mix Air Injection Layout



prior to the test was no longer blocked. This probably contributed to the formation of the slag fan along the top of the precombustor combustion chamber.

Overall, the results of this test series were very positive including:

- For the two tests conducted with the new precombustor mix annulus mixing configuration, there was no indication of excessive slag accumulation within the precombustor tangential exit. This slag accumulation had previously been the major contributing factor to the high precombustor chamber pressures that limited the operating duration.
- Preliminary indications, based on increases in precombustor chamber pressure followed by decreases in precombustor chamber pressure, were that the slag fans extending from the downstream end of the precombustor combustion chamber were self-limiting.
- The hardware configuration changes to the mix annulus secondary air injection and the changes in operating conditions (from non-slagging to slagging conditions) had enhanced overall combustor performance in terms of emissions and slag recovery. In particular, for the final precombustor mix annulus configuration (twelve short radius elbows) and final operating conditions of a precombustor stoichiometry of 1.0 and a precombustor coal split of forty-three percent, NO_X emission (0.20 pounds per million Btu) was somewhat lower than previous tests. This might be attributed to lower temperatures in the lower furnace caused by firing only one combustor, thereby reducing thermal NO_X created in the oxidizing furnace. The SO_2 emission from the furnace and stack was consistent with previous tests and the slag recovery (eighty percent) was slightly higher.

At the end of July, during a planned ten day outage, the following activities related to the combustion system, coal feed system, and limestone feed system were performed.

DAMAGE TO PRECOMBUSTOR B REPAIRED

Only Combustor A was operated, because of damage to Precombustor B observed during a routine inspection performed on July 7. The damaged area was within the precombustor secondary air mix annulus windbox and occurred prior to any of the precombustor mix annulus modifications discussed above. Specific damage included liquid slag flow covering the tube wall and uncooled metal surfaces extending approximately three feet upstream of the mix annulus secondary air annular opening; the melting of four of the structural gussets (three gussets on the west side of the mix annulus and one on the east side) between the inner and outer tube walls of the annular opening and the melting of approximately nine square feet of the uncooled outer annular wall of the windbox. Based on slag deposited into the mix annulus upstream of its annular opening, there was, apparently, a temporary disruption of air flow or an extremely low air flow to the mix annulus windbox that allowed hot combustion gases and slag to flow back into the air gap. A reasonable amount of air flow within the annular opening should have prevented such a back flow of combustion gases and freezing of slag. There was no similar damage to Combustor A, which was believed to have been operated under the same operating conditions. An attempt was made to review the test data to determine when this low flow condition may have occurred; however, the test data had been corrupted. The damaged areas of the precombustor windbox were repaired at the end of July, including the removal of the slag, replacement of the damaged gussets and damaged area on the uncooled windbox shell, replacement of the insulating material and the replacement of the damaged thermocouple. It was also discovered that this thermocouple had never provided a reading, because its wires were not properly terminated.

PRECOMBUSTORS A AND B MIX ANNULUS MODIFICATION

Subsequent to the repair of the Precombustor B mix annulus windbox, the mix annulus annular gap region was modified to incorporate fourteen short radius 90° elbows, identical to the configuration previously installed in Combustor A. For subsequent tests, various combinations of the elbows on each side of the mix annulus region were blocked off to modify the secondary air mixing patterns. The different configurations installed in July that were to be evaluated based on the simultaneous operation of Precombustors A and B in August were as follows. On Precombustor A, the two topmost elbows (one on each side of the mix annulus) remained blocked with refractory, leaving twelve open elbows, and the coal cyclone separator vent air ports were also blocked with refractory. On Precombustor B, the six topmost elbows (three on each side of the mix annulus) were blocked with refractory, leaving eight open elbows, and the mill air ports were left open. The configuration for Precombustor B is shown in Figure 4.9.12. The purpose of these different configurations was to evaluate cyclone vent air versus no cyclone vent air.

LIMESTONE FEED SYSTEM INSPECTION

On two occasions during July, the limestone feed system feeder had stopped during operation at low motor speeds. The stoppage was attributed to overheating of the motor, which tripped the breaker. During the downtime, the limestone feed system was inspected to determine the cause of the motor overheating. Results were as follows:

- A three inch by two inch by one inch limestone rock was found in the feeder discharge valve
- The limestone feed system was run without limestone with motor speeds of zero to one hundred percent, which indicated that both armature and field currents were less than nameplate values and that the system was functioning within acceptable limits

MISCELLANEOUS MODIFICATIONS

The following tasks were also performed:

- A new higher capacity load cell was installed and calibrated
- A modified baffle with longer sides was installed at the inlet of the feeder
- The bin vibrator was readjusted to provide more intense vibration with a shorter duty cycle

Some problems had been experienced with intermittent erroneous signals from the flow annubars installed on the precombustor mill air ports because of leakage through the purge valves. Based on the manufacturer’s recommendation, new upgraded purge valves were installed on the flow annubars at the beginning of July. Initial test results did not indicate a significant improvement over the original purge valves. However, during the downtime at the end of July, a detailed inspection of the flow annubar was performed. The annubars had a significant amount of coal dust packed in the ends that had not been cleaned out prior to installing the new purge valves. The annubars were subsequently cleaned.

4.10 AUGUST COMBUSTOR OPERATION

The objective of the test operations conducted during August was to resolve the problem of excessive slag accumulation within the precombustor that typically has occurred during the burning of coal with higher heating value below 7,400 Btu/lb.

Figure 4.10.1 shows the coal burn time during August. Power was generated on twenty-five out of its thirty-one days, with a total coal burn time of approximately 550 hours, surpassing the seventeen out of thirty days of power generation and total coal burn time of approximately 414 hours obtained in June.

Figure 4.10.2 shows daily NO_X emission averages during August. NO_X emission averaged approximately 0.26 pounds per million Btu over the twenty-five days of operation. NO_X emission was higher than before; perhaps because all, or a portion of the precombustor mill air was eliminated from Precombustor A. During tests starting August 5, in which the mill air ports on Precombustor A had been deliberately blocked off, the NO_X emission values were generally in the 0.27 to 0.33 pounds per million Btu range. When the precombustor mill air port plugs were removed for the test starting on August 14, the combustor NO_X emission values decreased to their normal value (0.20 to 0.25 pounds per million Btu). However, during a combustor restart on August 20, it became apparent that at least three of the precombustor mill air ports had been plugged with coal and the overall combustor NO_X levels were higher during that time. It should be noted that this coal had remained in the lines following the deliberate plugging of the ports for the August 5 test.

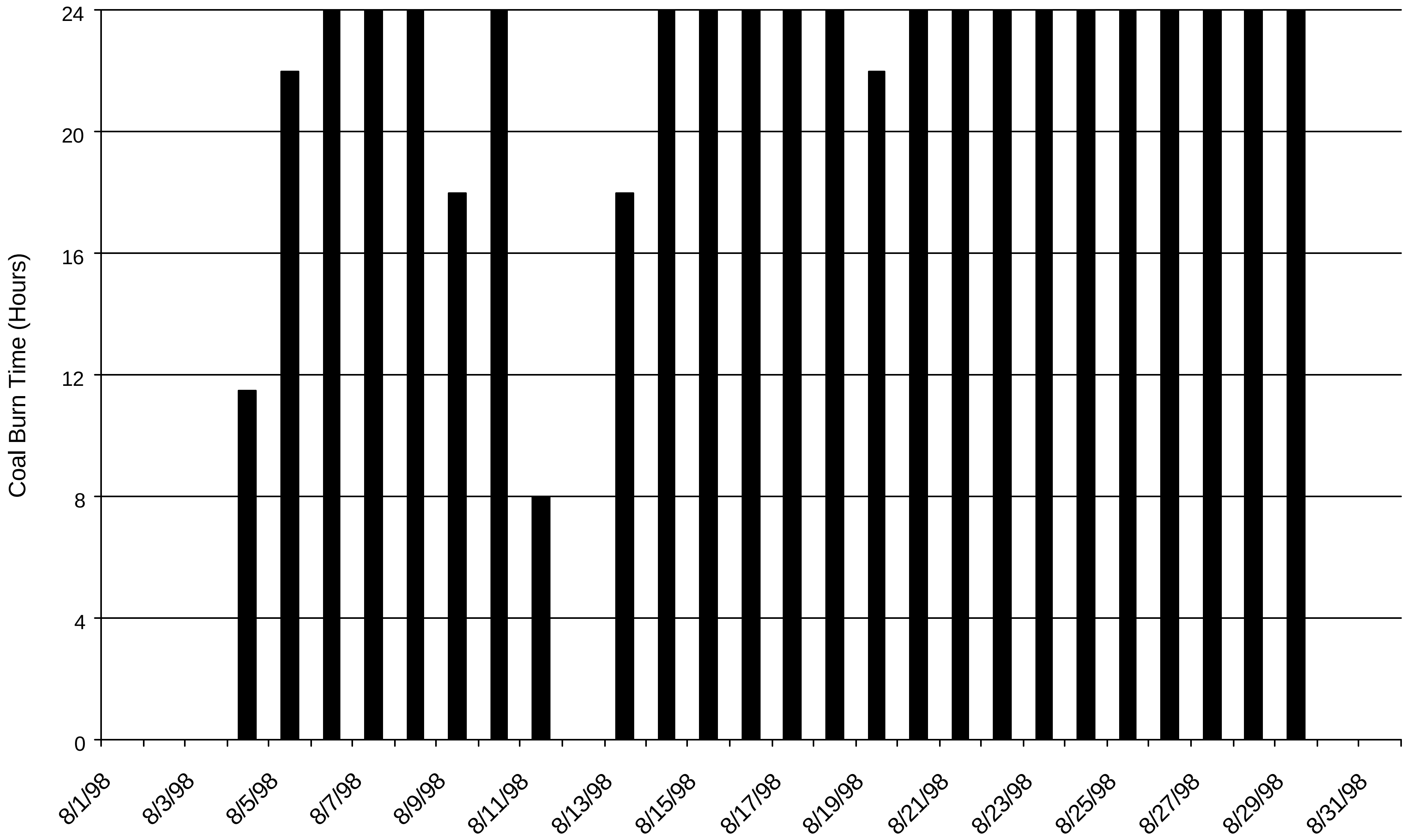
Figure 4.10.3 shows daily SO_2 emission averages for August. The average SO_2 emission was 3.1 ppm at the stack. The Ca/S ratio for the ROM coal was typically in the 1.1 to 1.5 range. Lower Ca/S ratios for ROM coal with 0.13 percent sulfur were effectively achieved by shutting the bin vibrator off for two hours out of a three-hour cycle. Additional limestone feeder checks were also performed to confirm the load cell readings at two feeder belt speeds. In general, the grab bag samples that were taken and weighed indicated that the actual limestone flow rate was within five percent of the indicated load cell flow rate. Tests were also conducted to characterize the limestone feeder at higher flow rates. A limestone flow rate of approximately 130 lb/min was measured at a feeder speed of fifty percent. This is very close to the required maximum feed rate. Therefore, a new drive gear on the feeder would allow the limestone feeder to operate continuously at lower flow rates, while maintaining its capability to satisfy its maximum required feed rate.

CONFIGURATIONS OF MIX ANNULUS AND MILL VENT PORTS (AUGUST 4 – 11)

The first test was initiated on August 4. The mix annulus annular gap region of both precombustors had been modified to incorporate fourteen short radius 90° elbows. For each test, various combinations of the elbows on each side of the mix annulus region had been blocked off to modify the secondary air mixing patterns. The objective of this test was to evaluate the effects of the mix annulus configuration (as previously described in Section 4.9) on precombustor slagging behavior.

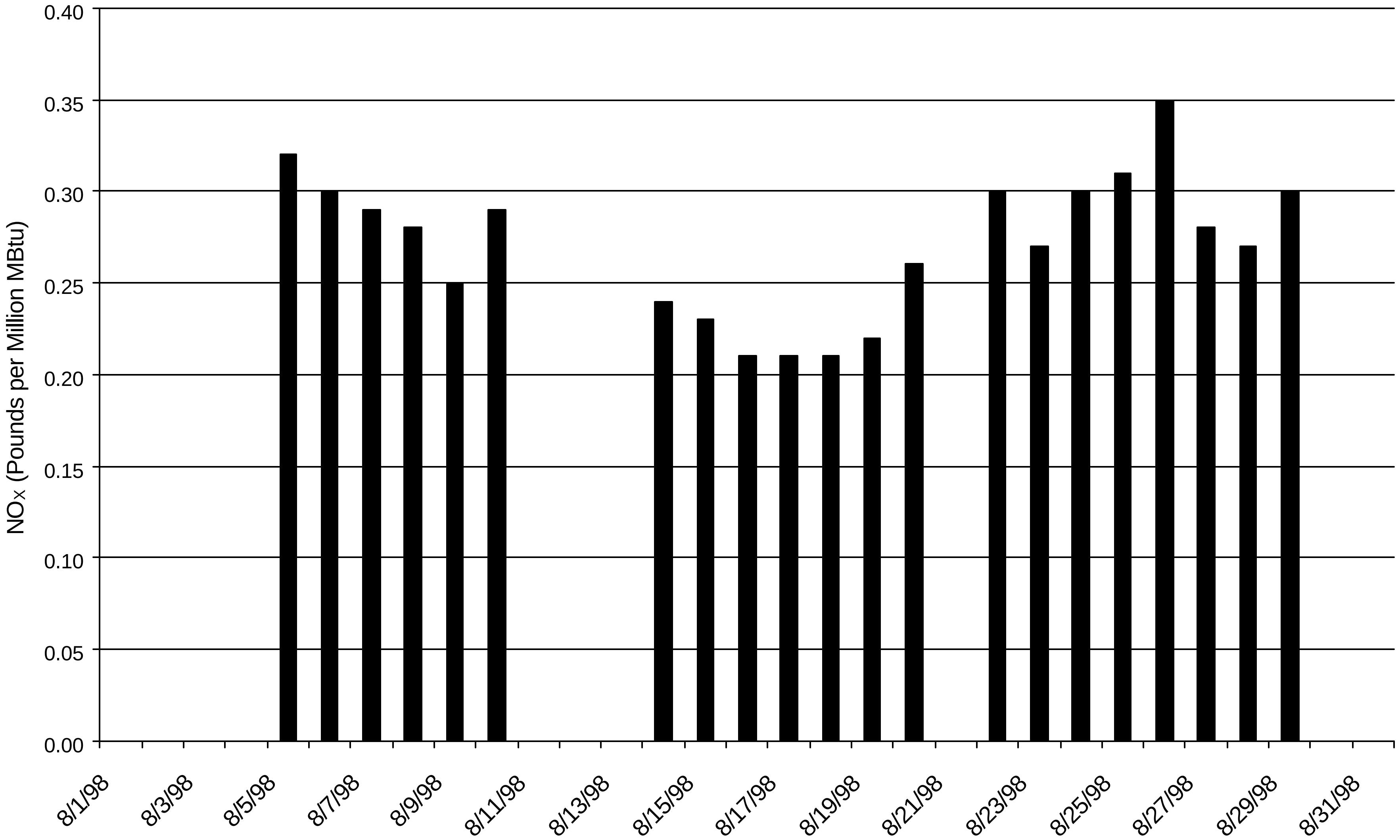
Mill vent air was eliminated from Precombustor A and remained intact for Precombustor B. During this initial test, there were two plant trips and one planned shutdown. The planned shutdown occurred during the first twenty-four hours of the test and was performed to evaluate the turbine during a hot restart. One plant trip occurred approximately twelve hours after restart of test operations and was attributed to operator error. Four days later, a black plant caused the second trip.

	Coal Burn Time (Hours)
8/1/98	0
8/2/98	0
8/3/98	0
8/4/98	11.5
8/5/98	22
8/6/98	24
8/7/98	24
8/8/98	24
8/9/98	18
8/10/98	24
8/11/98	8
8/12/98	0
8/13/98	18
8/14/98	24
8/15/98	24
8/16/98	24
8/17/98	24
8/18/98	24
8/19/98	22
8/20/98	24
8/21/98	24
8/22/98	24
8/23/98	24
8/24/98	24
8/25/98	24
8/26/98	24
8/27/98	24
8/28/98	24
8/29/98	24
8/30/98	0
8/31/98	0

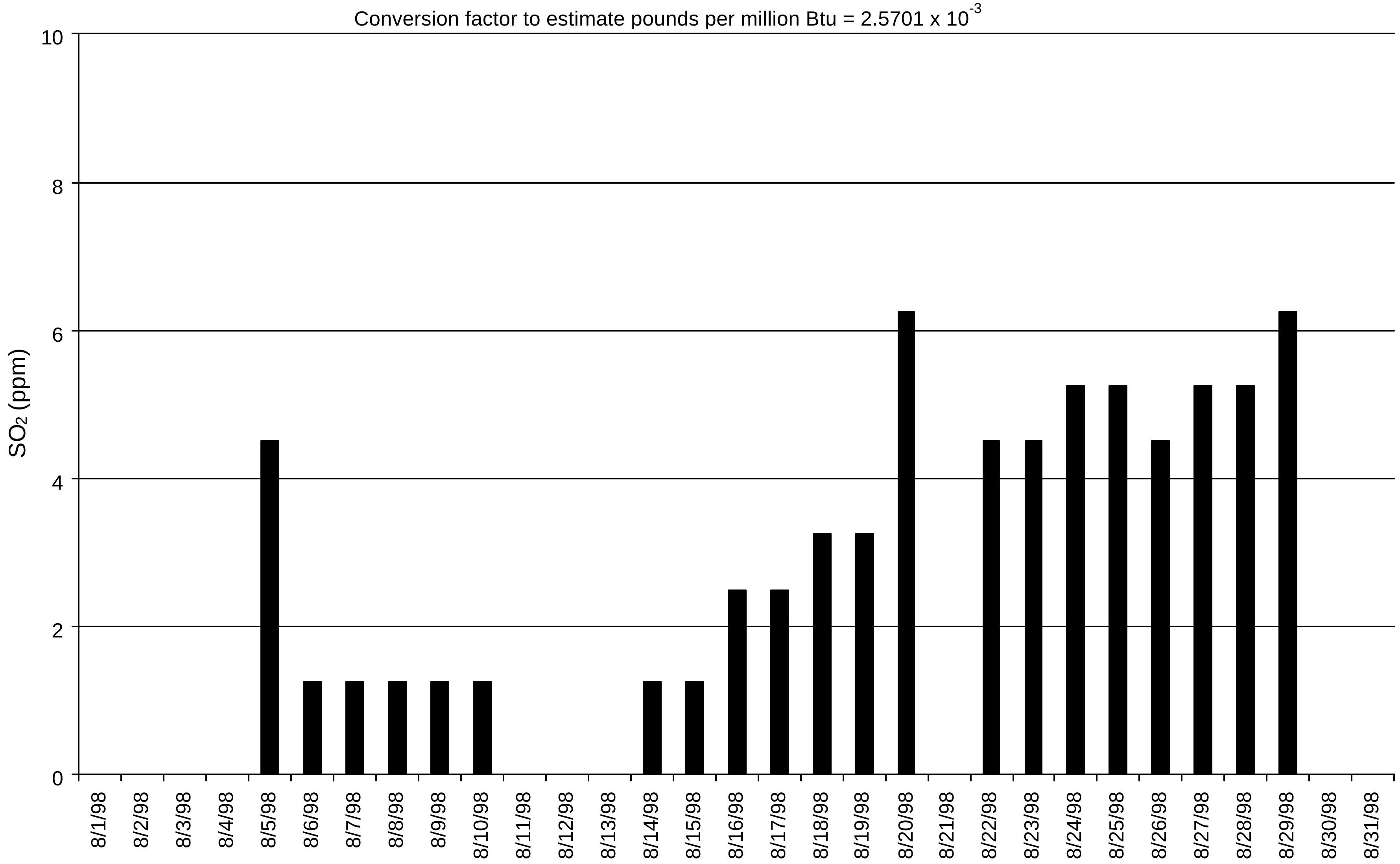


Coal Burn Time (Hours)
0
4
8
12
16
20
24
8/1/98
8/3/98
8/5/98
8/7/98
8/9/98
8/11/98
8/13/98
8/15/98
8/17/98
8/19/98
8/21/98
8/23/98
8/25/98
8/27/98
8/29/98
8/31/98

8/1/98	0
8/2/98	0
8/3/98	0
8/4/98	0
8/5/98	0.32
8/6/98	0.3
8/7/98	0.29
8/8/98	0.28
8/9/98	0.25
8/10/98	0.29
8/11/98	0
8/12/98	0
8/13/98	0
8/14/98	0.24
8/15/98	0.23
8/16/98	0.21
8/17/98	0.21
8/18/98	0.21
8/19/98	0.22
8/20/98	0.26
8/21/98	0
8/22/98	0.3
8/23/98	0.27
8/24/98	0.3
8/25/98	0.31
8/26/98	0.35
8/27/98	0.28
8/28/98	0.27
8/29/98	0.3
8/30/98	0
8/31/98	0


NOX (Pounds per Million MBtu)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
8/1/98
8/3/98
8/5/98
8/7/98
8/9/98
8/11/98
8/13/98
8/15/98
8/17/98
8/19/98
8/21/98
8/23/98
8/25/98
8/27/98
8/29/98
8/31/98

8/1/98	0
8/2/98	0
8/3/98	0
8/4/98	0
8/5/98	4.5
8/6/98	1.25
8/7/98	1.25
8/8/98	1.25
8/9/98	1.25
8/10/98	1.25
8/11/98	0
8/12/98	0
8/13/98	0
8/14/98	1.25
8/15/98	1.25
8/16/98	2.5
8/17/98	2.5
8/18/98	3.25
8/19/98	3.25
8/20/98	6.25
8/21/98	0
8/22/98	4.5
8/23/98	4.5
8/24/98	5.25
8/25/98	5.25
8/26/98	4.5
8/27/98	5.25
8/28/98	5.25
8/29/98	6.25
8/30/98	0
8/31/98	0


Conversion factor to estimate pounds per million Btu = 2.5701 x 10-3
SO2 (ppm)
0
2
4
6
8
10
8/1/98
8/2/98
8/3/98
8/4/98
8/5/98
8/6/98
8/7/98
8/8/98
8/9/98
8/10/98
8/11/98
8/12/98
8/13/98
8/14/98
8/15/98
8/16/98
8/17/98
8/18/98
8/19/98
8/20/98
8/21/98
8/22/98
8/23/98
8/24/98
8/25/98
8/26/98
8/27/98
8/28/98
8/29/98
8/30/98
8/31/98

Coal quality varied significantly over the duration of the test. There were periods when the inferred coal higher heating value was less than 6,500 Btu/lb and the last two days of the test were conducted with ROM coal with an inferred higher heating value greater than 7,300 Btu/lb. Online, a small increase in Precombustor A chamber pressure was observed. Poor quality, rough textured slag was observed through the rodding/view port just below the bottom mill vent port on the east side of Precombustor A, within the first forty-eight hours of firing coal. Chamber pressure on Precombustor B was very stable throughout the operation. The quality of slag on the drag chain was good to excellent throughout the run. The test was terminated on August 11, because of problems with the coal loading equipment. The total coal burn time for the test was approximately 150 hours, with 92 hours of continuous operation. Inspection of Precombustor A revealed that twelve inch fans were attached to both sides of the combustion chamber, leading to a small pressure drop. Most of the slag in the transition section and tangential inlet was black, glassy and thin. In general, Precombustor B had considerably less accumulation than Precombustor A. Only one small slag fan was observed on Precombustor B and both side walls were black and glassy. There was no slag buildup in the tangential inlet to Slagging Combustor B.

Because of a limited amount of waste coal available during the test and the frequent test trips, the results were not conclusive. However, comparison of the post-test slagging characteristics of the two precombustors indicated that the eight port Precombustor B mix annulus configuration with its mill vent air ports open caused less overall slag accumulation within the precombustor than in Precombustor A, with its twelve port mix annulus configuration without precombustor mill air. In addition, as noted above, the NO_X emissions for this test were typically 0.27 to 0.33 pounds per million Btu, which, while below the air quality permit level of 0.35 pounds per million Btu, was higher than the typical NO_X level of 0.20 to 0.25 pounds per million Btu. This slightly higher NO_X level was attributed to the elimination of the precombustor mill air on Precombustor A. Therefore, a decision was made to reconfigure Precombustor A to be identical to Precombustor B (i.e., eight port mix annulus configuration and precombustor mill air ports open).

MIXING ELBOW MIX ANNULUS CONFIGURATION, EIGHT PORTS (AUGUST 13 – 30)

The second test was initiated on August 13. Following an evaluation of the two configurations from the previous test, Precombustor A was reconfigured to match the Precombustor B, with four ports along each side wall (eight ports total). Because of flooding at the mine, representative waste coal was not available, so the entire test was conducted with 7,900 Btu/lb (average higher heating value) ROM coal. Precombustor B windbox pressure was very steady, indicating little, if any slag build up. Precombustor A windbox pressure alternately increased and decreased, suggesting the development of the slag fans at the end of the precombustor combustion chamber, which would cyclically form, break off, melt and reform.

Following six days of continuous operation, load was reduced to 55 MW gross to work on a boiler feedwater pump. The unit tripped offline approximately three hours later because of a problem with the lube oil pump filter on a pulverizer. The test was restarted several hours later and full load operation continued for the next ten days, until the test was terminated on August 29. It was discovered that the coal lines leading to the Precombustor A mill air ports had not been completely cleaned out following the August 11 shutdown. When the unit was restarted on August 13, it appeared that at least two or three of the precombustor mill air ports on the west side of Precombustor A were plugged with coal, as evidenced by coal line temperatures and the sound made by tapping on the pipe. The plugged coal line resulted from a failure to close the gate valve to the Precombustor A mill vent ports. This allowed coal to migrate past the flow damper and plug the coal pipes and the sixteen inch coal line leading to the precombustor.

Once the plugged line was discovered, the test was terminated to clean out the plugged coal line and to ensure that the configuration was correct to begin blended coal testing in September.

Preliminary indications (based on the observed slag sloughing behavior and corresponding decreases in precombustor chamber pressure) were that the slag fan, extending from the downstream end of the precombustor combustion chamber, was self limiting.

In summary, the following tests were conducted in August with results stated below:

- Modifications to the mix annulus elbow configurations of Combustors A and B had been performed in July so that Combustor A could be tested without cold coal cyclone vent air injection, while simultaneously testing Combustor B (which had cyclone vent air injection). Although frequent plant trips occurred because of other testing and non-technology related equipment and a supply of consistent quality blended coal was not achieved, Precombustor A was modified after the August 11 to August 14 test to match that of Precombustor B, based on less slag accumulation in Precombustor B.
- Flooding at the coal mine, during one of the Alaskan interior’s wettest years, prevented a delivery of waste coal and August test results were inconclusive.

4.11 SEPTEMBER COMBUSTOR OPERATION

During September, three tests were conducted, accumulating 334 hours of coal firing. The first test, accumulating 158 hours of coal burn time, was conducted primarily with ROM coal having an average higher heating value greater than 7,740 Btu/lb. The other two tests utilized a blended coal pile with average higher heating values of 7,283 ± 250 Btu/lb and 6,721± 120 Btu/lb. Figure 4.11.1 shows the coal burn time during September.

Figure 4.11.2 shows daily NO_X emission averages for September. NO_X emission was consistently below air quality permit requirements, averaging approximately 0.22 pounds per million Btu over the fourteen days of operation.

Figure 4.11.3 shows daily SO_2 emission averages for September. The average SO_2 emission for the month was 14.8 ppm at the stack. The Ca/S ratio for the ROM and waste coal burned during September typically ranged between 1.1 and 1.5. A new drive gear was installed on the limestone feeder to halve its flow rate at a given feeder motor speed to accommodate low limestone flow requirements. The feeder maintained its ability to provide 7,000 lb/hr limestone flow, as required by specification.

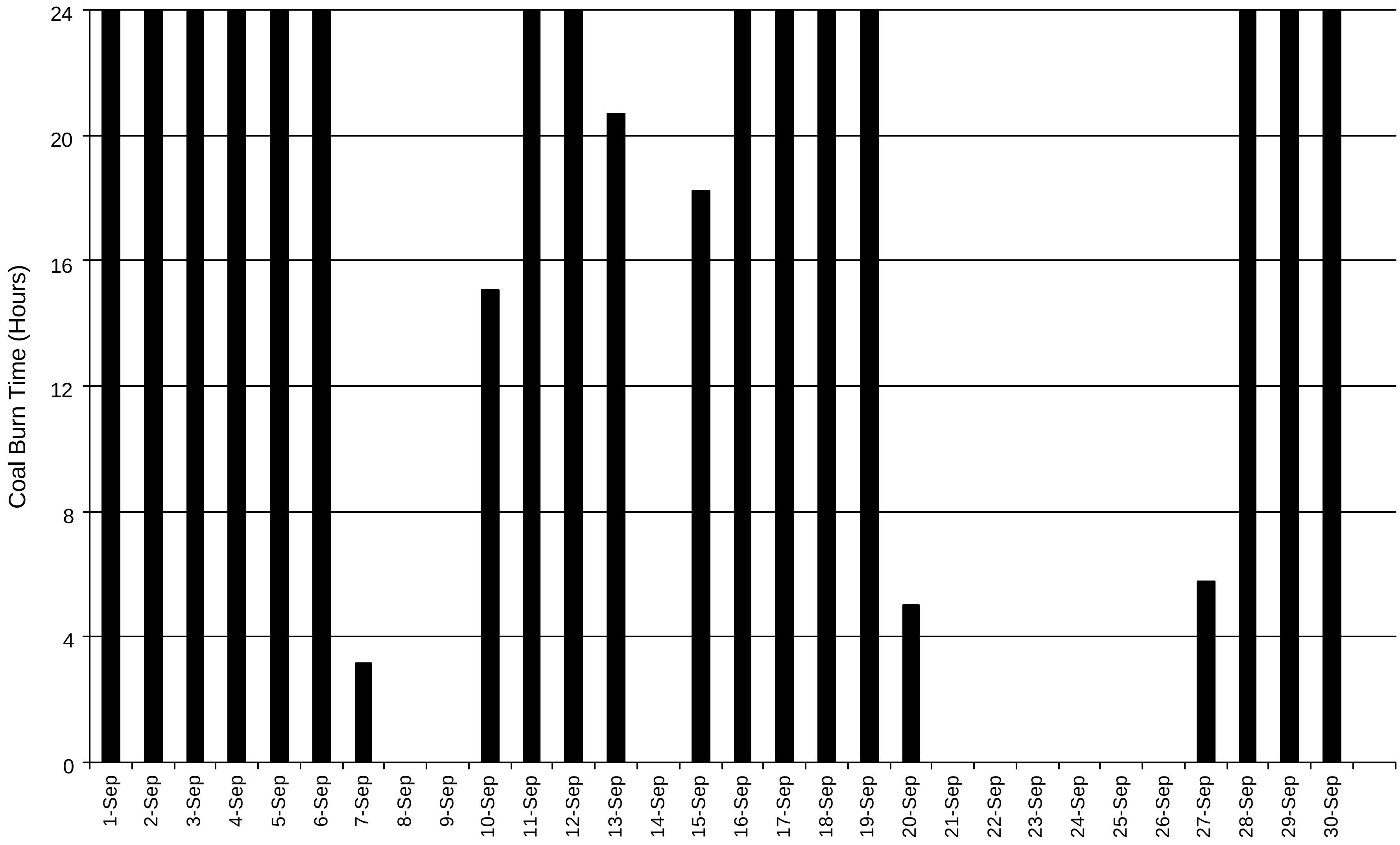
The first test was initiated on September 1. This was essentially a continuation of the previous test that had been terminated when it was discovered that there was coal plugged in three of the precombustor mill air ports, a result of an earlier configuration wherein the mill air ports had been deliberately blocked off. The mix annulus annular gap regions of both precombustors were identical with eight short radius 90° elbows in each precombustor.

This initial test lasted approximately six and a half days. ROM coal was fired during the first three days, because waste coal was not available. Thereafter, the coal supply was from a blended coal pile comprised of Seam 4 waste coal, Seam 3 ROM coal and ROM coal fines from Seam 3 and Seam 6. ROM coal fines contain a greater percentage of sandstone than larger sized ROM coal; therefore, fines have a lesser heating value that the ROM coal they were screened from. The inferred higher heating value was typically 8,000 Btu/lb for the ROM coal and 7,000 to 7,700 Btu/lb for the blended coal pile. NO_X and SO_2 emissions throughout the test duration were typically 0.20 pounds per million Btu of NO_X and 5 ppm (less than 0.10 pounds per million Btu) of SO_2. The test was terminated following six and a half days of operation because of increasing precombustor chamber pressures. Post-test inspection revealed that several of the plugged elbows at the top of the mix annulus had significant air leaks, which affected the air distribution in the mix annulus region. These plugged elbows were removed and replaced with refractory coated isolation plates. Precombustor mix annulus regions were reconfigured to improve the spatial distribution of the air jets around the circumference of the precombustor combustion chamber in both precombustors.

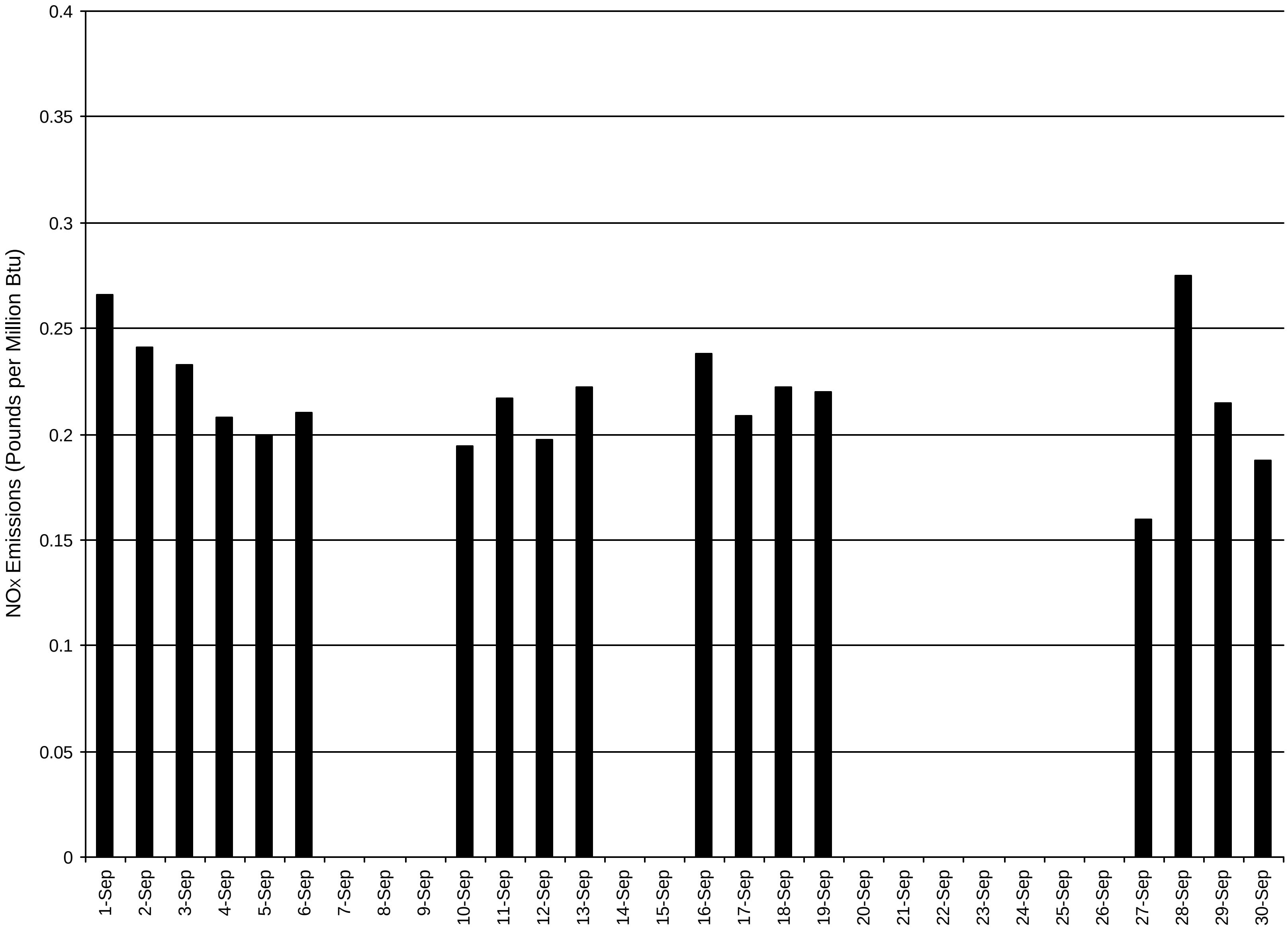
MIXING ELBOW MIX ANNULUS CONFIGURATION (SEPTEMBER 10 – 13, SEPTEMBER 15 – 19)

The mix annulus region reconfigurations of Precombustors A and B were to provide improved spatial distribution of the air jets, because the slag could flow out of the combustion chamber between each air jet rather than the jets essentially forming a continuous curtain of air. The air jets could entrain hot combustion gases from the combustion chamber, which improves the mixing and raises the average temperature of each air jet. The mix annulus for Precombustor B had six open mix annulus elbows, three on each side, alternating open and closed elbows around the circumference. The mix annulus for Precombustor A was similar; however, there was only five open elbows with three open ports on the east (head end) side and two open ports

Date	Coal Burn Time (Hours)
9/1/00	24
9/2/00	24
9/3/00	24
9/4/00	24
9/5/00	24
9/6/00	24
9/7/00	3.166667
9/8/00	0
9/9/00	0
9/10/00	15.05
9/11/00	24
9/12/00	24
9/13/00	20.7
9/14/00	0
9/15/00	18.25
9/16/00	24
9/17/00	24
9/18/00	24
9/19/00	24
9/20/00	5
9/21/00	0
9/22/00	0
9/23/00	0
9/24/00	0
9/25/00	0
9/26/00	0
9/27/00	5.766667
9/28/00	24
9/29/00	24
9/30/00	24


Coal Burn Time (Hours)
0
4
8
12
16
20
24
1-Sep
2-Sep
3-Sep
4-Sep
5-Sep
6-Sep
7-Sep
8-Sep
9-Sep
10-Sep
11-Sep
12-Sep
13-Sep
14-Sep
15-Sep
16-Sep
17-Sep
18-Sep
19-Sep
20-Sep
21-Sep
22-Sep
23-Sep
24-Sep
25-Sep
26-Sep
27-Sep
28-Sep
29-Sep
30-Sep

	Nox	S02f	SO2s
1-Sep	0.266	106	15
2-Sep	0.241	121	10
3-Sep	0.233	130	14
4-Sep	0.208	104	5
5-Sep	0.2	108	6
6-Sep	0.21	111	11
7-Sep			
8-Sep			
9-Sep			
10-Sep	0.194	120	10
11-Sep	0.217	110	10
12-Sep	0.197	141	16
13-Sep	0.222	134	22
14-Sep			
15-Sep			
16-Sep	0.238	146	20
17-Sep	0.209	142	25
18-Sep	0.222	138	23
19-Sep	0.22	124	21
20-Sep			
21-Sep			
22-Sep			
23-Sep			
24-Sep			
25-Sep			
26-Sep			
27-Sep	0.16		54.80069
28-Sep	0.275		24.80694
29-Sep	0.21477		21.65625
30-Sep	0.18776		26.866
Average	0.219786	123.9286	14.85714



NOx Emissions (Pounds per Million Btu)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1-Sep
2-Sep
3-Sep
4-Sep
5-Sep
6-Sep
7-Sep
8-Sep
9-Sep
10-Sep
11-Sep
12-Sep
13-Sep
14-Sep
15-Sep
16-Sep
17-Sep
18-Sep
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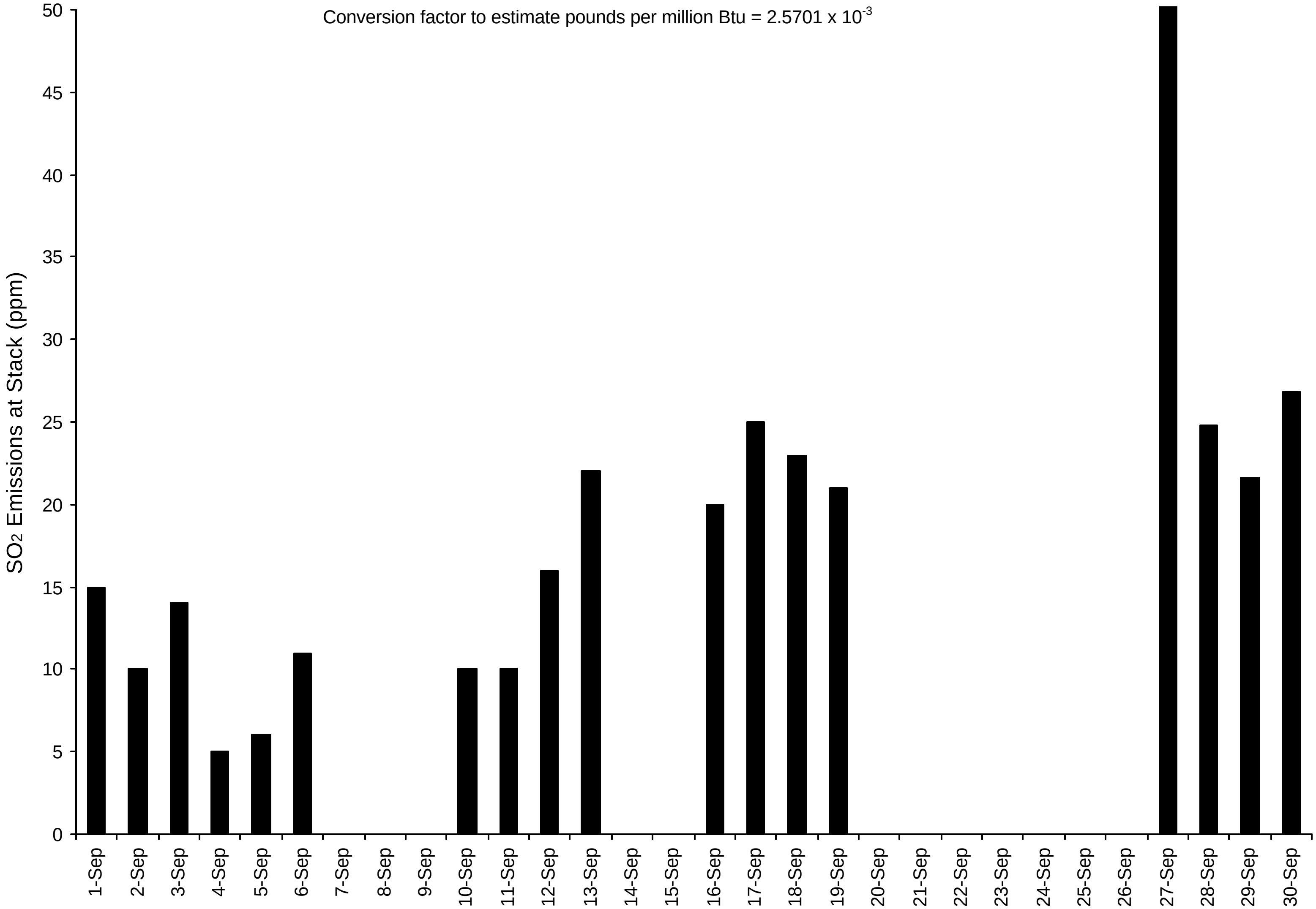
27-Sep
28-Sep
29-Sep
30-Sep


Conversion factor to estimate pounds per million Btu = 2.5701 x 10-3
SO2 Emissions at Stack (ppm)
0
5
10
15
20
25
30
35
40
45
50
1-Sep
2-Sep
3-Sep
4-Sep
5-Sep
6-Sep
7-Sep
8-Sep
9-Sep
10-Sep
11-Sep
12-Sep
13-Sep
14-Sep
15-Sep
16-Sep
17-Sep
18-Sep
19-Sep
20-Sep
21-Sep
22-Sep
23-Sep
24-Sep
25-Sep
26-Sep
27-Sep
28-Sep
29-Sep
30-Sep

on the west (furnace) side. The two open port furnace side configuration provided additional spacing between the open jets. These configurations are shown in Figures 4.11.4 and 4.11.5. The final two tests in September were performed with this configuration.

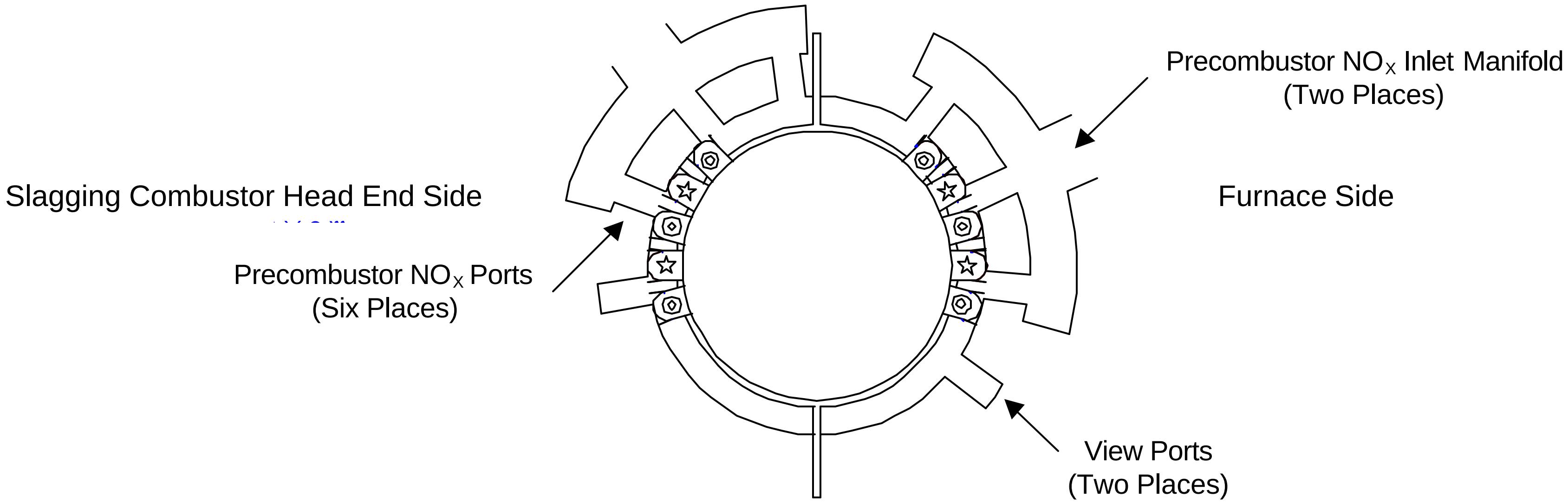
The first of these two tests was initiated on September 10. The entire test was conducted with the blended coal pile described above. Inferred higher heating value varied from 6,600 to 7,500 Btu/lb. The test was terminated following three days of full load operation, because of slag ash drag chain problems. Post-test inspection revealed only a minor slag fan on the furnace side of the Precombustor B combustion chamber and no slag accumulation anywhere within the precombustor. Precombustor A had a relatively minor accumulation of slag downstream of the mix annulus elbows that extended to the swirl dampers.

The second test of this configuration was initiated on September 15. There was no change to either precombustor for this test, since the previous test was not completed. Following forty hours of coal burn, unit load was reduced from 62 MW gross to 55 MW gross, because of continuing lack of adequate slag ash drag chain capacity. Load was reset to 62 MW gross after twelve hours at reduced load conditions. Slag quality and quantity were excellent during the entire test. NO_X emission was typically 0.20 pounds per million Btu and typical SO_2 concentration was less than 12 ppm. Post-test inspection revealed very minor slag accumulation in Precombustor A. Online pressure trends had indicated increasing precombustor pressure over the last two days of the test. However, this appeared to be caused by a relatively thick slag layer in the base of the tangential inlet rather than any other slag accumulation. Precombustor B had slag fans on both sides of the mix annulus. There was also a relatively minor accumulation of slag on the east (head end) side of the precombustor transition section downstream of the mix annulus elbows. Following four and a half days of operation, it was determined that there was a boiler water wall leak and the test was terminated. Post-test inspection revealed that there were two boiler water leaks; a leak in the flange on the attemperator spray nozzle and a leak in a boiler tube inside the overfire air seal box.

No testing was conducted between September 20 and September 26, while the tube section from the boiler waterwall was being replaced. Test operations resumed on September 27 and continued into October. These test operations are described in the next section.

In summary, three tests were conducted in September. The first test was primarily a continuation of the effort that began in August with all coal cyclone vent air ports open in both precombustors. The test was terminated because of increasing precombustor chamber pressure. So the precombustor mix annulus elbows in each precombustor were reconfigured to two configurations, each slightly different from the other. The second and third tests were terminated because of slag drag chain problems and a boiler tuber leak, respectively. Slag accumulation in both combustors was only minor; however, testing of the two similar combustor configurations continued into October, because more continuous operating time was required for evaluation.

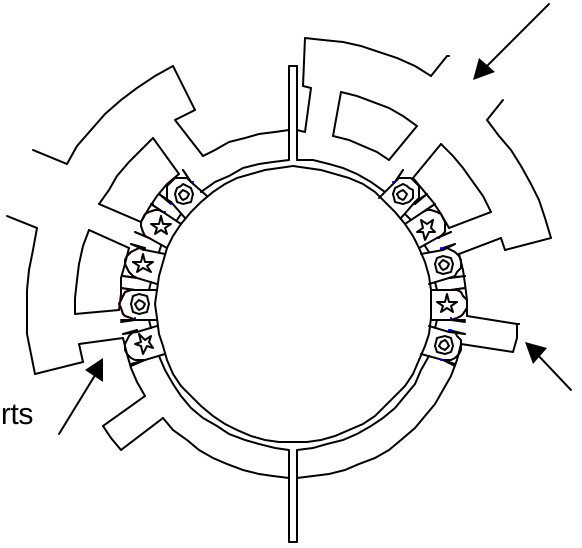
Figure 4.11.4 – Illustration of Precombustor B Six Port Mix Annulus Configuration



Note: ☆ refers to a closed mix air injection port

⬡ refers to an open mix air injection port

Figure 4.11.5 – Illustration of Precombustor A Five Port Mix Annulus Configuration



Note: ☆ refers to a closed mix air injection port

⊙ refers to an open mix air injection port

4.12 OCTOBER COMBUSTOR OPERATION

During October, one test was conducted accumulating 581 hours of coal firing with blended coal with a higher heating value between 6,600 and 7,500 Btu/lb on a twenty-four hour average over the twenty-four day period. Only one combustor was operated for most of October. The reason for only one combustor operation was because the 'B' exhauster fan rotor had suffered extensive erosion to its blades. Figures 4.12.1, 4.12.2 and 4.12.3 show coal burn time and NO_X and SO_2 emissions, respectively.

Significant progress was made to mitigate excessive slag accumulation within the precombustor which typically had occurred when burning blended coal with a higher heating value less than 7,400 Btu/lb. As noted in the previous months, the extent of slag accumulation within the precombustor had varied from test to test, as well as from one combustor to the other. Based on the post-test observations of the slag formation, as well as the variation in slag accumulation between the combustors, the cause of the excess slag accumulation appeared to be twofold, freezing of the slag exiting the precombustor combustion chamber at the mixing location of the mix annulus secondary air (770° F) and wide variations in the actual precombustor stoichiometry conditions caused by wide variations in the blended coal higher heating value (± 1,000 Btu/lb) between combustors. These variations in higher heating values were attributed to non-uniform blending and different higher heating value coal being fired in the two combustors. The combustor operated continuously with no significant slag accumulation, while burning blended coal with an average blended coal higher heating value of 7,000 ± 200 Btu/lb, and recovered from the slag accumulation (i.e., re-melted the slag) that occurred, while burning very low Btu coal (less than 6,500 Btu/lb). The re-melting of the slag accumulation occurred following approximately twelve hours of operation with blended coal with an average coal higher heating value greater than 6,800 Btu/lb. However, even with a blended coal pile, there were still significant variations in higher heating value, often as much as ± 1,000 Btu/lb, over a twenty-four hour period. Variations, which are believed to have significantly affected combustor performance, occurred when the coal higher heating value was continuously less than 6,500 Btu/lb for twenty-four hours or more and when there was a significant variation of the two heating values of the coal concurrently being fired in each of the two combustors, thereby affecting the stoichiometries of each combustor.

The low grade (less than 6,500 Btu/lb) coal apparently had ash with higher than acceptable fusion temperature and/or T_{250} for the combustor configurations at that time. Because of poor blending techniques, it is not known whether coal with such a low higher heating value was actually blended coal or all waste coal. Variation in the higher heating value between the combustors caused the precombustor stoichiometries in the two combustors to result in more than a 200° F difference between the actual precombustor exit temperature and the desired temperature. Therefore, a decision was made to perform and evaluate hardware changes to provide a broader operating envelope, with respect to firing coal with low and variable heat content.

MIXING ELBOW MIX ANNULUS CONFIGURATION (SEPTEMBER 27 – OCTOBER 21)

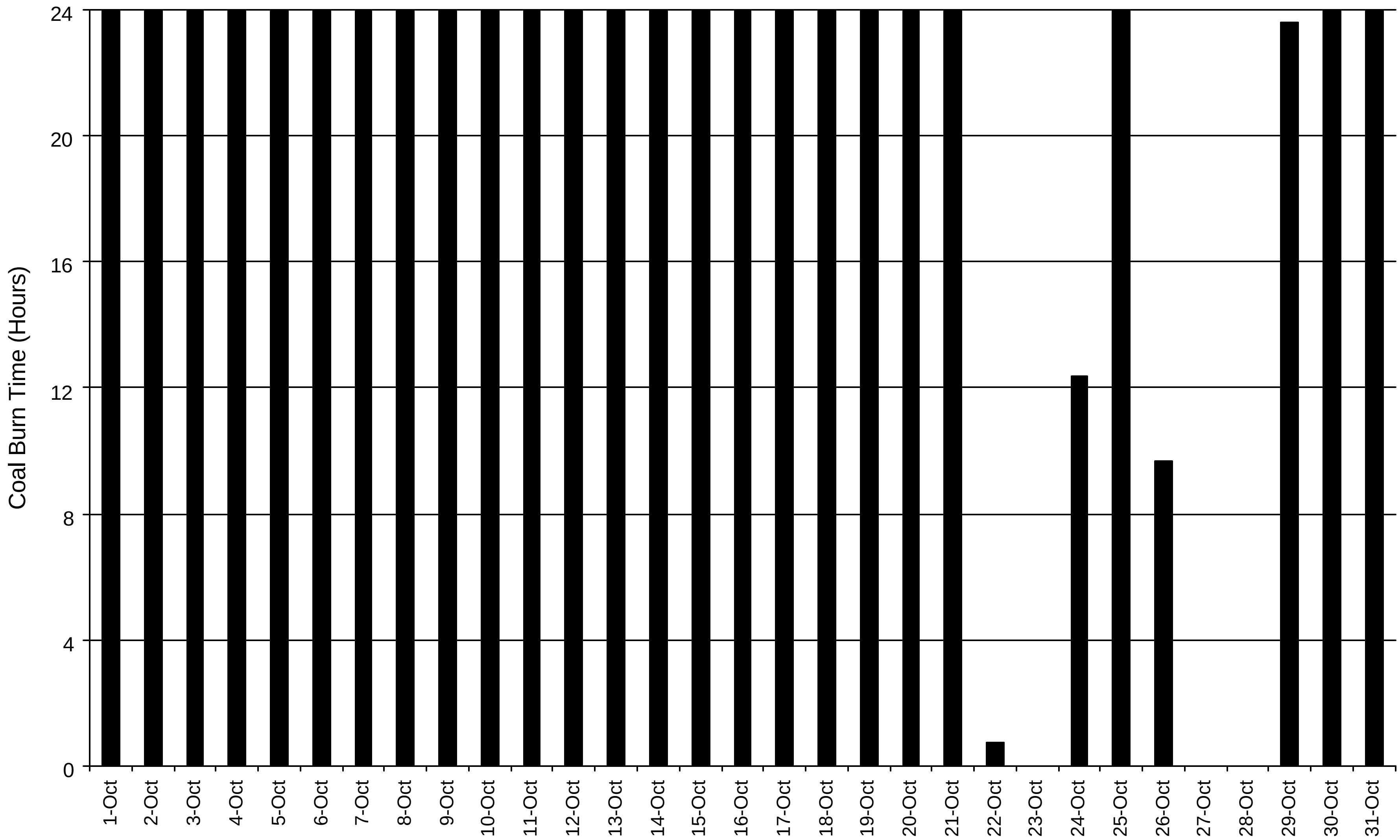
The improved spatial distribution of the precombustor mix annulus air jets that had been evaluated during September looked very promising for reducing the precombustor slag accumulation. However, the bottom air jet on the east (head end) side appeared to cool the collapsed slag fans that sloughed off the end of the combustion chamber. This cooling prevented the slag fan from being re-entrained into the slag river and flowing out of the precombustor. Therefore, the mix annulus regions of the precombustors were reconfigured to

Oct-98 SO2 ppm

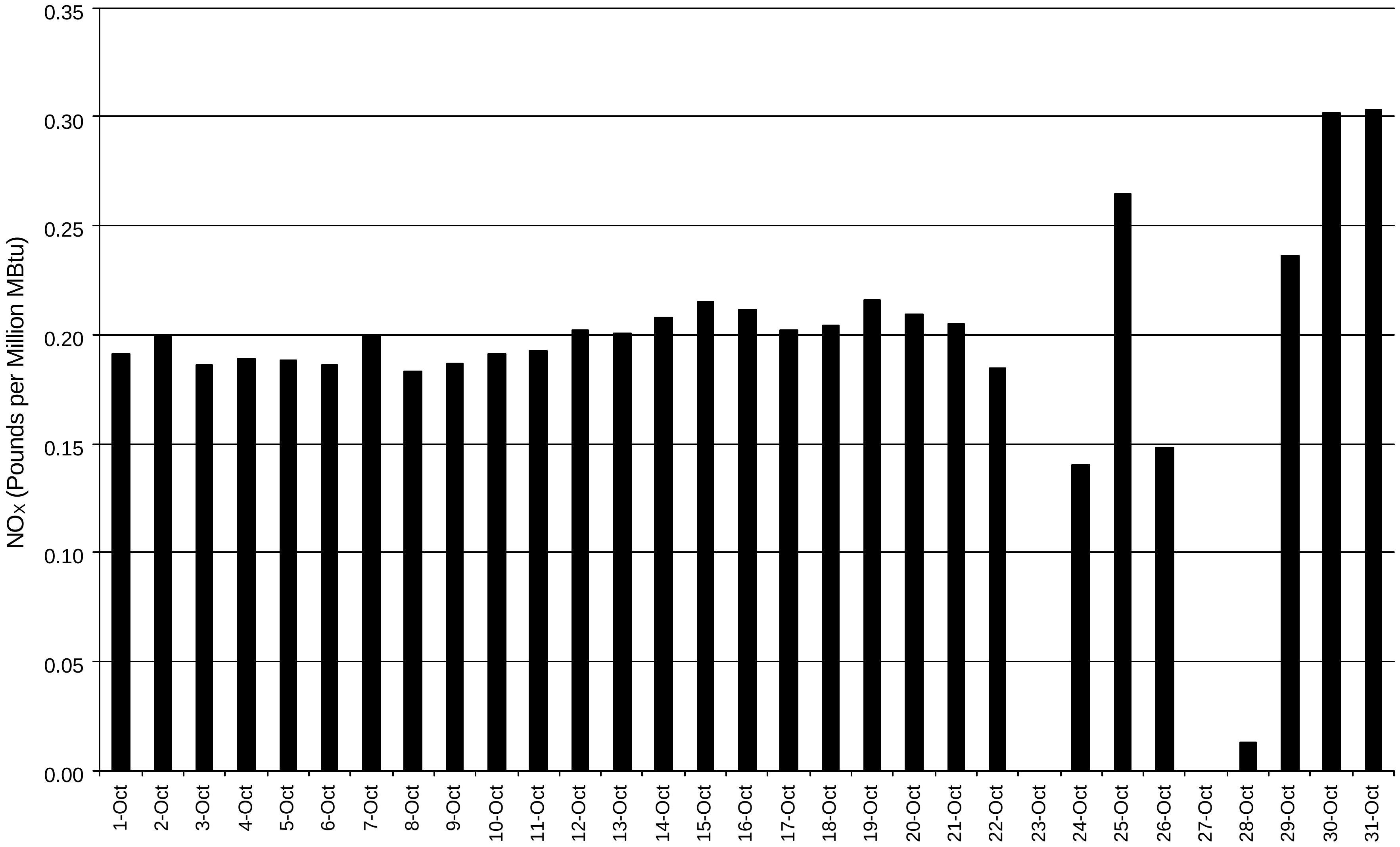
Date	Average	Calculated	lb/MBTu Average
1-Oct	21.915501	24.7078456	0.064176
2-Oct	14.146316	14.0061708	0.03638
3-Oct	5.3795852	5.37958524	0.013973
4-Oct	15.015844	9.64316354	0.025047
5-Oct	7.5123821	7.51238205	0.019513
6-Oct	6.1228312	6.12283116	0.015903
7-Oct	12.846256	13.0280246	0.033839
8-Oct	9.9339454	10.6371315	0.027629
9-Oct	11.775291	11.7752914	0.030585
10-Oct	6.0775501	6.07755014	0.015786
11-Oct	7.6061397	7.60613968	0.019756
12-Oct	8.6219799	8.62197985	0.022395
13-Oct	8.4898153	8.85841733	0.023009
14-Oct	8.683284	8.68328401	0.022554
15-Oct	9.8976633	10.5983342	0.027528
16-Oct	13.640922	13.2498468	0.034415
17-Oct	11.551132	11.9834268	0.031126
18-Oct	10.523699	10.5236987	0.027334
19-Oct	12.706265	12.7062648	0.033003
20-Oct	13.29737	14.1992245	0.036881
21-Oct	13.574486	14.1888404	0.036854
22-Oct	53.768106	53.7681062	0.139657
23-Oct	0.0099763	0.00997626	2.59E-05
24-Oct	38.039389	38.039389	0.098804
25-Oct	45.435062	45.4350617	0.118013
26-Oct	67.509782	67.5097816	0.17535
27-Oct	0.0100105	0.01001051	2.6E-05
28-Oct	9.7560671	9.75606714	0.02534
29-Oct	33.796763	22.5960531	0.058691
30-Oct	21.809556	20.1223668	0.052266
31-Oct	25.263134	22.5597555	0.058597

Date	Oct-98	NOx Average
	10/1/98	0.191
	10/2/98	0.1994
	10/3/98	0.1861
	10/4/98	0.189
	10/5/98	0.1885
	10/6/98	0.1864
	10/7/98	0.1993
	10/8/98	0.1828
	10/9/98	0.1868
	10/10/98	0.1909
	10/11/98	0.1927
	10/12/98	0.2018
	10/13/98	0.2008
	10/14/98	0.2077
	10/15/98	0.2148
	10/16/98	0.2114
	10/17/98	0.202
	10/18/98	0.2046
	10/19/98	0.216
	10/20/98	0.2098
	10/21/98	0.2049
	10/22/98	0.1844
	10/23/98	5E-05
	10/24/98	0.1405
	10/25/98	0.265
	10/26/98	0.1485
	10/27/98	5E-05
	10/28/98	0.0129
	10/29/98	0.2365
	10/30/98	0.3015
	10/31/98	0.3031

Date	Coal Burn Time (Hours)
10/1/00	24
10/2/00	24
10/3/00	24
10/4/00	24
10/5/00	24
10/6/00	24
10/7/00	24
10/8/00	24
10/9/00	24
10/10/00	24
10/11/00	24
10/12/00	24
10/13/00	24
10/14/00	24
10/15/00	24
10/16/00	24
10/17/00	24
10/18/00	24
10/19/00	24
10/20/00	24
10/21/00	24
10/22/00	0.733333
10/23/00	0
10/24/00	12.36667
10/25/00	24
10/26/00	9.65
10/27/00	0
10/28/00	0
10/29/00	23.61667
10/30/00	24
10/31/00	24


Coal Burn Time (Hours)
0
4
8
12
16
20
24
1-Oct
2-Oct
3-Oct
4-Oct
5-Oct
6-Oct
7-Oct
8-Oct
9-Oct
10-Oct
11-Oct
12-Oct
13-Oct
14-Oct
15-Oct
16-Oct
17-Oct
18-Oct
19-Oct
20-Oct
21-Oct
22-Oct
23-Oct
24-Oct
25-Oct
26-Oct
27-Oct
28-Oct
29-Oct
30-Oct
31-Oct

10/1/98	0.191047
10/2/98	0.19941
10/3/98	0.186073
10/4/98	0.188982
10/5/98	0.188486
10/6/98	0.186365
10/7/98	0.199273
10/8/98	0.182806
10/9/98	0.186798
10/10/98	0.190911
10/11/98	0.192725
10/12/98	0.20184
10/13/98	0.200773
10/14/98	0.207721
10/15/98	0.214844
10/16/98	0.211435
10/17/98	0.202038
10/18/98	0.204643
10/19/98	0.21599
10/20/98	0.209796
10/21/98	0.204933
10/22/98	0.18443
10/23/98	4.79E-05
10/24/98	0.140486
10/25/98	0.265004
10/26/98	0.148546
10/27/98	4.7E-05
10/28/98	0.01288
10/29/98	0.236462
10/30/98	0.301539
10/31/98	0.303112



NOx (Pounds per Million MBtu)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1-Oct
2-Oct
3-Oct
4-Oct
5-Oct
6-Oct
7-Oct
8-Oct
9-Oct
10-Oct
11-Oct
12-Oct
13-Oct
14-Oct
15-Oct
16-Oct
17-Oct
18-Oct
19-Oct
20-Oct
21-Oct
22-Oct
23-Oct
24-Oct
25-Oct
26-Oct
27-Oct
28-Oct
29-Oct
30-Oct
31-Oct

eliminate the bottom air jet on the east side of the mix annulus. Combustor B was configured with five mix annulus elbows, with two ports on the east (head end) side and three ports on the west (furnace) side (Figure 4.12.4). Combustor A was configured with four mix annulus elbows, with two ports on both the east and west sides (Figure 4.12.5). The two port furnace side configuration provided additional spacing between the open jets.

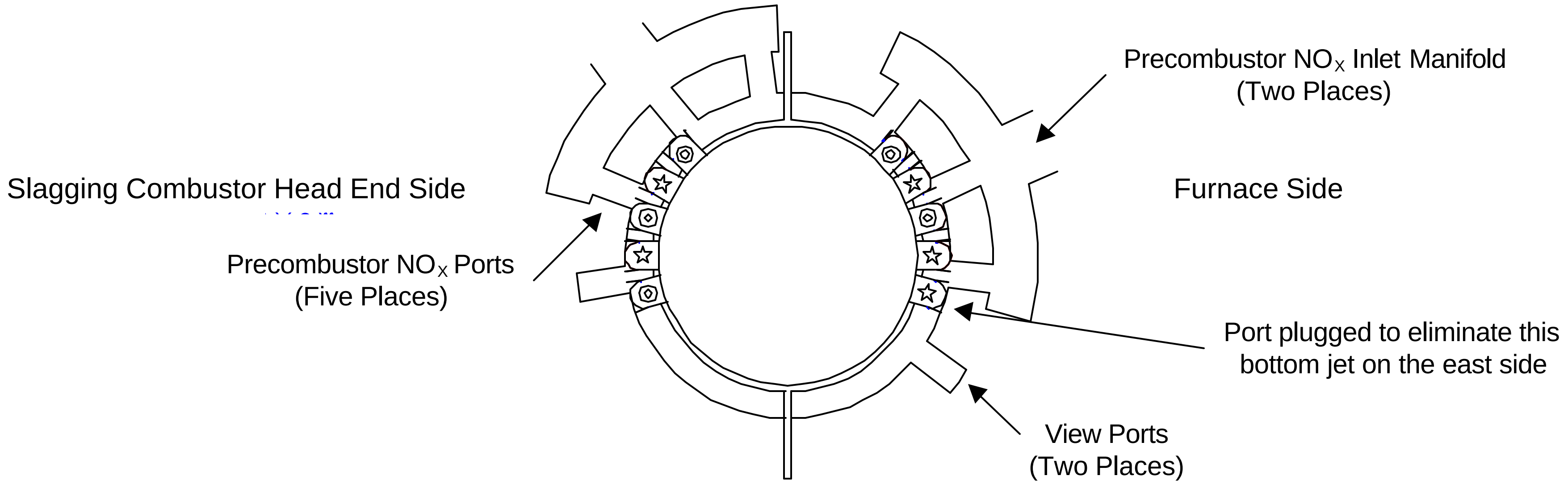
Only the Combustor B five port configuration was evaluated during this period. Combustor A was shut down in less than forty-eight hours because of a high vibration caused by severe non-uniform fan blade erosion on its mill exhauster fan. The installation of temporary secondary air piping from the Combustor A mix annulus supply to the head end of Slagging Combustor A commenced, while Combustor B continued to operate. This twenty-four day Combustor B configuration test, which more than tripled all previous continuous tests with blended coal, was terminated for a planned shutdown to inspect and repair Mill Exhauster B.

Precombustor chamber pressure was stable and there was no online indication of slag accumulation within the precombustor until twelve days into the test. Precombustor chamber pressure increased after a thirty-eight hour period, when blended coal higher heating value decreased from 6,600 to 5,800 Btu/lb. At the end of this thirty-eight hours, the precombustor windbox pressures indicated some slag accumulation within the precombustor tangential exit and a slag fan on the exit of the precombustor combustion chamber. However, following twelve subsequent hours, wherein the blended coal higher heating value returned to 6,950 Btu/lb, the slag formation within the tangential exit had melted (as indicated by the precombustor windbox pressures), the slag fan on the exit of the combustion chamber diminished and the flame scanner located on the precombustor NO_X air ports indicated an increase in flame intensity. Following this reduction in slag accumulation, the precombustor windbox pressures remained relatively constant for the remaining eight days of the test. When corrected for flow rate changes, the overall net increase in the precombustor chamber pressure was six inches water gauge, for the whole test.

Post-test inspection revealed a relatively thick slag river extending from the combustion chamber through the tangential exit. The slag river was concentrated along the centerline of the precombustor and was approximately one and a half feet high and two and a half feet wide. The head end side of the precombustor had no slag accumulation. The furnace side of the precombustor appeared to have a minor slag fan and some relatively minor slag accumulation both upstream and downstream of the swirl dampers. Temporary secondary air piping from the Precombustor B mix annulus supply line to the head end of its slagging combustor was installed and all mix annulus elbows were blocked off.

In summary, the testing performed in October was achievable (with minimum possible secondary air injection and with the best possible injection velocity and mixing) with the design mix annulus configuration. The steps taken to reduce secondary mix annulus air flow had incrementally improved precombustor slagging characteristics. Therefore, a decision to eliminate secondary air from the mix annuluses of Combustor B was made. The unused spare (outer diameter) coal injection ports at the head end of the slagging combustors would be used as an alternate flow path available to maintain overall slagging combustor stoichiometry. The new configuration is shown in Figure 4.12.6.

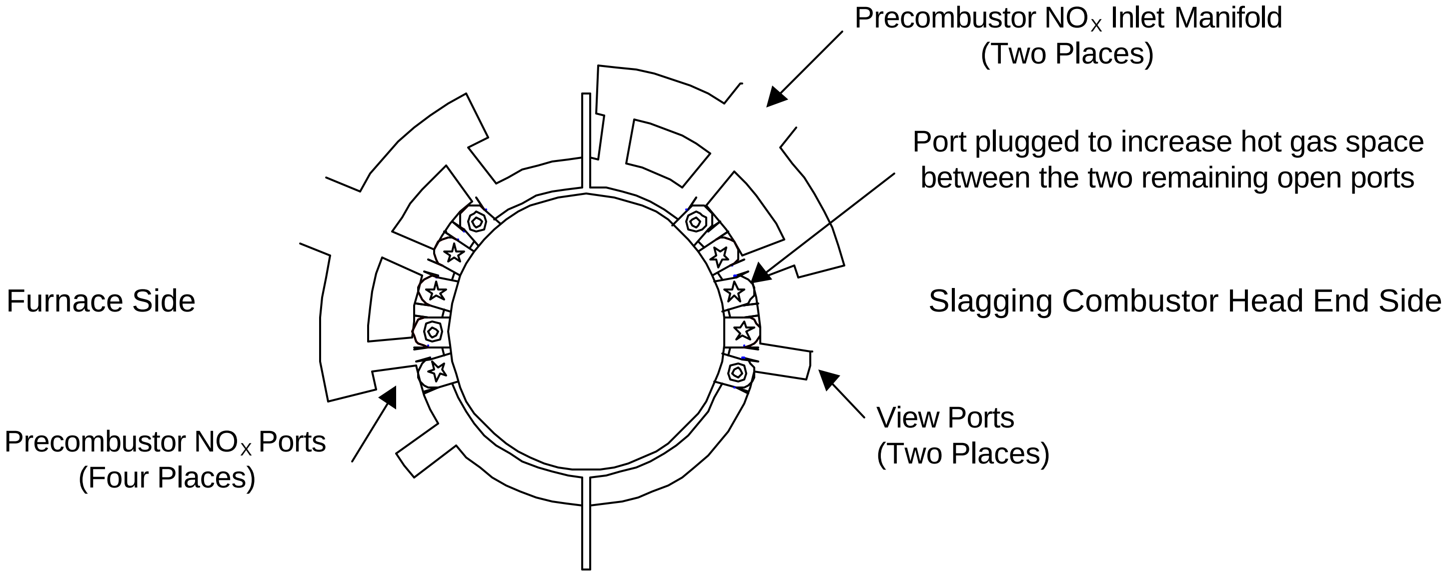
Figure 4.12.4 – Illustration of Precombustor B Five Port Mix Annulus Configuration



Note: ☆ refers to a closed mix air injection port

⬡ refers to an open mix air injection port

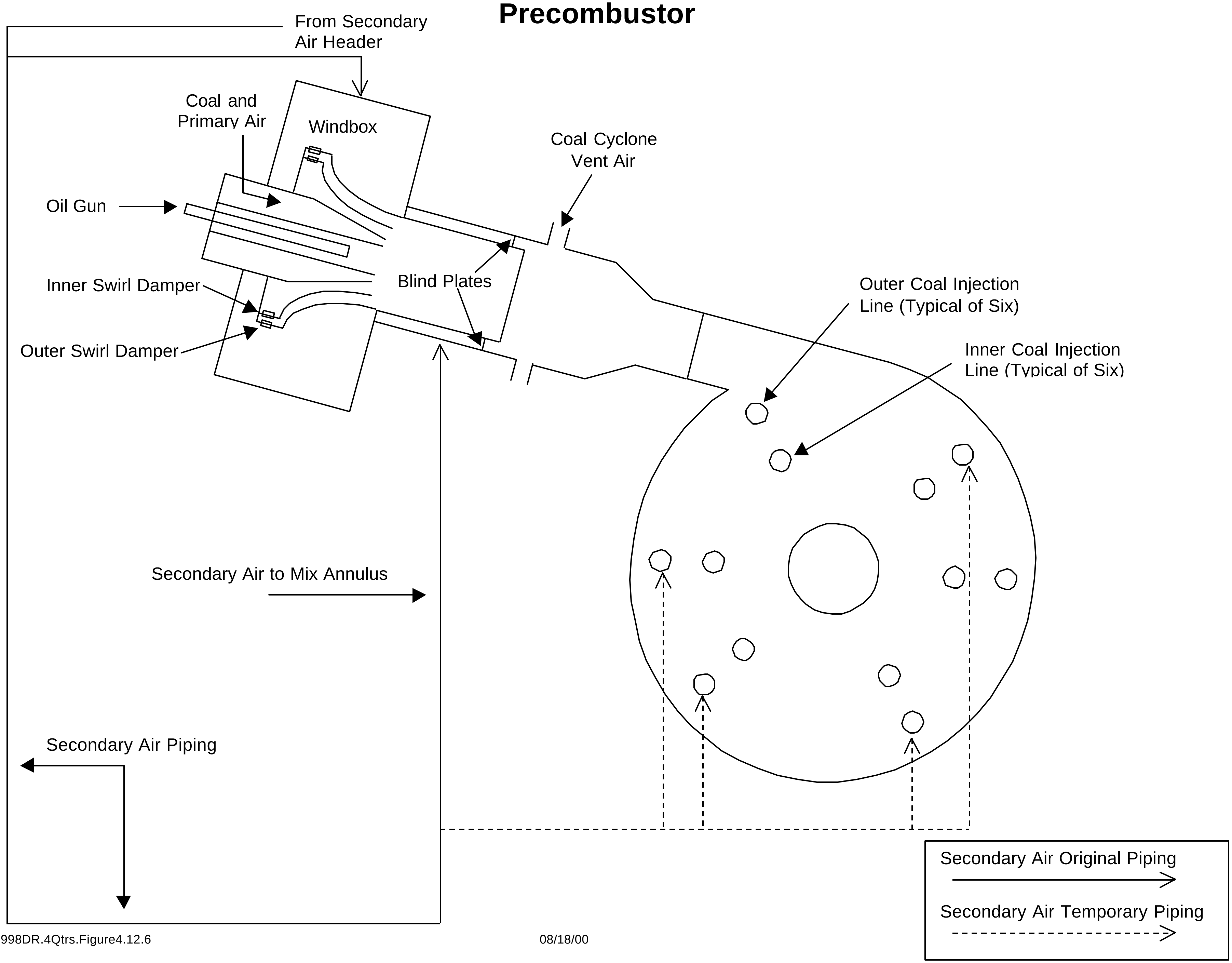
Figure 4.12.5 – Illustration of Precombustor A Four Port Mix Annulus Configuration



Note: ☆ refers to a closed mix air injection port

⊚ refers to an open mix air injection port

Figure 4.12.6 – Temporary Piping and Blind Plates to Remove All Mix Annulus Air from the Precombustor



4.13 NOVEMBER COMBUSTOR OPERATION

During November, two tests were conducted accumulating 685 hours of coal firing. During both tests, there were numerous test stops on Combustor A caused by various facility problems. The longest continuous test duration during November was 389 hours. Both tests were conducted using a blended coal pile with an average inferred coal higher heating value of 6,942 ± 650 Btu/lb, based on a twenty-four hour average. Figures 4.13.1, 4.13.2 and 4.13.3 show coal burn time and NO_X and SO_2 emissions, respectively.

From July through October, all of the precombustor configuration changes had been relatively minor. The mix annulus secondary air was injected through 90° elbows in various arrangements immediately downstream of the precombustor combustion chamber to direct the mix annulus secondary air into the core flow of the precombustor combustion products to promote active mixing of the two streams. During November, a relatively major change to the precombustor configuration was tested. The mix annulus secondary air injection within the precombustor was blocked off and all of the mix annulus secondary air was redirected to the unused alternate coal injection ports that had been provided on the slagging combustor.

ELIMINATION OF MIX ANNULUS SECONDARY AIR (OCT 29 – NOV 15, NOV 19 – DEC 3)

This series of tests focused on eliminating secondary mix annulus air and reducing the coal cyclone vent air (also referred to as precombustor NO_X air) injected into the precombustor. Mixing of secondary air with the combustion products from the precombustor combustion chamber was eliminated to prevent the slag from freezing at the mixing interface. It also decreased the precombustor exit stoichiometry, thereby increasing precombustor exit temperature by approximately 200° F.

The precombustor mix annulus opening was completely blocked off with refractory and the mix annulus secondary air was ducted to the unused outer radius ports on the slagging combustor head end. For both tests conducted during November, four six inch ports on the head end, as well as the annular region surrounding the slagging combustor oil ignitor, were used for injecting the secondary air.

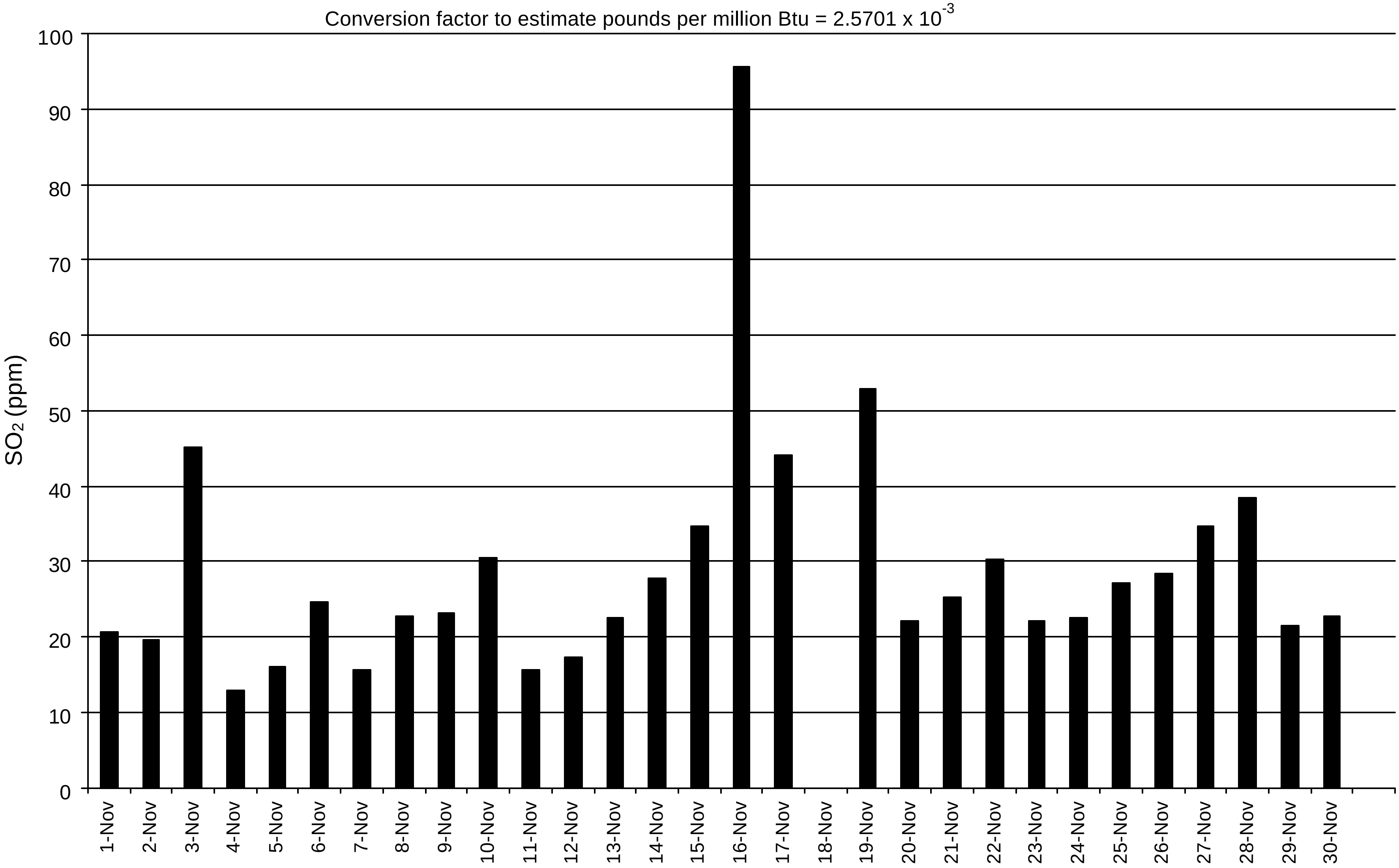
The precombustor NO_X air flow rate was 30,000 lb/hr for the first test. It was reduced to 20,000 lb/hr for the second test. For a precombustor chamber stoichiometry of 1.05, the calculated precombustor exit temperature was estimated at approximately 3,000° F for the first test and increased 50° F for the second test.

Gradual increases in precombustor chamber pressures, indicating slag accumulation within the tangential exit of the precombustor, occurred during both tests. In general, this followed periods when twenty-four hour average coal higher heating value decreased below 6,600 Btu/lb. Post-test inspections revealed a slag bubble (a hollow, thin glassy slag formation) forming around the precombustor mill air injection ports and extending down through the precombustor tangential exit. Based on these results, mill vent air flow into Precombustor A was eliminated to get rid of the slag bubble by raising the precombustor exit temperature approximately 200° F. The precombustor NO_X ports in Combustor B remained open so that coal fines in the mill vent air wouldn't have to be ignited by the less intense oil fire (at the boiler NO_X ports leading into the furnace) during startup of the first combustor. This would require Combustor B to be started on coal before Combustor A.

		Nov-98	SO2 ppm		
Tag	**Date**		**Average**	Calculate	lb/Mbtu
2FG-UR22A		11/1/98	20.62818	19.626301	0.050977
		11/2/98	19.5824	18.50561	0.048067
		11/3/98	45.09283	25.818409	0.067061
		11/4/98	12.80497	11.365213	0.02952
		11/5/98	16.07187	15.306089	0.039756
		11/6/98	24.60255	18.174358	0.047206
		11/7/98	15.64635	15.888357	0.041268
		11/8/98	22.80072	21.01793	0.054592
		11/9/98	23.22021	22.052238	0.057279
		11/10/98	30.58936	25.853767	0.067153
		11/11/98	15.66223	18.572707	0.048241
		11/12/98	17.35306	19.017858	0.049397
		11/13/98	22.59201	20.205267	0.052481
		11/14/98	27.68354	25.717753	0.066799
		11/15/98	34.70665	70.692463	0.183617
		11/16/98	95.69663	95.696628	0.248563
		11/17/98	44.11092	44.110918	0.114574
		11/18/98	0.005969	0.0059694	1.55E-05
		11/19/98	52.98996	60.779639	0.157869
		11/20/98	22.11799	19.775063	0.051364
		11/21/98	25.26367	21.093223	0.054788
		11/22/98	30.29545	23.511745	0.061069
		11/23/98	22.11529	20.168566	0.052386
		11/24/98	22.46851	30.676012	0.079678
		11/25/98	27.19522	95.699645	0.248571
		11/26/98	28.2978	21.565939	0.056015
		11/27/98	34.63568	27.585932	0.071652
		11/28/98	38.42551	28.048518	0.072853
		11/29/98	21.38824	18.372779	0.047722
		11/30/98	22.75669	20.626766	0.053576

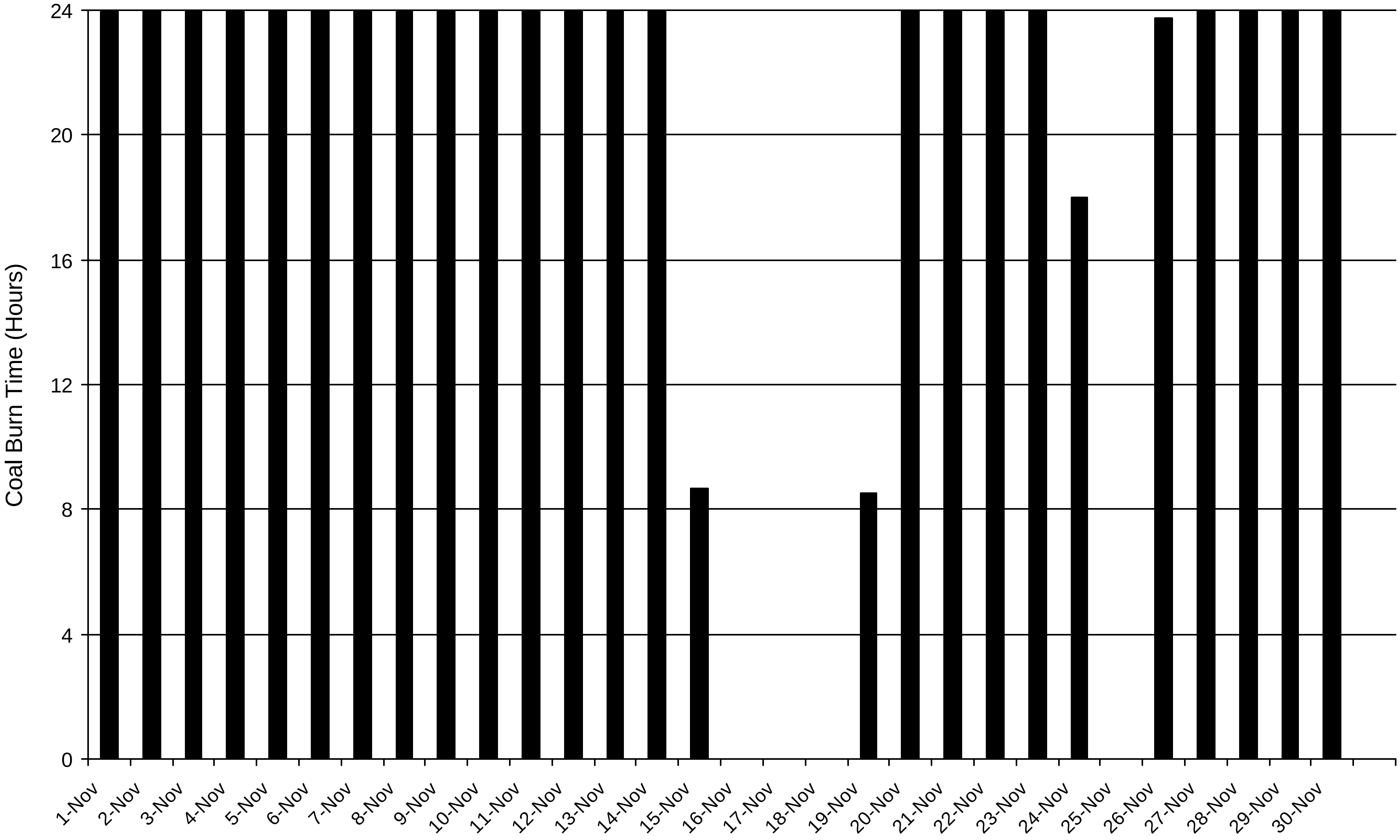
Nov-98 NOx

Date	**Average**
11/1/98	0.30395
11/2/98	0.27183
11/3/98	0.26494
11/4/98	0.25383
11/5/98	0.24519
11/6/98	0.27191
11/7/98	0.30431
11/8/98	0.29257
11/9/98	0.31698
11/10/98	0.22862
11/11/98	0.21392
11/12/98	0.26351
11/13/98	0.26564
11/14/98	0.31374
11/15/98	0.2847
11/16/98	0.23871
11/17/98	0.10541
11/18/98	3.5E-05
11/19/98	0.2561
11/20/98	0.31493
11/21/98	0.28571
11/22/98	0.27529
11/23/98	0.26834
11/24/98	0.24086
11/25/98	0.17751
11/26/98	0.31659
11/27/98	0.29058
11/28/98	0.24706
11/29/98	0.26953
11/30/98	0.25091



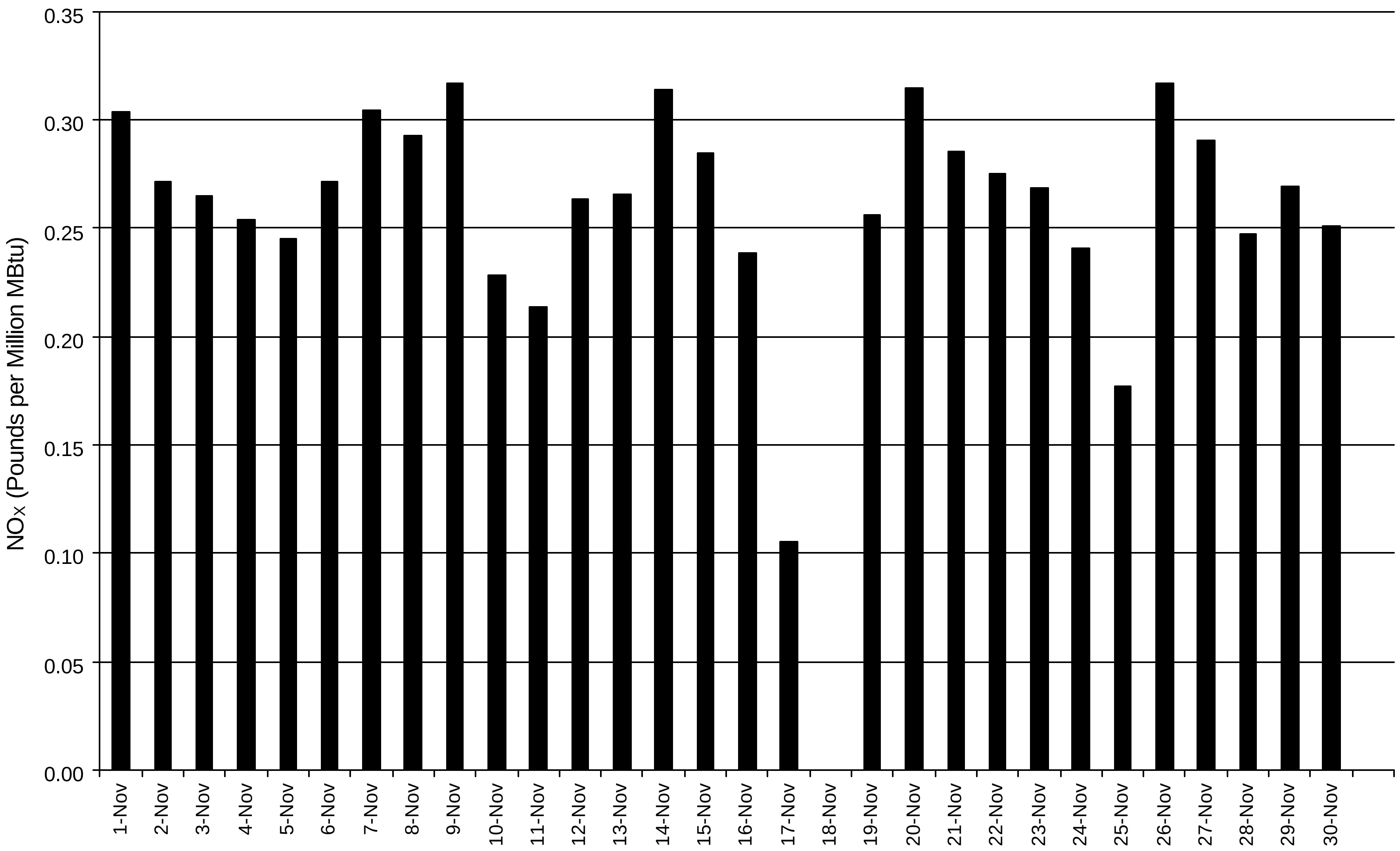
Conversion factor to estimate pounds per million Btu = 2.5701 x 10^{-3}

Date	Coal Burn Time (Hours)
11/1/00	24
11/2/00	24
11/3/00	24
11/4/00	24
11/5/00	24
11/6/00	24
11/7/00	24
11/8/00	24
11/9/00	24
11/10/00	24
11/11/00	24
11/12/00	24
11/13/00	24
11/14/00	24
11/15/00	8.666667
11/16/00	0
11/17/00	0
11/18/00	0
11/19/00	8.5
11/20/00	24
11/21/00	24
11/22/00	24
11/23/00	24
11/24/00	18
11/25/00	0
11/26/00	23.75
11/27/00	24
11/28/00	24
11/29/00	24
11/30/00	24


Coal Burn Time (Hours)
0
4
8
12
16
20
24
1-Nov
2-Nov
3-Nov
4-Nov
5-Nov
6-Nov
7-Nov
8-Nov
9-Nov
10-Nov
11-Nov
12-Nov
13-Nov
14-Nov
15-Nov
16-Nov
17-Nov
18-Nov
19-Nov
20-Nov
21-Nov
22-Nov
23-Nov
24-Nov
25-Nov
26-Nov
27-Nov
28-Nov
29-Nov
30-Nov

Nov-98 NOx

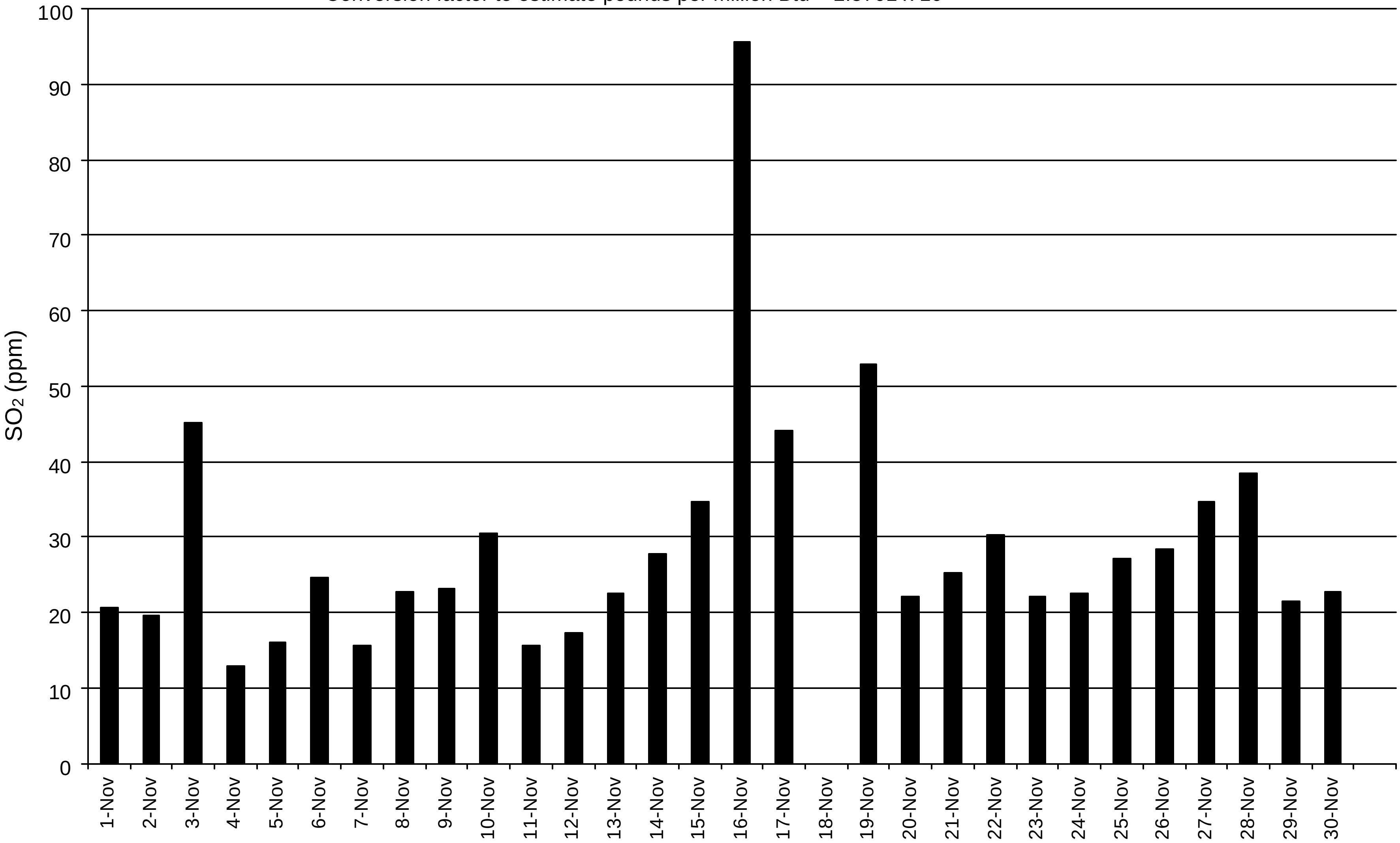
Date	**Average**
11/1/98	0.30395
11/2/98	0.271827
11/3/98	0.264944
11/4/98	0.253828
11/5/98	0.245188
11/6/98	0.271912
11/7/98	0.304309
11/8/98	0.29257
11/9/98	0.316978
11/10/98	0.228621
11/11/98	0.213924
11/12/98	0.263515
11/13/98	0.265635
11/14/98	0.313738
11/15/98	0.284702
11/16/98	0.238713
11/17/98	0.105409
11/18/98	3.49E-05
11/19/98	0.256101
11/20/98	0.314925
11/21/98	0.285714
11/22/98	0.275286
11/23/98	0.268341
11/24/98	0.240859
11/25/98	0.177506
11/26/98	0.316591
11/27/98	0.290582
11/28/98	0.24706
11/29/98	0.269534
11/30/98	0.250911



NOX (Pounds per Million MBtu)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1-Nov
2-Nov
3-Nov
4-Nov
5-Nov
6-Nov
7-Nov
8-Nov
9-Nov
10-Nov
11-Nov
12-Nov
13-Nov
14-Nov
15-Nov
16-Nov
17-Nov
18-Nov
19-Nov
20-Nov
21-Nov
22-Nov
23-Nov
24-Nov
25-Nov
26-Nov
27-Nov
28-Nov
29-Nov
30-Nov

Nov-98	SO2 ppm	lb/Mbtu*385	
Date	**Average**	Calculate	lb/Mbtu
11/1/98	20.62818	19.6263	0.050977
11/2/98	19.5824	18.50561	0.048067
11/3/98	45.09283	25.81841	0.067061
11/4/98	12.80497	11.36521	0.02952
11/5/98	16.07187	15.30609	0.039756
11/6/98	24.60255	18.17436	0.047206
11/7/98	15.64635	15.88836	0.041268
11/8/98	22.80072	21.01793	0.054592
11/9/98	23.22021	22.05224	0.057279
11/10/98	30.58936	25.85377	0.067153
11/11/98	15.66223	18.57271	0.048241
11/12/98	17.35306	19.01786	0.049397
11/13/98	22.59201	20.20527	0.052481
11/14/98	27.68354	25.71775	0.066799
11/15/98	34.70665	70.69246	0.183617
11/16/98	95.69663	95.69663	0.248563
11/17/98	44.11092	44.11092	0.114574
11/18/98	0.005969	0.005969	1.55E-05
11/19/98	52.98996	60.77964	0.157869
11/20/98	22.11799	19.77506	0.051364
11/21/98	25.26367	21.09322	0.054788
11/22/98	30.29545	23.51174	0.061069
11/23/98	22.11529	20.16857	0.052386
11/24/98	22.46851	30.67601	0.079678
11/25/98	27.19522	95.69964	0.248571
11/26/98	28.2978	21.56594	0.056015
11/27/98	34.63568	27.58593	0.071652
11/28/98	38.42551	28.04852	0.072853
11/29/98	21.38824	18.37278	0.047722
11/30/98	22.75669	20.62677	0.053576

Conversion factor to estimate pounds per million Btu = 2.5701 x 10^{-3}



In summary, testing in November was performed with approximately 7,000 Btu/lb blended coal and no mix annulus flow to the precombustors. Slag formed around the precombustor NO_X ports, so the precombustor NO_X flow to the combustor was eliminated in December. The precombustor NO_X ports to Combustor B remained open for startup considerations. This configuration, eliminating all unnecessary secondary and coal cyclone vent air from Combustor A, would be tested in December.

4.14 DECEMBER COMBUSTOR OPERATION

Precombustor mix annulus flow and precombustor mill vent air were eliminated from the precombustor in December. Test operations were limited because of a variety of facility and instrumentation problems; therefore, the test series was resumed in 1999. However, one test was conducted, accumulating 305 hours, firing 6,741 ± 180 Btu/lb (twenty-four hour average) blended coal. Throughout the test, there were numerous incidents of loss of coal on Feeder Belt B, caused by frozen coal in the coal silo. The longest continuous operating duration during December was 285 hours on Combustor A and 184 hours on Combustor B. This was the longest continuous operating duration on Combustor A to date, while burning blended coal. The plant was shut down for planned maintenance activities from December 22 through January 17. Figures 4.14.1, 4.14.2 and 4.14.3 show coal burn time and NO_X and SO_2 emissions, respectively.

ELIMINATION OF PRECOMBUSTOR MIX ANNULUS AIR AND MILL AIR (DECEMBER 7 – 21)

For this test series, Precombustor A mill vent air was directed to the furnace, while (as in November) mix annulus secondary air continued to be directed to the slagging combustor head end. Therefore, the precombustor was configured as a standard low NO_X burner with a single secondary air flow (divided between inner and outer registers) and coal feed. The precombustor stoichiometry was held relatively constant at 1.0 to 1.2. The precombustor coal split was varied from forty-three to thirty-eight percent.

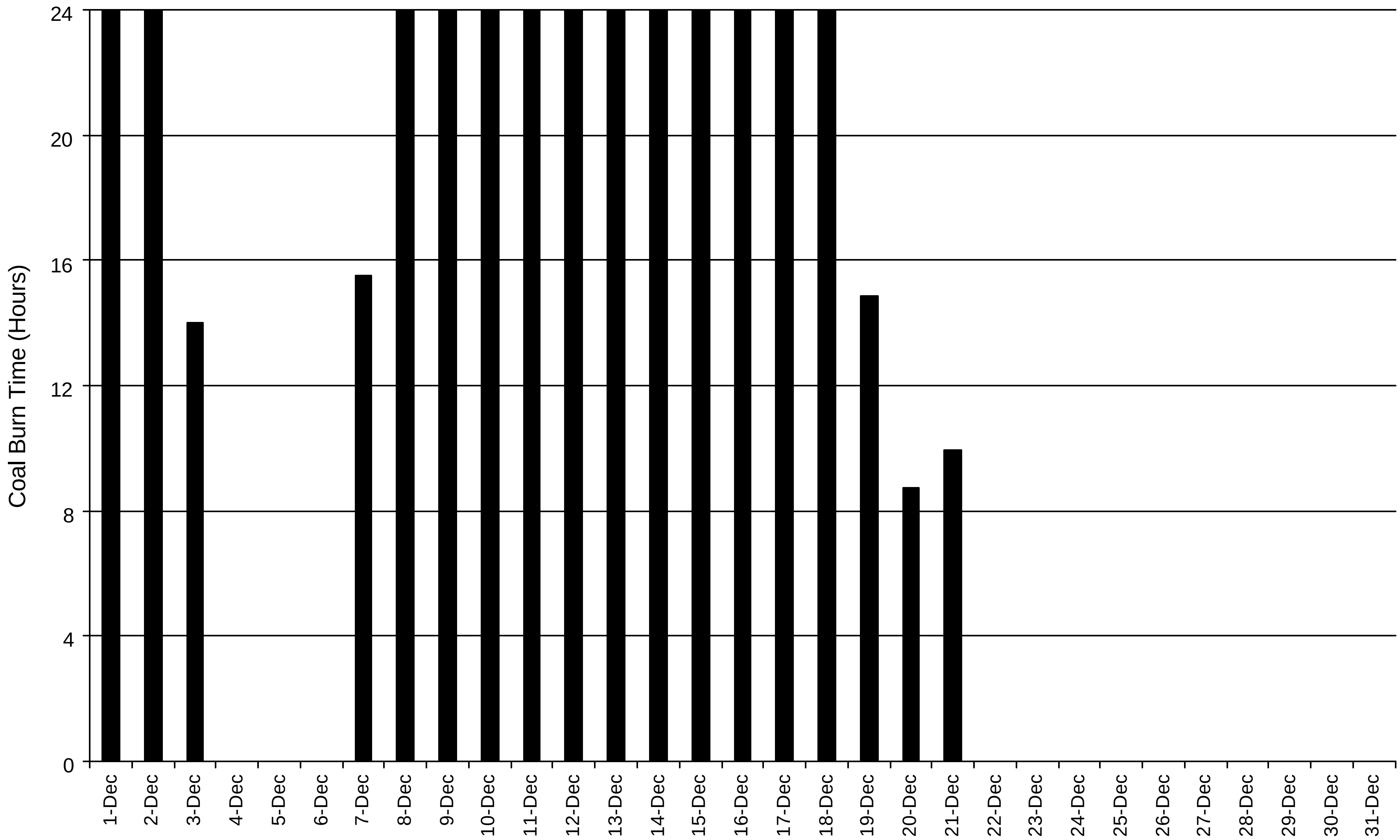
The precombustor mill air ports on Combustor A were blocked off within the precombustor and the openings were covered with refractory. The precombustor mill air ports on Combustor B were left open and a rodding port with purge and aspirating air was added to each precombustor mill air port. The purpose of this configuration for Combustor B was to enable the mill air to be initially transported to the precombustor, per the standard startup procedure, and then transferred to the furnace following sufficient warm-up of the furnace. For this configuration, Combustor B was required to fire on coal at half load prior to firing coal in Combustor A.

Precombustor operating parameters were varied to determine optimum operating conditions for the new precombustor configuration. Based on the online indications in December, the best operating conditions were a precombustor coal split of less than forty percent, a precombustor stoichiometry of 1.0 to 1.1 and reduced axial tertiary air flow. Furthermore, limestone added to the precombustor appeared to be beneficial in terms of reducing or minimizing the formation of slag accumulation within the precombustor and did not have a negative impact on SO_2 emission. When limestone was being added to Precombustor A, there was a minor increase in limestone flow rate (from a Ca/S ratio of 1.6 to 1.7), with a negligible effect on the SO_2 concentration at the stack, from an average of 27 ppm to an average of 30 ppm.

At the end of the December test, there was no slag accumulation within either precombustor. However, post-test slagging conditions may not have been representative of the online slag condition because the oil ignitors were operated frequently during the last two days of the test to compensate for loss of coal flow caused by frozen coal plugging the coal silo outlets.

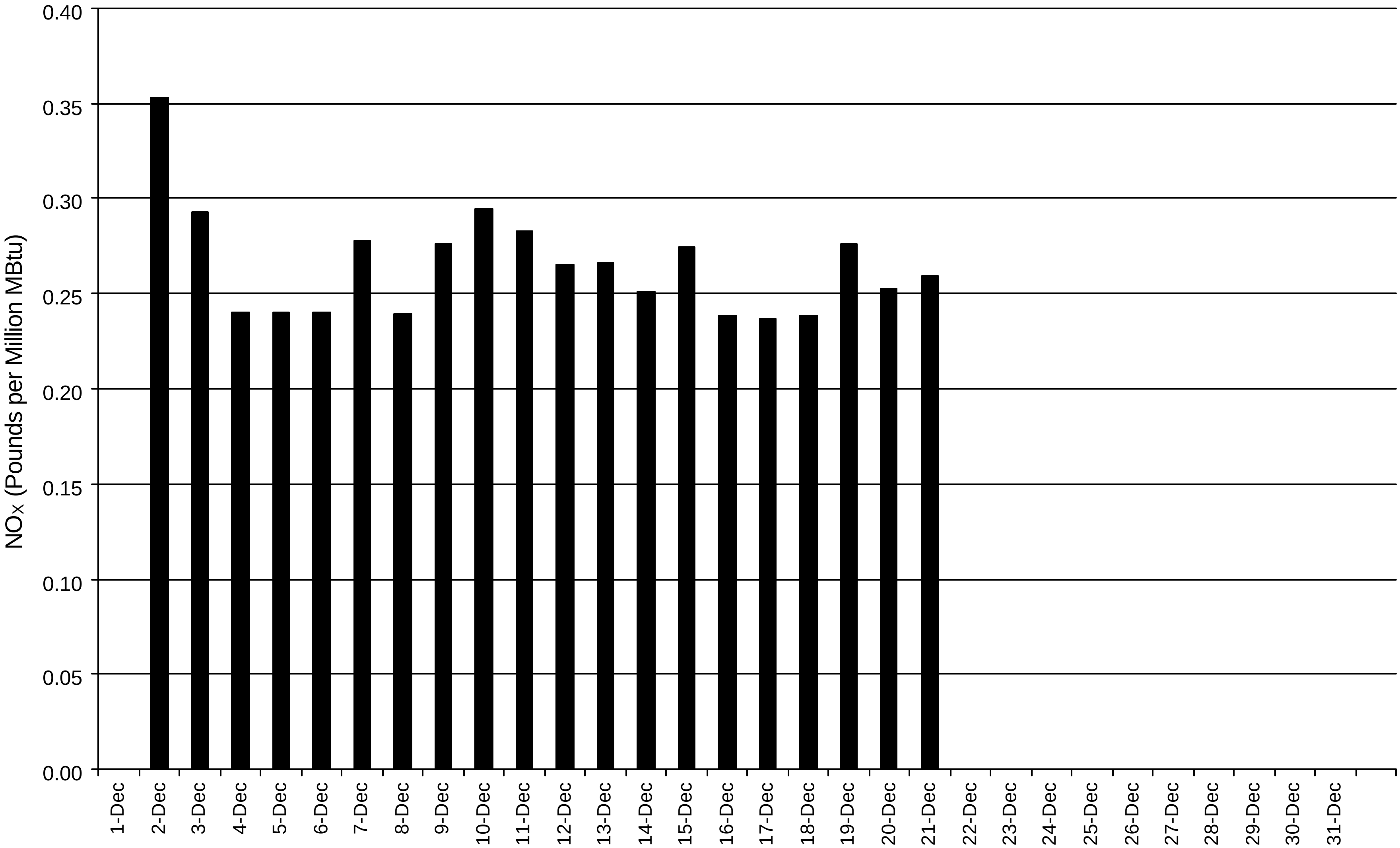
During the month the combustors were operated and progress in the characterization of the combustors and reliability of the unit was achieved. The unit continued to improve throughout the year.

Date	Coal Burn Time (Hours)
12/1/00	24
12/2/00	24
12/3/00	14
12/4/00	0
12/5/00	0
12/6/00	0
12/7/00	15.5
12/8/00	24
12/9/00	24
12/10/00	24
12/11/00	24
12/12/00	24
12/13/00	24
12/14/00	24
12/15/00	24
12/16/00	24
12/17/00	24
12/18/00	24
12/19/00	14.88333
12/20/00	8.716667
12/21/00	9.933333
12/22/00	0
12/23/00	0
12/24/00	0
12/25/00	0
12/26/00	0
12/27/00	0
12/28/00	0
12/29/00	0
12/30/00	0
12/31/00	0



Coal Burn Time (Hours)
0
4
8
12
16
20
24
1-Dec
2-Dec
3-Dec
4-Dec
5-Dec
6-Dec
7-Dec
8-Dec
9-Dec
10-Dec
11-Dec
12-Dec
13-Dec
14-Dec
15-Dec
16-Dec
17-Dec
18-Dec
19-Dec
20-Dec
21-Dec
22-Dec
23-Dec
24-Dec
25-Dec
26-Dec
27-Dec
28-Dec
29-Dec
30-Dec
31-Dec

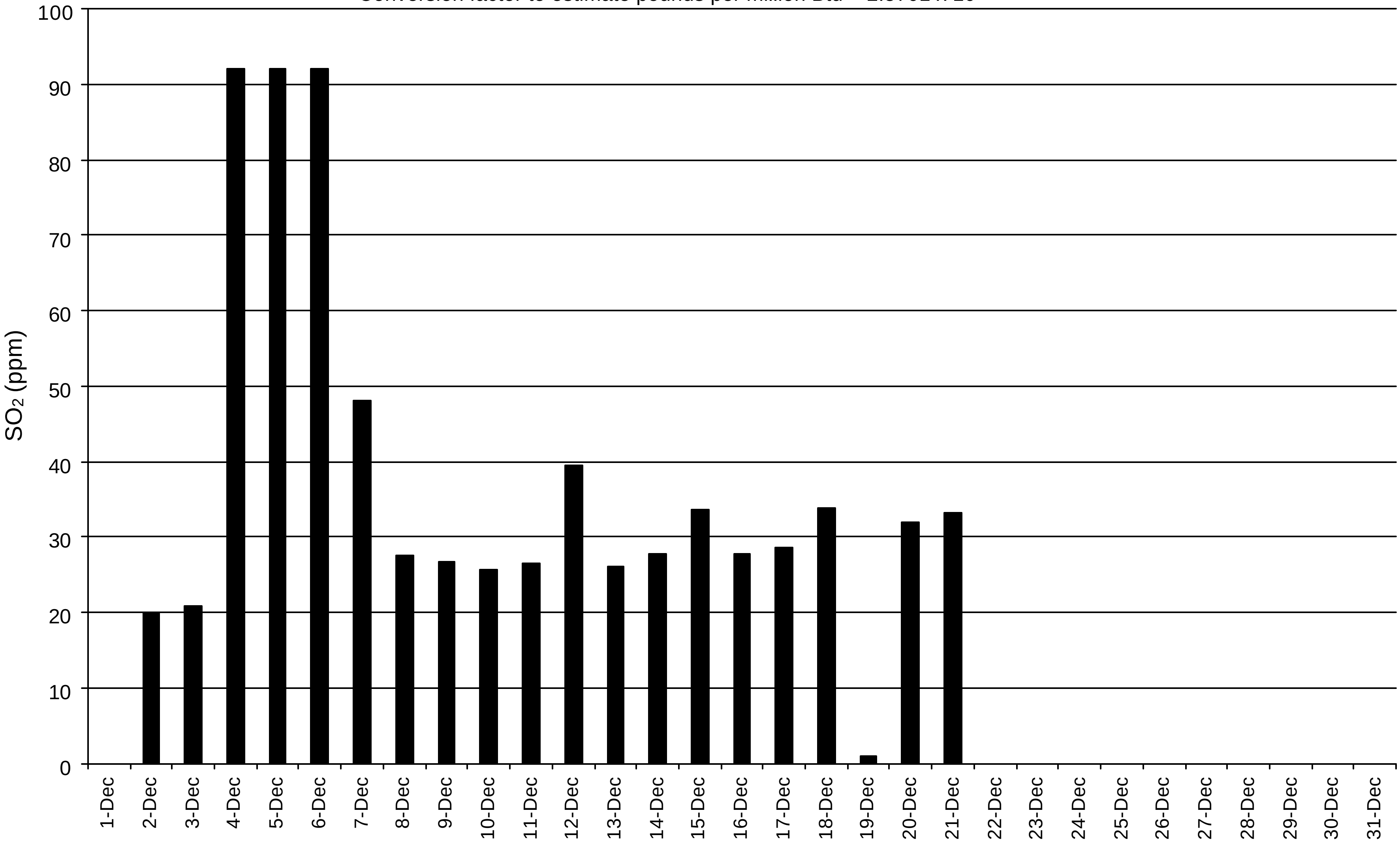
Dec-98 Date	NOx Average
1-Dec	0
12/2/98	0.353256
12/3/98	0.292781
12/4/98	0.239831
12/5/98	0.239901
12/6/98	0.239896
12/7/98	0.278103
12/8/98	0.239241
12/9/98	0.275966
12/10/98	0.294334
12/11/98	0.28235
12/12/98	0.265251
12/13/98	0.265729
12/14/98	0.250686
12/15/98	0.274238
12/16/98	0.238757
12/17/98	0.236449
12/18/98	0.237994
12/19/98	0.275757
12/20/98	0.252503
12/21/98	0.259561
12/22/98	0
12/23/98	0
12/24/98	0
12/25/98	0
12/26/98	0
12/27/98	0
12/28/98	0
12/29/98	0
12/30/98	0
12/31/98	0



NOX (Pounds per Million MBtu)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1-Dec
2-Dec
3-Dec
4-Dec
5-Dec
6-Dec
7-Dec
8-Dec
9-Dec
10-Dec
11-Dec
12-Dec
13-Dec
14-Dec
15-Dec
16-Dec
17-Dec
18-Dec
19-Dec
20-Dec
21-Dec
22-Dec
23-Dec
24-Dec
25-Dec
26-Dec
27-Dec
28-Dec
29-Dec
30-Dec
31-Dec

Dec-98	SO2 ppm	lb/mbtu*385=ppm	
Date	**Average**	Calculate	**lb/mbtu**
1-Dec	0		
12/2/98	20.1287	20.1287	0.052282
12/3/98	20.88026	47.76519	0.124065
12/4/98	92.15975	92.15975	0.239376
12/5/98	92.16445	92.16445	0.239388
12/6/98	92.16326	92.16326	0.239385
12/7/98	48.2049	66.96913	0.173946
12/8/98	27.61504	26.88779	0.069838
12/9/98	26.81818	25.82762	0.067085
12/10/98	25.70003	23.69048	0.061534
12/11/98	26.55171	26.02876	0.067607
12/12/98	39.58498	27.69881	0.071945
12/13/98	26.00612	23.88845	0.062048
12/14/98	27.77543	26.12099	0.067847
12/15/98	33.6922	28.19946	0.073245
12/16/98	27.81621	26.70818	0.069372
12/17/98	28.60539	28.72742	0.074617
12/18/98	33.95372	31.38366	0.081516
12/19/98	0.946183	0.946183	0.002458
12/20/98	31.96743	42.77052	0.111092
12/21/98	33.28957	61.92928	0.160855
12/22/98	0		
12/23/98	0		
12/24/98	0		
12/25/98	0		
12/26/98	0		
12/27/98	0		
12/28/98	0		
12/29/98	0		
12/30/98	0		
12/31/98	0		

Conversion factor to estimate pounds per million Btu = 2.5701 x 10^{-3}



5.0 EQUIPMENT AND SYSTEM PROBLEMS

The resolution or status of the following system and equipment problems that occurred in 1998 are discussed in this section.

- Condensate System
  - Condensate Pump A Failure
- Boiler Steam, Water and Feedwater
  - Main Steam Stop Valve Leak
  - Steam Drum Level and Level Control
  - Boiler Feed Pump Problems
  - Boiler Tube and Attemperator Flange Leaks
- Combustion and Combustion Control
  - Furnace Pressure Excursions When Initiating Coal Flow
  - Secondary Air Flow Damper Control Failure
  - Precombustor NO_X Port Piping Overheating
  - Precombustor Slagging
  - Flame Scanner Slagging
  - Swirl Damper Immobility
  - Coal Quality Management
- Pulverized Coal and Coal Transport Air
  - Mill Exhauster Fan Seal Leakage
  - Mill Exhauster Fan Blade Erosion
  - Erroneous Coal Cyclone Vent to Precombustor Flow Measurement
  - Precombustor Mill Air Port Leakage
- Flue Gas Desulfurization (FGD)
  - Recycle Surge Bin Inventory Management
  - Recycle and Feed Slurry Pump Seal Leakage
  - Recycle Slurry Pump Suction Pluggage
  - Restricted Atomizer Spray Flow
  - Atomizer High Vibration
- Fly Ash Removal, Transport and Unloading
  - Baghouse Filter Wear
  - Plugged Line on Outlet from Rotary Feeder to Recycle Mix Tank
  - Fly Ash Pugmill Plugging
- Slag Ash Removal
  - Slag Drag Chain Overloading
  - Inclined Slag Transfer Drag Chain Problems
  - Bucket Elevator Plugging
- Waste Water
  - Restricted Flow through Multi-Media Waste Water Filters (MMWWF's)

CONDENSATE PUMP A FAILURE

It appeared that the shaft on Condensate Pump 1A failed as the result of improper adjustment after renewal of packing. The necessary replacement pump components were provided and installed and the pump is now performing correctly.

MAIN STEAM STOP VALVE LEAK

Overheating within the turbine noise enclosure occurred, but appears to have caused only superficial damage to some wiring insulation. The high temperatures were caused by a steam leak on the stop valve flange that was stopped by tightening its bolts under the direction of the turbine manufacturer representative. The flange is still being monitored and appears to be in acceptable condition.

STEAM DRUM LEVEL AND LEVEL CONTROL

At times, the level in the drum was not the same at both ends and, in particular, when the drum level changed significantly. When the steam drum level changed abruptly, the level indicated by the level transmitters on the control board and the level shown simultaneously on the electro eye were not the same. Sometimes the operator effectively intervened by placing the feedwater flow control valve in manual and then controlling the feedwater flow based on the level indicator believed to be most accurate. If the level was not maintained or (because of erroneous indications) appeared not to be maintained by the system logic within predetermined drum high and low level limits, the unit tripped. Specifically, the boiler circulating pumps tripped because a level transmitter provided an incorrect level indication. Therefore, a level switch was incorporated and is now used instead of the level transmitter by system logic to trip the pumps. Also, an interval drum level indicator equalization line was installed. Drum level control stability is now acceptable.

BOILER FEED PUMP PROBLEMS

The following boiler feed pump problems occurred:

1. Boiler feed pump suction line water hammer
2. Multiple boiler feed pump trips
3. Boiler feed pump seal leakage
4. Boiler feed pump lube oil pump trips

The boiler feed pump trips were probably caused by high vibration created from a suction line water hammer. It is also believed that seal leakage was either caused or exacerbated by the suction line water hammer. Therefore, the root cause of items one through three is believed to be the suction line water hammer.

The cause of the suction line water hammer is not clearly known; however, the automatic boiler feed pump recirculation valve did stick open. Thus, recirculation flow (back to the deaerator) may have occurred when it was not desired and, perhaps, even though stuck open, the valve may not have provided sufficient recirculation flow. Thus, insufficient recirculation flow may have caused high temperature water to be discharged from the operating boiler feed pump so that this warmer feedwater was fed back through the non-operating boiler feed pump and into its suction line. This warmer water may have flowed upward into the suction leg of the non-operating pump so that, if flashed into steam at some elevation above the boiler feed pump (yet below the vertex of the inverted "Y" from the deaerator to the two boiler feed pumps), it would result in a steam bubble rising in the warm leg of the unused boiler feed pump until it reached the colder leg of the running boiler feed pump, thereby collapsing and causing a water hammer.

This scenario does not necessarily explain any or all of the incidents of water hammers that occurred; however, after rebuilding automatic recirculation valve components, the problems with items one through three diminished.

Item four was independent of items one through three and was caused by lube oil pump motor failures. The motors were not sized for the power requirements and were replaced with heavier duty motors to eliminate this problem.

BOILER TUBE AND ATTEMPERATOR FLANGE LEAKS

A boiler tube leak occurred at the seam weld. A small notch was evident in the weld region at the inside surface and sporadic unfused short zones containing an oxide-like substance were noted in the tube wall for a distance of up to 0.045 inches from the inside surface. These zones coincided with the center of the weld. The cause of the leak could not be conclusively determined, because the mating fracture surfaces were eroded; however, the unfused zones at the center of the weld suggested a defective seam weld was a factor in the failure.

The leaking attemperator flange components were repaired and/or replaced as necessary.

FURNACE PRESSURE EXCURSIONS WHEN INITIATING COAL FLOW

Furnace pressure excursions occurred when initiating coal flow as a result of opening the fire valves too quickly. This problem has not reoccurred since the instrument air supply was throttled to slowly open the fire valves.

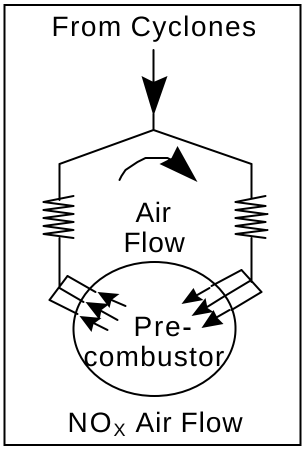
SECONDARY AIR FLOW CONTROL DAMPER FAILURE

A broken instrument air line to one of the secondary air flow control dampers resulted in the unit tripping based on poor stoichiometry, as determined from air flow measurement and system logic. The air line was repaired and no further problems have occurred.

PRECOMBUSTOR NO_X PORT OVERHEATING

The overheating was believed to have resulted from a pressure difference between the precombustor NO_X ports, causing a circulation pattern from one or more higher pressure precombustor NO_X ports through the supply piping to one or more lower pressure precombustor NO_X ports (refer to the sketch below). This circulation was noted to have occurred while firing oil during startup of the unit, when there is little or no air flow from the pulverizers through the coal cyclone vents. In addition, a similar condition existed after the transfer was made of cyclone vent air from the precombustor cyclone NO_X ports to the boiler NO_X ports. This transfer occurs at a coal flow rate of approximately 17,000 pounds per hour (per combustor coal flow). In order to prevent the circulation pattern from occurring, approximately 35,000 pounds per hour of the 110,000 pounds per hour total primary air is currently being vented to the precombustor NO_X ports. This leaves approximately 35,000 pounds per hour of carrier air (air which transports coal from the cyclone coal outlets to the precombustor and slagging combustor) and 40,000 pounds per hour of cyclone vent air to the boiler NO_X ports. Air to the precombustor NO_X ports eliminates circulation of combustion gas through the NO_X port piping which is believed to have caused a fire in the cyclone vent piping on one occasion prior to maintaining the flow to the precombustor NO_X ports after transfer to the boiler NO_X ports.

If the precombustor NO_X port flow can not be eliminated, improper slagging may occur when waste coal is fired.



Recirculation Problem

PRECOMBUSTOR SLAGGING

Slagging, although not initially supposed to occur in the precombustor, did occur. Therefore, a decision was made in the second quarter of 1998 to deliberately operate the precombustor in a slagging mode. Potential causes identified for this unpredicted slagging are:

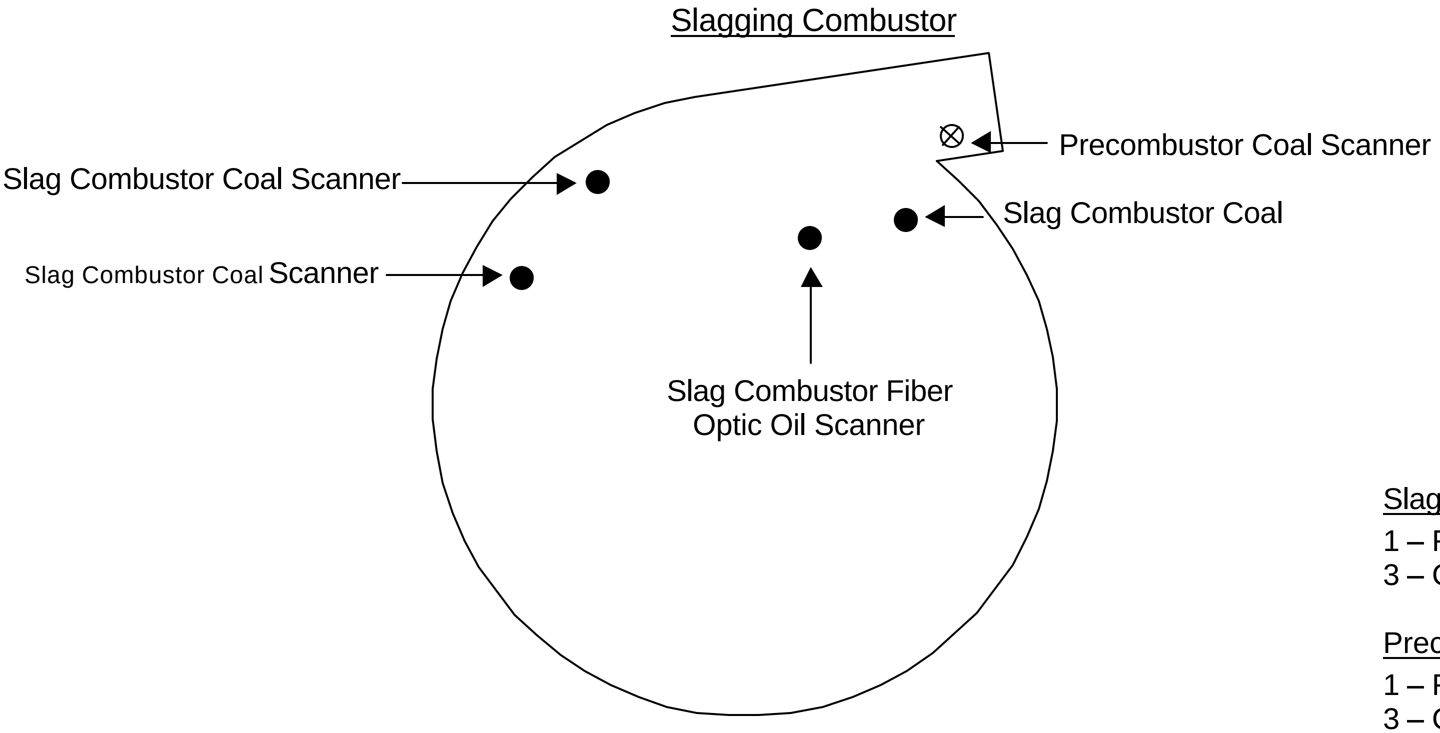
a) The local effects of injecting the relatively cold cyclone vent air (134° F) and 750° F secondary air into the precombustor can exit gas stream. The precombustor can refers to the inner portion of the air flow relative to the annular flow from the precombustor mix annulus.
b) Stoichiometry not adjusted relative to the temperature at which coal ash becomes slag, since coal ash of blended waste coal consists of ROM coal ash particles (T_{250} = approx. 2900°F). It was not possible to operate at gas temperatures between 2300 - 2900°F without melting some but not all ash. The sticky but unmelted particles accumulated. As such, precombustor slagging could be caused by the inability to adjust for varying heating value and/or slagging temperature of the coal because of varying coal and ash properties.
c) Inadequate mixing just downstream of the mix annulus causing slag to form and be cooled and frozen by secondary air from the mix annulus.

There was no slagging in the precombustors in December. However, because of the extent of firing on oil, this issue cannot be said to be resolved.

FLAME SCANNER SLAGGING

Many ignitor positions were tried in an attempt to find locations allowing reliable flame detection. The flame detector ports were often obstructed by slag. There is currently one oil flame scanner on each precombustor and on each slagging combustor. Each oil flame scanner is located in the air pipe of the oil gun itself. Coal flame scanners are currently located in the area between the coal burner and the inner wall of the precombustor can, on the east horizontal precombustor NO_X rodding port (optical scanner) and in the east tangential rodding port (Precombustor A only). Figure 5.1 shows the approximate locations and numbers of scanners as of the end of March.

Figure 5.0.1 – Approximate Locations and Numbers of Precombustor and Slagging Combustor Scanners

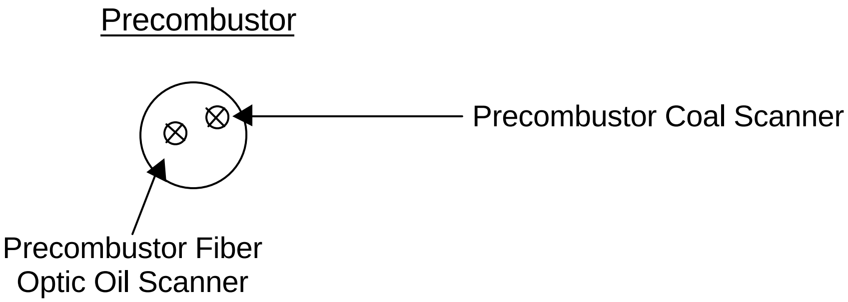


Slagging Combustor

1 – Fiber Optic Oil Scanner
3 – Coal Scanners

Precombustor

1 – Fiber Optic Oil Scanner
3 – Coal Scanners



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On the head end of each slagging combustor there are three coal flame scanners located in selected rodding ports of the outer ring made up of the six outer coal injection ports. Coal is currently injected into the inner ring of ports. No trips due to loss of flame detection occurred after March and the scanner locations selected during the first quarter on the head end of the slagging combustor were not altered. Sometimes the required cleaning frequency was higher than desired, because of concern that all slagging combustor scanners could slag over and cause a unit trip before they could be cleaned. However, this never occurred and did not continue to be a major or frequent problem.

SWIRL DAMPER IMMOBILITY

The swirl dampers are inserted and retracted into the outlet gas flow from the precombustor to control the velocity of the gas from the precombustor as it discharges tangentially into the slagging combustor. The motor drives for the swirl dampers were not designed for the ambient temperatures experienced in the present location and were not capable of sustaining the loads required to insert and retract the dampers through the slag which, at present, forms in the precombustors. New drives utilizing metal, rather than plastic, gearing and a roller and track arrangement were designed and installed. The required force to insert the dampers was not achieved. However, since HCCP is to be a base loaded unit, the dampers were effectively set to a fixed position associated with the full load firing rate of each combustor.

COAL QUALITY MANAGEMENT

Certain ROM coal, particularly Seam 6 coal, is difficult to grind. Suspended particles not ground to a fineness sufficient to be swept through the mill classifiers accumulate in the pulverizer creating considerable coal inventory between the coal feeders and the combustors. This was seen by the high differential pressures experienced across the mills when using Seam 6 coal. As a result, the actual instantaneous (recognizing there must always be some time delay between coal leaving the feeder and entering combustors) coal feed rate to the combustors is not identical to the feeder feed rate because of changing coal inventory in the pulverizers. The buildup of coal in the pulverizers is believed to have caused at least one pulverizer trip. In addition, if coal inventory in the mill suddenly decreases, the firing rate suddenly increases, causing load swings and difficulty in maintaining steam drum level. This was resolved by future blending of Seam 6 coal with other coal.

The unit undergoes large load swings when the coal heating value is inconsistent. Large variations in coal heating value occurred, even in fuels that were supposed to be of consistent heating value. Separate ROM and waste coal piles sourced two separate hoppers each with controllable outlet feeder speeds. Feeder speeds were automatically varied from the two separate waste and ROM hoppers to maintain a constant heating value based on the online ash, moisture and estimated heating value of the fuel analyzer on the HCCP and Unit 1 common conveyor, which is downstream of the two variable speed feeders.

Unfortunately, there were times when coal from the waste hopper had a higher heating value than the ROM coal, so increasing the feeder speed from the waste coal hopper, which was supposed to have a lower heating value than ROM coal, was obviously unsuccessful. The most successful method of achieving a blend of waste and ROM coal, with a relatively uniform heating value, was to provide a layered pile with alternating layers of waste and ROM coal. A front end loader was used to lift through a vertical wall at the edge of the pile, thereby gathering a mixture of the layers.

In addition to the mixing which occurred in the coal pile, both hoppers were fed so that their respective feeders would provide a mix from each hopper. Then the coal feed into the two plant silos, one silo for each of the two combustors, was alternated via automatic flop gates. These were alternated approximately once per every fifty tons loaded, thereby providing a more uniform heating value to the combustors at any given time.

MILL EXHAUSTER FAN SEAL LEAKAGE

The inboard (motor side) and outboard mill exhauster seals on both mill exhausters have leaked coal dust from the positive pressure, which occurs at the fan casing/shaft interface to atmosphere. Mill exhauster seal leakage was mitigated by providing a field applied silicon seal to the outside of the two shaft seals at each fan casing shaft penetration. The space between the inner and outer seals was purged using sufficient plant compressed air to create a higher pressure between the seals than the adjacent pressure inside the fan casing.

MILL EXHAUSTER FAN BLADE EROSION

The abrasive HCCP coal eroded the mill exhauster fan blades. The blades were rebuilt onsite using tungsten carbide, but eroded again between October and December. New rotors with blades of Barberite™, a more erosion resistant material, were installed in December for testing in 1999.

ERRONEOUS COAL CYCLONE VENT TO PRECOMBUSTOR FLOW MEASUREMENT

Flow measurements in the line to the precombustor mill vent air ports, used to adjust flow between the precombustor NO_X ports and the boiler NO_X ports, were erroneous, because the purge air valves, which provide compressed air to blow coal dust out of the static pressure and total pressure measurement orifices, leaked. The leaking valves were replaced. This mitigated problems with flow measurement errors; however, it did not eliminate them. Alternative flow measuring methods are being investigated including the possibility of eliminating the need to measure the flow or eliminating the flow itself.

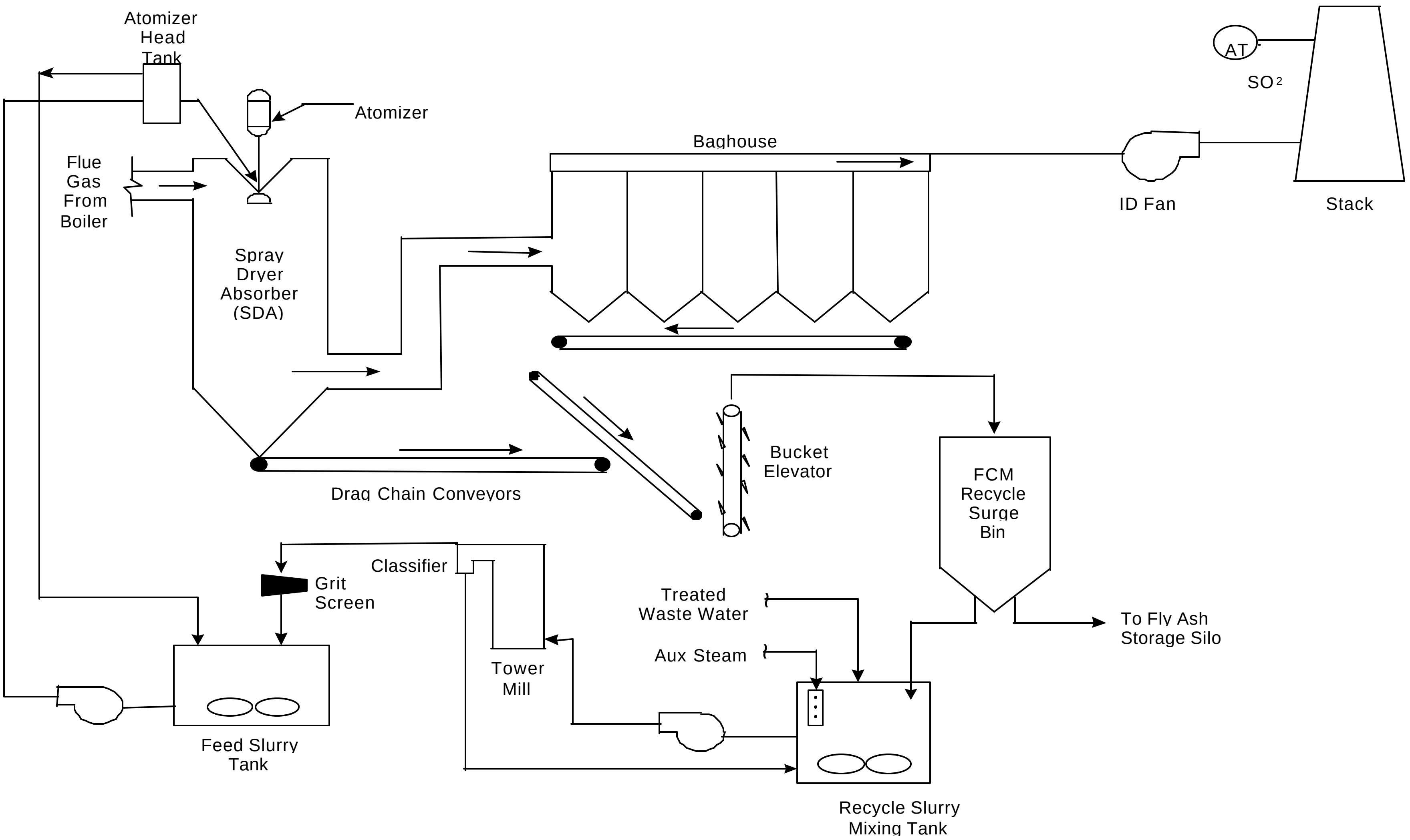
PRECOMBUSTOR MILL AIR PORT LEAKAGE

The precombustor NO_X ports (where a portion of the coal cyclone vent air is vented to the precombustor) leaked coal dust from the positive pressure inside the combustor through the grooved-end mechanical joint victaulic coupling gaskets. This type of joint was provided to allow for the thermal growth of the precombustor nozzles relative to the connecting piping. High gas temperatures were not anticipated in this area and the gaskets failed due to exposure to temperatures exceeding the coupling gasket design temperature. The victaulic couplings were replaced with butt-welded metal bellow expansion joints designed for much higher temperatures. Subsequent precombustor mill air port leaks were caused by poor welds at the interface between the mill vent piping and its connection to the seal box on the precombustor. The welds were repaired and there were no more leaks.

RECYCLE SURGE BIN INVENTORY MANAGEMENT

A limestone feed rate of less than twice the desired amount could not be achieved with the original equipment; consequently a new gear drive was installed on the limestone feeder so that the feeder speed was halved. There is a significant time delay (several hours) between the time limestone is injected into the combustors and when it is actually utilized for SO_2 removal (in the spray dryer absorber system). This delay results from the limestone having been flash calcined, collected in the baghouse hoppers (along with some previously reacted FCM and inert fly ash), passed through the recycle bin, mixed in the recycle mix tank, ground in the tower mill, flowed to the feed slurry tank and pumped through the atomizer (see Figure 5.2). The recycle bin is filled via the fly ash drag chain. Filling is initiated when there is a high level in either one of the rear baghouse hoppers (where more material is collected than any of the other hoppers) or upon high

Figure 5.0.2 – Flue Gas Desulfurization System



levels in any other two baghouse hoppers. Once the fly ash drag chains begin to operate, they continue operating until all high levels have cleared unless a high-high level occurs in the recycle surge bin. A high-high surge bin level causes the fly ash drag chains to stop until the high-high level clears. The recycle surge bin outlet rotary valve speed is controlled to maintain the setpoint of recycle mix tank solids concentration. The recycle surge bin outlet rotary valve discharges to the fly ash transport line on high level. It runs until there is a low level in the bin. This problem was not resolved in 1998 and another speed reducing gear was installed later.

RECYCLE AND FEED SLURRY PUMP SEAL LEAKAGE

The recycle slurry pump and feed slurry pump seal leakages were attributed to a buildup of solids between the rotating shaft seal assembly and the stationary seal flange of the flushless mechanical seals. This buildup is believed to have caused a slight separation of the rotating and stationary mechanical seal surfaces, leading to seal failure. Holes were drilled through the stationary seal flange to provide approximately three gallons per minute of relatively clean filtered waste water to purge any buildup of solids from the sealing surfaces. Seal leakage problems appear to have been eliminated since this modification.

RECYCLE SLURRY PUMP SUCTION PLUGGAGE

Recycle slurry pump pluggage was attributed primarily to chunks of agglomerated ash (originating from wet ash deposits which eventually dried and flaked off from the upper walls of the SDA) being fed via the rotary feeder from the recycle surge bin into the recycle mix tank. These chunks then became lodged at the inlet to the pump impeller. The short-term and long-term solutions to this problem are listed below.

Short-term solutions:

- The affected pump discharge valve was closed, the pump suction line was back flushed using filtered waste water, then the pump was restored to its normal operating configuration.
- The pumps were switched, suction piping disassembled and the blockage cleared on the original pump.
- When the SDA drag chain carried chunks, they were open discharged from it, so the chunks didn't reach the recycle mix tank.

Long-term solution:

- The formation of the chunks in the SDA was eliminated. These chunks resulted from wet deposits on the upper walls of the SDA caused by excessive atomizer spray flow based on slurry solids concentration and the approach to saturation temperature in the SDA. Slurry solids concentration was increased from approximately thirty to forty percent solids. Spray flow was limited, while flushing the atomizer, and the spray flow was reduced as solids concentration decreased.

RESTRICTED ATOMIZER SPRAY FLOW

Restricted atomizer spray flow was attributed to the agglomeration of particles somewhere between the atomizer and the head tank outlet strainer. This agglomeration either built up and gradually constricted flow or released a chunk, which then was caught downstream, where it suddenly restricted flow. The frequency of plugging appeared to be related to the level of unreacted calcium (as calcium oxide and calcium hydroxide) in the fly ash. Flushing the atomizer with filtered waste water (approximately once every twelve hours) appeared to mitigate restriction of atomizer spray flow. In addition, providing coal from a pre-blended pile improved the ability to operate with consistently lower levels of unreacted calcium compounds in the slurry. Various logic changes in the control system alleviated the problem, but did not solve it.

ATOMIZER HIGH VIBRATION

High vibration levels in the SDA atomizer have been attributed to the formation and release of an agglomeration of particles larger than approximately 3/16 inch. These particles are believed to eventually block off or inhibit flow from one of more of the nozzles in the atomizer wheel, creating vibration. Flushing the atomizer with relatively clean filtered waste water has decreased vibration.

BAGHOUSE FILTER WEAR

Excessive fabric filter wear, especially adjacent to compartment walls opposite the compartment inlet ducts, caused increased stack opacity. Poor inlet gas distribution caused the filters to rub against the compartment side walls and against each other, resulting in holes in the fabric. Flow distribution baffles were designed for installation in early 1999 to mitigate fabric filter wear.

PLUGGED LINE ON OUTLET FROM ROTARY FEEDER TO RECYCLE MIX TANK

Plugging of the pipe, which feeds powdered FCM into the recycle mix tank, was attributed to poor tank level control and vent scrubber plugging. Both are believed to cause the inside of the feed pipe to become wet, resulting in the powder sticking to the inside wall of the pipe. Poor tank level control may have caused alternating rising and lowering tank levels to wet the inside surface of the pipe, thereby creating a plug. Vent scrubber plugging sometimes caused malfunctioning of the level indicator/controller. When the vent scrubber plugs, excessive dust in the moist, warm environment above the slurry surface in the tank is believed to cake dust on the level indicator/controller and on the inside of the FCM feed pipe. If the water level drops below the bottom of the feed pipe, splashing water may wet the inside of the pipe, which also causes caking. This issue has not yet been resolved.

FLY ASH PUGMILL PLUGGING

Pugmill plugging was caused by:

1. Improper ratio of dust suppression water to fly ash during unloading
2. Failure to clean out the pugmill after completing unloading operations, causing the wet fly ash to set-up into a cement-like mixture
3. Excessive CaO concentration in the fly ash

Items one and two were corrected, as operators became more proficient at unloading fly ash from the silo to the dump trucks. Item three was avoided by pre-blending the coal in the coal yard. This provided a blended coal with sulfur and ash contents that deviated less from well mixed (or average) values. Therefore, it was not necessary to provide an incrementally higher limestone flow to compensate for larger deviations resulting in excess CaO concentration in the fly ash.

SLAG DRAG CHAIN OVERLOADING

When low heating value, high ash coal was encountered, the tension at the head end of the slag drag chain increased causing the flights to lift off the dewatering ramp. Therefore, material slid back down the dewatering ramp. Eventually, the slag drag chain could not remove the slag as fast as it was produced, resulting in excess hydraulic pressure and shutdown. The increased chain tension also caused damage to the sprocket teeth and hydraulic motor support at the head end of the slag drag chain as well as bending the flights.

The bent flights were straightened, the hydraulic drive motor support was replaced, the interfering flanges of the breaker beams were trimmed and modifications were performed near the head end idlers and sprocket to keep the flights centered and to keep them down onto the slag tank outlet ramp. In addition, a larger hydraulic drive was provided to increase the speed of flights removing slag and support the modifications that were performed on the configuration of the some of the flights in an attempt to remove more material per flight.

Extension plates, parallel to the dewatering table, were welded onto the bottom of each flight, so that, when the drag chain lifted off the dewatering table, the material laid on top of the parallel plates rather than sliding back down the ramp. In addition, small drain holes were added to the flights, resulting in better dewatering, which also helped to minimize loss of slag material from the flights as they traveled up the dewatering ramp. The slag drag chain has operated reliably since the modifications.

INCLINED SLAG TRANSFER DRAG CHAIN PROBLEMS

The slag transfer drag chain failed as a result of material being caught between the chain and the head end and tail end sprockets and pulleys. There was also a buildup of material at the tail end, which resulted in the chain breaking. The under side of the tail end was provided with an opening for any excess material carried around the head pulley to drop out into a small hopper which is emptied by an eductor discharging to the slag ash drag chain reservoir. The head end of the conveyor was first modified to wipe material away from the chain before it passed over the head sprocket and the tail end was provided with an idler sprocket rather than the initial idler pulley. This prevents the chains from getting out of alignment with each other. The table on which the top strand of chain and flights is dragged across was removed and the direction of the transfer drag chain conveyor was reversed so that material fell directly to its bottom table to be dragged by the bottom strand of chain and flights. Any material dribbling from the head pulley discharge also fell to the bottom table where it was dragged up toward the head end rather than down toward the tail end of the conveyor. The transfer drag chain operated more reliably since the modifications; however, further modification to the slag transfer drag chain was required to minimize and dispose of tail end material dribble and to reduce drag chain wear.

BUCKET ELEVATOR PLUGGING

The slag bucket elevator discharges to the bottom/slag ash silo via a transition chute. The transition chute had a reduced cross section through which the material flowed. The reduced cross section caused material to backup into the discharge chute and eventually caused the material to be carried over the head sprocket which clogged the tail end of the bucket elevator. The discharge chute transition piece was first modified to provide a more gradual cross section reduction. This improved the situation but did not eliminated pluggage. As a further measure to assist material movement, a vibrator was added to the chute work and no pluggage has occurred since.

RESTRICTED FLOW THROUGH MULTI-MEDIA WASTE WATER FILTERS (MMWWF'S)

Restricted flow through the MMWWF's was attributed to the highly turbid, highly alkaline slag drag chain circulation water used as make-up to the filtered waste water system, via the dirty waste water tank and the MMWWF's. Using water directly from the slag ash drag chain as backwash for these filters also contributed to the problem. The quality of this water was degraded further when FGD sump water, resulting from recycle slurry tank and/or feed slurry tank overflow or (during preparation for shutting the plant down) drainage, was pumped to the slag drag chain.

The high turbidity of the slag drag chain circulation water caused the MMWWF's to plug. The FGD slurry water, in particular, tended to plug these filters quickly. The high alkalinity of this water also caused the filtered waste water to be transferred to a neutralization tank. Then neutralized water from the neutralization tank returned to the dirty waste water tank and passed through the MMWWF's again, before flowing to the filtered waste water tank (if its pH was low enough) or returning to the neutralization tank again (if recontaminated with too much additional high alkaline make-up water).

The slag ash drag make-up source to the dirty waste water tank was replaced with river water. This reduced alkalinity and mitigated MMWWF pluggage.

6.0 EMISSIONS

CEMS ratification testing was completed successfully. Actual stack emissions versus maximum allowable emissions were as follows:

Emission	**Actual**	**Maximum Allowed**
Stack SO_2	0.05 to 0.06 pounds per million Btu	.10 pounds per million Btu
Stack NO_X	0.25 to 0.35 pounds per million Btu	.35 pounds per million Btu
Stack opacity	Two to seven percent	Twenty percent

NO_X EMISSIONS

An optimum slagging combustor stoichiometric ratio of 0.78 to 0.80 was established to minimize NO_x emissions. The precombustor stoichiometry, although it has some effect on NO_X emission, was based primarily on the slagging characteristics required for reliable continuous operation.

SO_2 EMISSIONS

SO_2 emissions were typically below the limit of 0.10 pounds per million Btu. The mode of control showing the greatest success was to maintain SDA outlet temperature at approximately 15° F above the minimum allowable outlet temperature. The SDA outlet temperature can be lowered quickly as a short term method to obtain increased SO_2 removal efficiency, while adjusting limestone flow as required for long term SO_2 removal adjustments.

STACK OPACITY

Stack opacity did not exceed the maximum allowable limit of twenty percent; however, bag wear continued to increase opacity until the worn bags were replaced. Better gas distribution into the bags should remedy this problem.

7.0 1999 SCHEDULE

- Test the slagging combustor/precombustor air injection configuration with blended coal
- Modify the air injection configuration, if required, to obtain continuous operation on blended coal
- Perform modifications and maintenance, as required, to prepare for the ninety-day commercial operation test
- Perform ninety-day commercial operation test
- Turn plant over to GVEA

QUARTERLY TECHNICAL REPORT NO. 29-32
JANUARY 1 TO DECEMBER 31, 1998

APPENDICES

A. HCCP YEAR TO DATE REPORT (DECEMBER 1998)

B. GLOSSARY OF TERMS AND ACRONYMS

C. HCCP OPERATIONAL HISTORY 1998

B. GLOSSARY OF TERMS AND ACRONYMS

AIDEA	Alaska Industrial Development and Export Authority
Blended Coal	A blend of waste coal with any combination of run of mine (ROM) seam coal and/or fines
Ca/S Ratio	Calcium to sulfur ratio; refers to the ratio of reactive calcium leaving the furnace divided by the theoretical amount required to completely react with all of the sulfur in the coal
Clinker	A large piece of frozen slag having no dimension smaller than approximately eight inches
DOE	U.S. Department of Energy
°F	Degrees Fahrenheit
Fines	Material which passes through a one-quarter inch by two inch mesh, while screening the larger sized coal
FGD	Flue Gas Desulfurization
GVEA	Golden Valley Electric Association, Inc.
HCCP	Healy Clean Coal Project
Higher Heating Value	The total chemical energy released during combustion, including the latent heat associated with condensing all water vapor
Inferred Higher Heating Value	The inferred higher heating value is calculated as a function of boiler duty (estimated as turbine gross generation multiplied by the gross turbine heat rate) divided by an assumed boiler efficiency and then divided by the mass flow of coal into the pulverizers to determine energy released per unit (mass) of fuel fired
IPC	Inlet Pressure Control
MFT	Master Fuel Trip
MMWWF's	Multi-Media Waste Water Filters
N_2	Molecular Nitrogen
NFPA	National Fire Protection Association
NO_X	Oxides of Nitrogen
O_2	Oxygen
ROM	Run of Mine
SO_2	Sulfur Dioxide
SDA	Spray Dryer Absorber
Slag	Molten ash or ash that was once molten and then refrozen
Stoichiometric Ratio	The ratio of reagent actually supplied to react with a given quantity of reactant divided by the amount of reagent theoretically required to completely react with that quantity of reactant

Stoichiometric Ratio, Precombustor	When used in relation to the precombustors, it is the air provided relative to the quantity of air required to (in theory) completely combust all of the coal flowing to the precombustor
Stoichiometric Ratio, Slagging Combustor	When used in relation to the slagging combustors, it is the total air provided to the precombustor and slagging combustor relative to the quantity of air required to (in theory) completely combust all of the coal entering the head end of the slagging combustor, plus the coal entering the precombustor
T_{250}	The temperature (° F) at which molten slag has a viscosity equal to 250 Poise

Wednesday, July 1, 1998

- Unit 2 offline for shutdown

1035 Set turbine for cold start

Wednesday, July 1, 1998

Thursday, July 2, 1998

- Unit 2 online with 45.0 MW, turbine follow mode
- SO_2 at 149.9 ppm, .249 lbs/mBtu, NOx at .292, opacity at 0.0

Thursday, July 2, 1998

- HCCP online with 58.7 MW, density 41.1, slurry 121.0°

Friday, July 3, 1998

- Unit 2 online with 60 MW, coordinated mode, setpoint 60 MW
- SO_2 9.0 ppm, .020 lbs/mBtu, NOx .232, opacity .2%

Friday, July 3, 1998

- Unit 2 online with 60 MW, coordinated mode, setpoint 60 MW
- SO_2 3.0 ppm, .007 lbs/mBtu, NOx .224, opacity 12.4

Saturday, July 4, 1998

- Generator online with 61 MW, coordinated mode, +77°
- SO_2 0.24 lbs/mBtu, NOx 0.22 lbs/mBtu, CO 1.5 ppm, opacity 15%

Saturday, July 4, 1998

- Generator online with 60 MW, coordinated mode
- SO_2 24.1 ppm, .058 mmBtu, NOx .270, opacity 1.6%

Sunday, July 5, 1998

- Generator online with 60.0 MW, coordinated mode, +76°F
- SO_2 6.9 and 0.16, NOx .303, CO 2.5 ppm, opacity 1.8%

Sunday, July 5, 1998

- Generator online, 60.2 MW, coordinated mode
- Stack 18.9 ppm, inlet 136.8 ppm, NOx .273, opacity 1.8%

Monday, July 6, 1998

- Generator online with 61 MW, coordinated mode, +79°F
- SO_2 8.1/.019, NOx .279, CO B 36.7, O_2 B 3.8%, opacity 7%

0423 SO_2 at 44.3 ppm, SDA in at 202 ppm, limestone to 50%

Monday, July 6, 1998

- Generator online, 60 MW, coordinated mode
- SDA in service 476 ppm, density 43%, SO_2 190/32 ppm
- SO_2 .075 mmBtu, NOx .251, opacity 10.2%

1527 Generator offline, field breaker open

Tuesday, July 7, 1998

- Unit 2 offline

Tuesday, July 7, 1998

- HCCP offline for maintenance, plugged combustor

Wednesday, July 8, 1998

- Unit 2 offline for maintenance, combustors plugged

Wednesday, July 8, 1998

- HCCP offline for maintenance

Thursday, July 9, 1998

- Unit 2 offline, plugged combustors

Thursday, July 9, 1998

- Unit 2 offline for maintenance

Friday, July 10, 1998

- Generator offline

Friday, July 10, 1998

- Generator offline, baghouse bypassed, SDA off

0917 A Ignitor in service, minimum of 70 psi

- Precombustor at 80, 90 psi

1345 Turbine roll off (cold)

Saturday, July 11, 1998

- Generator online with 29.2 MW, IPC, +62°F
- O_2 5.9%, CO 1.7 ppm, SO_2 0.249 lbs/mBtu, NOx .182 lbs/mBtu, opacity 1.2%

Saturday, July 11, 1998

- Generator online with 29 MW
- Spray at 27.6 gal/min, density 40.5%, SO_2 119.9/0.8, .002 mmBtu, NOx .190, opacity 12.1%

Sunday, July 12, 1998

- Generator online with 27 MW, IPC, outside temp +58°F
- Opacity 33%, SO_2 .56 ppm/.005 lbs/mBtu, NOx .211 lbs/mBtu, O_2 7.4%, CO 34.6

0555 FD fan 45", mill differential pressure 31", combustor differential pressure 32". Notified dispatch that we're coming down per Clive

Sunday, July 12, 1998

- Generator online at 28.4 MW, baghouse and SDA in service

1148 Generator offline, tripped turbine, MFT

Monday, July 13, 1998

- Generator offline for combustor work, +60°F outside temperature

Monday, July 13, 1998

- Generator offline, plant shut down

Tuesday, July 14, 1998

- Generator offline for combustor repair, outside temp +58°

Tuesday, July 14, 1998

- Generator offline, plant shut down for maintenance

Wednesday, July 15, 1998

- HCCP offline for maintenance

Wednesday, July 15, 1998

- Unit 2 offline for combustor repairs

Thursday, July 16, 1998

- Unit 2 offline for maintenance

Thursday, July 16, 1998

- Unit 2 offline for combustor maintenance

1244 A Precombustor torch in

1335 A Slag Combustor torch in

1403 A Slag Combustor torch out

1425 A Slag Combustor torch in

1823 Cold start on turbine

Friday, July 17, 1998

- Unit 2 offline for maintenance
- A Combustor on, 80 and 70

2110 B Precombustor in

2115 Slag combustor in

Friday, July 17, 1998

- Unit 2 online with 27.9 MW, SDA and baghouse in service

- SO_2 at 0.9 ppm, .003 lbs/mBtu, NOx at 0.231, opacity at 1.1%

0730 Recycle Slurry Pump P1 off for Everett Tilton

Saturday, July 18, 1998

- Unit 2 online with 28.2 MW, SDA and baghouse in service
- Stack opacity at 1.3%, NOx at .303, SO_2 at .002, density at 39.9%, limestone feed 25 lbs/min

0245 Tripped turbine and boiler

Saturday, July 18, 1998

- Unit 2 offline with a plugged A Combustor

Sunday, July 19, 1998

- Unit 2 offline for maintenance

Sunday, July 19, 1998

- Unit 2 offline
- A Precombustor ignitor in service, 70 psi

0850 Precombustor torch in, purge complete

0939 Slag combustor torch in. Precombustor at 70 psi, slag combustor at 70 psi.

1412 Turbine cold start

Monday, July 20, 1998

- Unit 2 online with 32.5 MW

Monday, July 20, 1998

- Generator online with 30 MW, IPC mode, +77°F
- Opacity at 1.2%, O_2 at 6.3%, SO_2 at 0.6/.001, NOx at 0.217, CO at 1.0

Tuesday, July 21, 1998

- Unit 2 online at 27.6 MW, IPC mode

Tuesday, July 21, 1998

- Generator online with 29.4 MW, IPC mode, +58°
- Opacity at 1.0%, O_2 at 7.4%, SO_2 at 4.1/0.011, NOx at 0.189, CO at 0.7

Tuesday, July 22, 1998

- Unit 2 online at 26.9 MW, A Combustor Coal only

Tuesday, July 22, 1998

- Generator online with 28.4 MW, IPC mode, +66°
- Opacity at 1.1%, O_2 at 7.5%, SO_2 at 4.9/0.013, NOx at 0.245, CO at 0.7

Thursday, July 23, 1998

- Unit online at 29.6 MW, IPC mode

0620 Precombustor and slag combustor torches in

Thursday, July 23, 1998

- Generator online with 16.4 MW, IPC mode, +50°

0756 Tripped, MFT. Operator error, closed coal valve

Friday, July 24, 1998

- Unit 2 offline for maintenance

Friday, July 24, 1998

- Unit 2 offline for maintenance

Saturday, July 25, 1998

Saturday, July 25, 1998

- Unit 2 offline for shutdown

Sunday, July 26, 1998

Sunday, July 26, 1998

- Unit 2 offline

Monday, July 27, 1998

- Unit 2 offline for maintenance

Monday, July 27, 1998

- Unit 2 offline for shutdown

Tuesday, July 28, 1998

Tuesday, July 28, 1998

- Plant shutdown for maintenance, +51°

Wednesday, July 29, 1998

- Plant shutdown

Wednesday, July 29, 1998

- Plant shutdown for maintenance, +52°

Thursday, July 30, 1998

- Unit offline for maintenance

Thursday, July 30, 1998

- Plant shutdown for maintenance, +70°

Friday, July 31, 1998

- Plant shutdown for maintenance

Friday, July 31, 1998

- Plant shutdown for maintenance, +58°