DOE/PC/91160--T11

FINAL

DEVELOPMENT AND TESTING OF A HIGH EFFICIENCY ADVANCED COAL COMBUSTOR PHASE III INDUSTRIAL BOILER RETROFIT

DOE CONTRACT NO. DE-AC 22-91PC91160

C-E CONTRACT NO. 33691

Contract Period of Performance: 9/30/91 to 12/31/96

Technical Progress Report No. 17
Technical Progress Report No. 18
Technical Progress Report No. 19

Period Covered by Report: October 1, 1995 to June 30, 1996

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July 29, 1996

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Executive Summary

The objective of this project is to retrofit a burner, capable of firing microfine coal, to a standard gas/oil designed industrial boiler to assess the technical and economic viability of displacing premium fuels with microfine coal. This report documents the technical aspects of this project during the last three quarters [seventeenth (October '95 through December '95), eighteenth (January '96 through March '96), and nineteenth (April '96 through June '96)] of the program.

The overall program has consisted of five major tasks:

1.0 A review of current state-of-the-art coal firing system components.
2.0 Design and experimental testing of a prototype HEACC (High Efficiency Advanced Coal Combustor) burner.
3.0 Installation and testing of a prototype HEACC system in a commercial retrofit application.
4.0 Economics evaluation of the HEACC concept for retrofit applications.
5.0 Long term demonstration under commercial user demand conditions.

During this reporting Task 5 Long term (~1000 hrs) demonstration testing was successfully completed with the ABB's new RSFC microfine coal burner per Demonstration Test Plan. The test plan consisted of four (4) key area as follows:

1. Establishing the effect of burner operational parameters within the envelope of the Penn State boiler.

2. Establishing the effect of boiler operational parameters on burner performance.

3. Characterizing burner and boiler operation under startup and shutdown operation and switching from natural gas to coal and the reverse.

4. Establishing the effects of ash deposition on burner and boiler performance and assessment of ash management.

Figure 1 depicts the areas identified above in a schedular fashion. A decision to use RSFC burner during the Task 5 testing instead of HEACC burner (Task 3) was to improve both combustion efficiency and NOx in this Penn State boiler, in which the bulk residence time is only about 0.7 seconds. The RSFC burner has demonstrated, as expected, better performance (lower NOx and higher combustion efficiency) during the Task 5 ~1000 hr testing compared to the HEACC (Task 3 ~400 hr testing). Figure 2 shows NOx vs. Combustion Efficiency for both HEACC and RSFC burners. At ~450 ppm (0.6 lb/MBtu) NOx emissions (which is the project target), combustion efficiencies of ~97% (somewhat below ~98%, project target) can be maintained during the continuous operation. At the higher NOx (~500 -600 ppm) emissions, ~98 - 99% can also be achieved with the new RSFC burner. With the HEACC burner (Task 3) the highest combustion efficiency while maintaining the NOx emissions target (~450 ppm) was ~95.3%.

Figure 1 Plan /Schedule for Task 5 -1000 Hour Demonstration Phase Testing

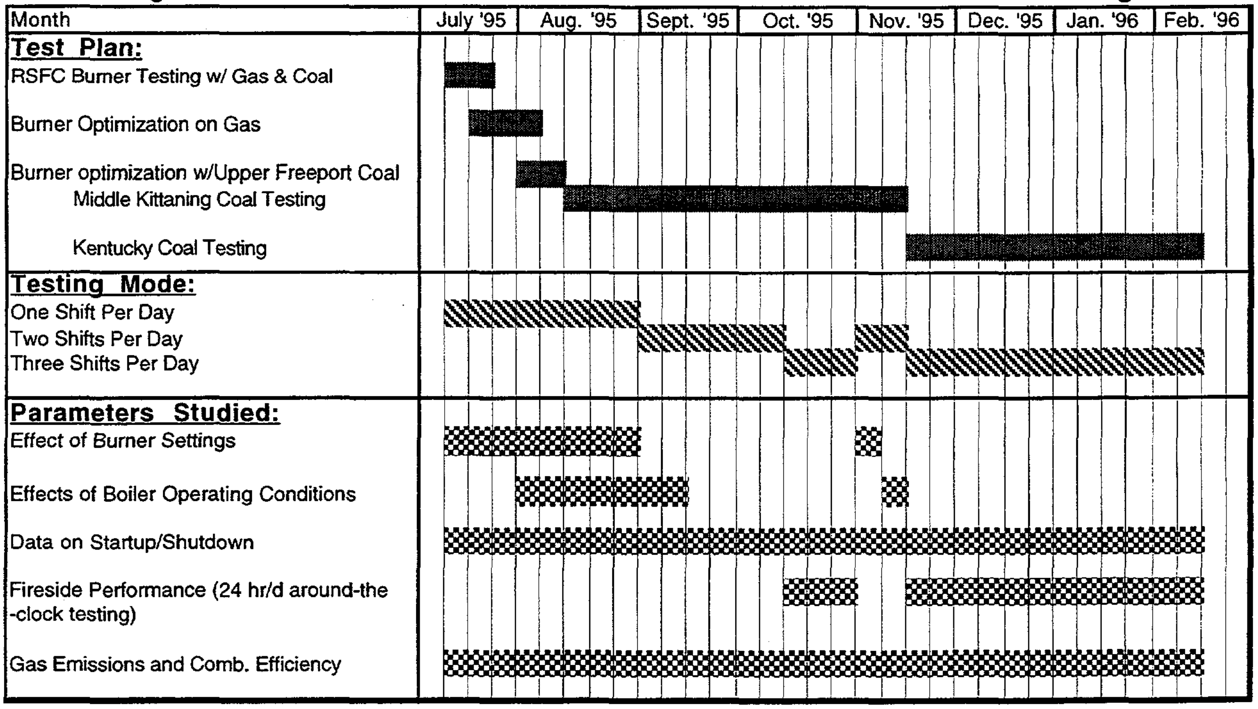

Table 1 Selected Analysis of the Coals

Analysis	HEACC (Task 3) Used for 400 hr Testing		RSFC (Task 5) Used for 1,000 hrs Testing		
	Brookville	Kentucky	Upper Freeport	Middle Kittanning	Kentucky
Proximate, Wt%					
Moisture	8.2	6.3	4.3	3.8	4.5
Volatile Matter	33.1	33.3	30.6	29.8	33.4
Fixed Carbon	55.8	55.4	58.9	62.2	58.8
Ash	2.9	4.5	6.2	4.2	3.3
HHV, Btu/lb	13,250	13,010	13,430	14,010	13,700
Ash Fusion Temp. °F					
IDT	2,820	2,803	-	2,432	2,544
ST	+3,000	+3,000	-	2,506	2,800
FT	+3,000	+3,000	-	+2,800	+2,800

Three different coals were tested as part of the Task 5 demonstration testing period. Upper Freeport was used exclusively during the beginning of the demonstration testing for purposes of assessing the effect of changing burner operational parameters. Middle Kittanning and Kentucky coals were used during the around-the-clock-testing periods when ash deposition effects were the focus of the testing.

Figure 2

NO_x vs. Combustion Efficiency for HEACC and RSFC Burners in PSU's Boiler Firing Microfine Coal

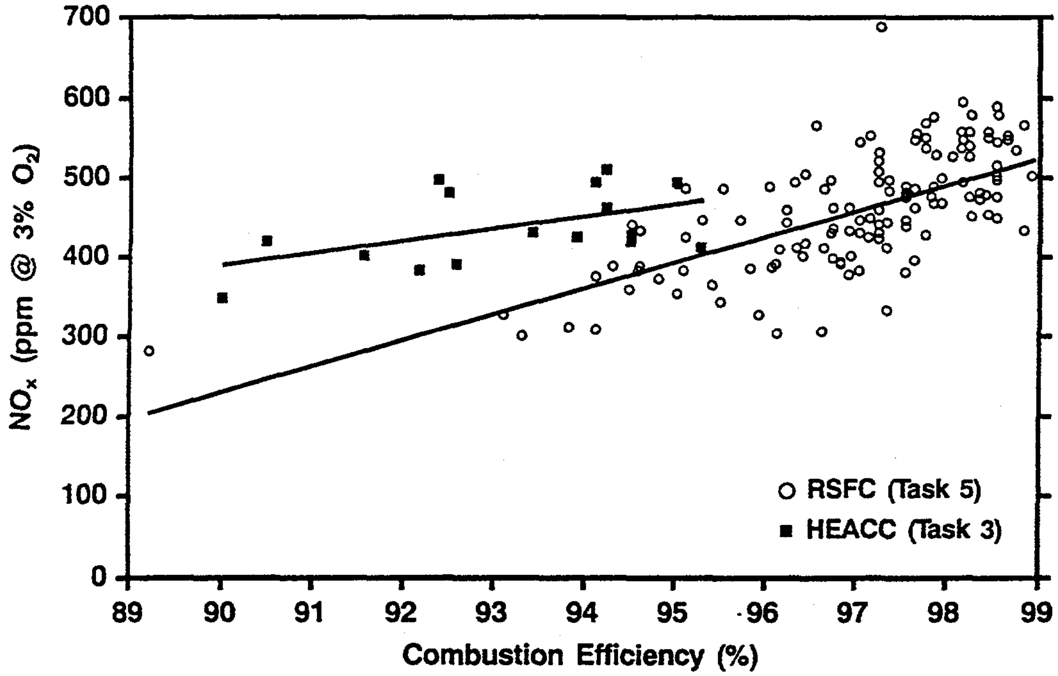

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Table 1 shows the analysis of the coals mentioned as well as the coals that had been tested under earlier Tasks in the project with the HEACC. All of the coals are low ash with respectably high fusibility temperatures, the idea being to minimize impacts of ash on boiler operation.

Total hours accumulated firing natural gas, cofiring natural gas and micronized coal, and 100% micronized coal are as follow:

Date	Hours Firing Natural Gas	Hours Cofiring Natural Gas and Micronized Coal	Hours Firing Micronized Coal
July 1995	55.7	4.0	8.7
August 1995	46.0	9.0	74.7
September 1995	2.9	1.8	31.6
October 1995	27.4	6.5	182.6
November 1995	11.1	3.2	219.3
December 1995	2.8	0.3	136.9
January 1996	4.9	2.5	192.3
February 1996	23.3	3.3	156.4
TOTAL	174.1	30.6	1,002.5

The data reduction /evaluation and interpretation from the Task 5 were completed. Two technical papers: (1) "Demonstration of Microfine Coal Firing with the RSFC Burner in a Gas/Oil Designed Industrial Boiler" was presented at the 21 st International Technical Conference on Coal Utilization & Fuel Systems, held in Clearwater, Florida, during March 18-21, 1996; (2) "Firing Microfine Coal in the RSFC Burner for 1000 Hours in a Gas/Oil Designed Industrial Boiler" was prepared for First Joint Power and Fuel Systems Contractor's Conference, held in Pittsburgh, Pennsylvania, during July 9 -11, 1996.

The following specific conclusions are based on results of the Task 5 Demonstration Testing in the Penn State Boiler:

- NOx levels when firing natural gas with the RSFC burner ranged from 45 to 55 ppm for a clean furnace and 60 to 70 ppm for a dirty furnace compared to values of 140 to 200 ppm for the HEACC under clean or dirty conditions.

- Short term testing (less than 12 continuous hours) has shown the RSFC burner to be able to achieve NOx levels in the Penn State boiler ranging from 350 to 450 ppm while achieving combustion efficiencies of 96.5% to 97.5%. The HEACC (Task 3) had comparable NOx values, 350 to 450 ppm, and lower combustion efficiencies 94% to 95%. The RSFC burner has shown its ability to attain higher combustion efficiencies under comparable conditions.

- Long term testing has shown a tendency toward increasing both NOx and combustion efficiency with time. It is believed that the growth of ash deposits on waterwall tubes causes temperatures to increase which adversely affect thermal NOx and work in favor of increasing combustion efficiency.

- Based on long term results in the Penn State boiler management of ash deposits and ash removal when burning coal in a boiler designed for oil and gas is a concern if the boiler is to be operated for periods greater than about one week. For the long term test of 136 hours, about 16% of the ash in the as-fired coal was retained in the radiant section of the furnace with no means of removal other than manual removal when the boiler was taken off line.

- When firing coal the Penn State boiler must be operated at about 80% of its rated capacity to avoid producing excessively high temperatures entering the bag filter.

- Burner startup and shutdown as well as flame stability and scanner signal strength during long term testing were all excellent.

- The Penn State boiler with a volumetric heat release rate of 50,000 Btu/ft^3-hr, a bulk residence time of 0.7 seconds and a design steam production rate of 15,000 lb/hr represents the most challenging end of the spectrum for retrofitting coal in an oil/gas designed boiler.

During the next quarter we plan to continue and complete preparation of the Task 5 Report. Also prepare and submit a commercialization plan (Task 4) to DOE/PETC.

1.0 Introduction

The objective of this project is to retrofit a burner capable of firing microfine coal to a standard gas/oil designed industrial boiler to assess the technical and economic viability of displacing premium fuels with microfine coal. A complete microfine pulverized coal milling and firing system will be retrofitted to an existing 15,000 lb/hr package boiler located in the East Campus Steam Plant of the Pennsylvania State University.

Following a brief burner confirmation test at ABB/CE's Power Plant Laboratories, the complete retrofit milling and firing system at Penn State will be run for a total of 400 hours on microfine coal to obtain performance and economic data for comparison against a base fuel (natural gas) case. Pending acceptable technical and economic results, a 1000 hour test will then be run under normal user demands to evaluate the system's capability to perform acceptably under field conditions. It is expected that a successful outcome of this program will help facilitate the acceptance of clean coal technology by American industry. The technical approach chosen for this program, namely direct firing of dry microfine pulverized, low ash coal is the fastest track technology available to displace significant quantities of oil and natural gas in industrial equipment.

2.0 Task 1 Design, Fabricate and Integrate Components

Complete

3.0 Task 2 Preliminary System Tests at ABB Combustion Engineering

Complete

4.0 Task 3 Proof-of-Concept-Tests at Penn State

Complete

5.0 Task 4 Economic Evaluation and Commercialization Plan

No work was scheduled or performed during this quarter.

6.0 Task 5 Site Demonstration

6.1 Summary of Activities

During this reporting Task 5 Long term (~1000 hrs) demonstration testing was successfully completed with the ABB's new RSFC microfine coal burner per Demonstration Test Plan. Approximately 174, 31, and 1003 hours have been accumulated firing natural gas, cofiring gas and micronized coal, and 100% micronized coal, respectively, during this demonstration.

The following specific conclusions are based on results of the Task 5 Demonstration Testing in the Penn State Boiler:

- NOx levels when firing natural gas with the RSFC burner ranged from 45 to 55 ppm for a clean furnace and 60 to 70 ppm for a dirty furnace compared to values of 140 to 200 ppm for the HEACC under clean or dirty conditions.

- Short term testing (less than 12 continuous hours) has shown the RSFC burner to be able to achieve NOx levels in the Penn State boiler ranging from 350 to 450 ppm while achieving combustion efficiencies of 96.5% to 97.5%. The HEACC (Task 3) had comparable NOx values, 350 to 450 ppm, and lower combustion efficiencies 94% to 95%. The RSFC burner has shown its ability to attain higher combustion efficiencies under comparable conditions.

- Long term testing has shown a tendency toward increasing both NOx and combustion efficiency with time. It is believed that the growth of ash deposits on waterwall tubes causes temperatures to increase which adversely affect thermal NOx and work in favor of increasing combustion efficiency.

- Based on long term results in the Penn State boiler management of ash deposits and ash removal when burning coal in a boiler designed for oil and gas is a concern if the boiler is to be operated for periods greater than about one week. For the long term test of 136 hours, about 16% of the ash in the as-fired coal was retained in the radiant section of the furnace with no means of removal other than manual removal when the boiler was taken off line.

- When firing coal the Penn State boiler must be operated at about 80% of its rated capacity to avoid producing excessively high temperatures entering the bag filter.

- Burner startup and shutdown as well as flame stability and scanner signal strength during long term testing were all excellent.

- The Penn State boiler with a volumetric heat release rate of 50,000 Btu/ft^3-hr, a bulk residence time of 0.7 seconds and a design steam production rate of 15,000 lb/hr represents the most challenging end of the spectrum for retrofitting coal in an oil/gas designed boiler.

6.2 Summary of Monthly Activities

This section contains a summary of the activities conducted at Penn State from October 1995 through June 1996.

October '95
During October, activities focused on completing the feedwater pump installation and continuing Task 5 Demonstration testing with the RSFC-based burner, as per test plan. Results to date with the RSFC-based burner testing while firing 100% Middle Kittaning coal show that the Penn State boiler can be operated on a continuous basis while

maintaining NOx emissions at ~360 - 420 ppm (less than 443 ppm (0.6 lb/MBtu), which is the project target) and combustion efficiencies of ~96 - 97% (somewhat below ~ 98%, project target). Excellent flame shape/stability can be maintained with this RSFC-based burner. At the higher NOx (~600 ppm) emissions, ~98-99 % combustion efficiency can also be achieved. Long-term on-going testing will provide information/data on management of ash and its impact on boiler performance. A day-by-day synopsis of the Penn State boiler operation for October follows:

- October 2 through 5 -- The feedwater pump arrived on October 2 and was set into place. Since the location of the new feedwater pump inlet was not identical to that of the old pump, repiping was necessary. In addition, the electrical hookups were completed and the boiler operated to check out the pump.
- October 6 -- The boiler was operated to complete checking out the pump.
- October 9 -- ABB CE personnel were on site and the modified burner (radial scoops were installed on three of the six tertiary air scoops by ABB CE) was fired on natural gas and on micronized coal. The burner was operated with the primary air damper 100% open, the secondary air damper 100% open, the tertiary air damper 50% open, and the axial inlet 0% open (100/100/50/0; Subsequent discussions of damper settings will use this type of identification) when firing coal and collecting particulate samples from the cyclone (located in the ducting prior to the baghouse) and baghouse outlet. Coal combustion efficiency, based on the baghouse sample (subsequent combustion efficiencies are based on the baghouse sample), averaged 93.3±0.7%. NO_x and CO emissions averaged 297 and 219 ppm, respectively, at an O_2 concentration of 3.6%.
- October 10 -- The boiler was operated for approximately two hours on coal to evaluate the effect of the radial scoops. The radial scoops caused turbulence within the tertiary air zone which reduced the swirl number. The boiler was shutdown and the burner removed. Modifications to the radial air inlets were started, which involved removing the scoops and installing a damper over the inlet, which was flush with the tertiary air barrel.
- October 11 -- The axial air inlet modifications were completed and the burner reinstalled. Two tests were conducted firing micronized coal. The damper settings during these tests were 100/100/50/0 and 100/100/50/25. Coal combustion efficiencies for the tests were 95.1±0.8 and 96.1±0.5%, respectively. NO_x and CO emissions and O_2 concentrations were 380 and 369 ppm, 130 and 125 ppm, and 3.6 and 3.8%, respectively, for the two tests.
- October 12 -- Two shifts per day operation was conducted for October 12 and 13. Tests No. 1 and 2 were conducted and the results are contained in the coal-fired summary sheet.
- October 13 -- Tests No. 3 and 4 were conducted and the results are contained in the coal-fired summary sheet.
- October 16 -- Three shifts per day operation was conducted for the week of October 16. The operation was to investigate deposition and perform matrix testing. Tests No. 6, 7 and 8 were completed and the results are contained in the coal-fired summary sheet.

- October 17 -- Tests No. 9, 10, 11A, 11B, 13, and 14 were completed and the results are contained in the coal-fired summary sheet. Test No. 12 was replaced with Tests No. 11A and 11B, 0/100/50/75 and 0/100/50/25, respectively.

  The cage mill was packed with coal during Test No. 14 and coal could not be transferred from the 25-ton main hopper to the 3-ton surge hopper; consequently, the boiler was down for approximately two hours.
- October 18 -- Tests No. 15, 16, 17, 18, and 19 were completed and the results are contained in the coal-fired summary sheet. Upon the conclusion of Test No. 16, a mill isolation valve (knife valve between the mill and burner) inexplicably closed. The boiler was brought back on line without any further incident. Penn State's Office of Physical Plant informed EFRC that there was an electrical spike at the East Campus Steam Plant (next door to the demonstration boiler) around the time of the valve closure. The normally closed valve is pneumatically operated. Possibly the electrical spike caused a fluctuation in Penn State's air compressors, which in turn caused the valve to close due to insufficient air pressure to keep it open.

  The dampers were set to conduct Test No. 20 and the flame was observed to be on the back wall. The test was not conducted and testing continued with Test No. 21.
- October 19 -- Tests No. 21, 22, 25, and 29 were completed and the results are contained in the coal-fired summary sheet. Tests No. 23, 24, 26, 27, and 28 were not conducted because the flame was on the back wall.
- October 20 -- Tests No. 30, 31, 33, and 35 were completed and the results are contained in the coal-fired summary sheet. Test No. 32 was not conducted because the flame was on the back wall during Test No. 31; damper settings for Test No. 32 would have resulted in a long flame also.
- October 23 -- The boiler was not operated because the site was prepared for an open house on October 24.
- October 24 -- Testing resumed with two shift per day operation. Two tests were conducted with damper settings of 100/100/50/0 and coal transport air levels of 385 and 340 acfm.

  A Micronized Coal transfer session was held at Penn State and was attended by delegates from New State Electric & Gas Corporation, CONSOL, Eastman Kodak, and the U.S. Department of Energy. Presentations were given by Penn State, ABB CE, and TCS Inc. (mill manufacturer), and the boiler was toured during micronized coal firing.
- October 25 -- Two tests were conducted with damper settings of 100/100/50/0 and coal transport air levels of 300 and 400 acfm.
- October 26 -- The boiler was cleaned to remove ash from the furnace and the breaching which connects the boiler outlet to the heat-pipe heat exchanger. This was done in preparation of a 12-day test (24 hour/day operation over a two week period including the weekend). Work on assembling a new floor air sparge system was started.
- October 27 -- The air sparge system was completed and installed. The boiler was prepared for the testing to begin on midnight Sunday (October 29).
- October 30 -- The continuous test began at midnight Sunday (October 29). The boiler was brought down at 0800 hours to repair the chemical feed line

into the steam drum. Steam was leaking around the pipe. Coal firing resumed at ~1600 hours.

- October 31 -- Continuous micronized coal testing was conducted. ABB CE performed in-furnace testing. The furnace was mapped for gaseous concentration, temperature, and heat flux. In addition, an in-furnace camera was used to observe and record the inside of the furnace, and Penn State used an in-situ particle counter-sizer-velocimeter to map the furnace.

November '95

During November, activities focused on continuing the long-term test series to investigate the ash deposition effects, replacing worn bagfilters in the baghouse, conducting combustion performance testing, and performing data reduction. The plan is to complete one continuous long-term test in which the boiler shut down is only due to the coal firing (i.e., ash deposition) but not due to any system related failure. A day-by-day synopsis of the Penn State boiler operation for November follows:

- November 1 -- A test to investigate deposition was started on Sunday, October 29, 1995 at midnight. The plans were to operate 24h/day for twelve days (two weeks of operation including the weekend). The boiler was brought down at 0800 hours (all time is referenced as military time) on October 30, 1995 to repair the chemical feed line into the steam drum. Steam was leaking around the pipe. Coal firing resumed at ~1600 hours and was fired for 24 hours on October 31, 1995.

  Operation on November 1 was a continuation of that on October 31, 1995. The burner was operated with the primary air damper 100% open, the secondary air damper closed (0% open), the tertiary air damper 25% open, and the radial damper closed (100/0/25/0; Subsequent discussions of damper settings will use this type of identification).

  The boiler was operated until 1230 hours and was shutdown to replace the bearing in the ash screw which transfers ash from the baghouse to the ash storage bin. While the bearing was being replaced, two thermocouples were installed on the end of the burner to monitor metal temperature (burner metal temperature is contained in the attached coal-fired summary sheet). Operation resumed at 2200 hours.

  Particulate samples were collected from the cyclone (located in the ducting prior to the baghouse) and baghouse outlet. Coal combustion efficiency, based on the baghouse sample (subsequent combustion efficiencies are based on the baghouse sample), averaged 98.5±0.1% for samples collected from 0000 to 0800 hours. NO_x and CO emissions averaged 573 and 107 ppm, respectively, at an O_2 concentration of 3.5%. Combustion results after replacing the ash screw bearing (2200 to 2400 hours) were 96.6% combustion efficiency, and 410 and 129 ppm NO_x and CO, respectively, at an O_2 concentration of 3.7%, damper settings of 100/100/50/50, and mill air flow of 320-340 acfm.

  ABB CE performed in-furnace testing which started ~2200 hours and continued into the morning of November 2 (0400 hours). The furnace was mapped for gaseous concentration, temperature, and heat flux.

- November 2 -- Continuous micronized coal testing was conducted from 0000 to 0930 hours with the damper settings at 100/100/50/50 and 320-340 acfm mill air flow. Coal combustion efficiency averaged 96.7±0.6% and NO_x and CO emissions averaged 430 and 150 ppm, respectively, at an O_2 concentration of 3.5%.

  Mill air flow was then increased to 380-400 acfm at 1030 hours and testing continued through 1200 hours on 11/03/95. The average combustion efficiency and emissions for this period were 96.3±0.6%, 172 ppm CO, and 408 ppm NO_x.

  ABB CE performed in-furnace testing on November 2 at the higher mill air flow rate. The furnace was mapped for gaseous concentration, temperature, and heat flux. In addition, Penn State used an in-situ particle counter-sizer-velocimeter to map the furnace.
- November 3 through 6 -- On November 3 at 1200 hours, the burner damper settings were changed to 100/100/50/0 to shorten the flame because it was striking the back wall. The boiler was operated at this set of conditions, with ~400 acfm mill air flow, until 1800 hours. At 1800 hours, the mill air flow was reduced and the boiler was operated at 350 to 385 acfm until it was shut down on November 6. Averaged results for this time period are contained in the coal-fired summary sheet.

  The boiler was shut down on November 6 at 1230 hours because ash was observed coming from the stack. A manhole in the baghouse hopper was opened and the bottom of the baghouse was inspected to determine if bagfilters had come loose and fallen into the hopper. Since none were found, it was suspected that there were bagfilters with holes. The top of the baghouse was opened to see if failed bags could be identified by ash on the plenum (bagfilter outlet to the ID fan). None could be identified during a brief inspection. It was too warm to work on the top of the baghouse; therefore, the top was closed and the baghouse was allowed to cool down prior to further action.

  The boiler was opened up to cool down in order to clean the furnace and breaching. In addition, equipment maintenance was conducted and data reduction performed.
- November 7 -- The top of the baghouse was opened again to identify failed bagfilters. However, it started to rain and work was stopped. The cleaning of the boiler was completed and data reduction continued.
- November 8 -- Pulverized limestone was fed into the boiler (with the ID fan on) and drawn into the baghouse. Six bags were found to be defective after opening the top of the baghouse and checking the plenum. The bags/cages were removed and lowered to the ground. In addition, data reduction continued.
- November 9 -- Six new bags were installed on the cages and they were reinstalled in the baghouse. Limestone was fed into the boiler to condition the bags. The plenum was checked and no leaks were detected. The boiler was then cleaned to remove excess limestone from the system. The floor air sparge system was assembled.
- November 10 -- Water and steam were introduced into the boiler and a cold startup was conducted to prepare for testing on Monday.

- November 13 and 14 -- The boiler was brought on line at midnight on Sunday, November 12, 1994 to conduct a week of continuous testing. After firing for two hours, the boiler was brought off line because the rotary valve located between the baghouse ash hopper and ash screw was not operating. The valve was made operational and testing resumed at 1200 hours and continued through 2230 hours on November 14. The boiler was operated with damper settings of 100/100/50/0 and mill air flows of 370 to 400 acfm. Testing was stopped on November 14 because water/oil were detected in the sample line.
- November 15 -- The analyzers were repaired and the boiler was brought back on line at the start of the midnight (November 16) to 8 a.m. shift.
- November 16 and 17 -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flows of 370 to 410 acfm.
- November 20 -- The boiler was drained of water and the ends of the steam and mud drum were removed in preparation of the yearly boiler inspection (conducted for insurance purposes). The furnace and breaching were cleaned of ash and 275 and 94 lb were removed, respectively. A new floor ash sparge system was constructed. In addition, data reduction was conducted.
- November 21 -- The boiler was inspected, the drums sealed, water and steam reintroduced into the boiler, and the boiler was brought on line. However, computer (data acquisition system) problems were experienced and the boiler was shut down until the next day.
- November 22 -- The computer for the data acquisition system was replaced and the system made operational. The boiler was operated from 1630 to 2230 hours with damper settings of 100/100/50/0 and mill air flows of 375 to 400 acfm.
- November 23 -- Thanksgiving Holiday
- November 24 -- Data reduction was conducted.
- November 27 -- Testing was not conducted because the boiler control panel did not have power. The system was made operational for testing the following day.
- November 28 -- The boiler was operated for one shift with damper settings of 100/100/50/0 and mill air flows of 380 to 400 acfm.
- November 29 -- The boiler was operated for one shift with damper settings of 100/100/50/0, mill air flows of 300 to 330 acfm, and a coal gun setting of 36.5" . All previous testing in November was with a coal gun setting of 39.5".
- November 30 -- The boiler was operated for two shifts with the first shift conducting testing with damper settings of 100/100/50/0, mill air flows of 300 to 330 acfm, and a coal gun setting of 39.5" . The second shift started testing with damper settings of 100/100/50/0, mill air flows of ~400 acfm, and a coal gun setting of 39.5". Testing was terminated after two hours because ash was again observed being emitted from the stack indicating that more bags were failing.

December '95
During this reporting period, activities focused on conducting a second long-term test to investigate deposition (the first was conducted in November 1995), replacing worn bagfilters in the baghouse, and continue performing data reduction. Plots of: (1) coal combustion efficiency as a function of time for testing conducted from November 28 through December 14, 1995 (the date of the last complete analysis), and; (2) NO_X and CO emissions as a function of time for testing from November 28 through December 14, 1995 are attached. A 136 hours of continuous around-the-clock ash deposition test was successfully conducted during this month (Dec.13 '95 to Dec. 19 '95). The boiler outlet pressure on Dec. 19 1995 decreased from ~1.0" W.C. to -1.5" at 7:00 am to -1.8" at 8:00 am. The entrance into the convective pass was nearly plugged and decision was made to shut down the boiler after 136 hours of continuous operation.

A day-by-day synopsis of the Penn State boiler operation for December follows:

- December 1 -- Testing was terminated on November 30, 1995 because ash was observed being emitted from the stack indicating that bags were failing. This was the second time this occurred in less than a month. During the first incident, six bags were found with holes and were replaced. This time a decision was made to replace all the bags (There is a total of 196 in the baghouse.) at one time rather than a few every three weeks.
  Activities included data reduction and equipment maintenance (i.e., replacing the transfer fan shaft and impellers).
- December 4 -- New bags were ordered with a partial delivery expected Friday, December 8, and the balance on Monday, December 11. Approximately 150 of the bags/cages were removed from the baghouse and put on top of the boilerhouse. The venturis and bags were removed from the cages, the bags were put into drums for disposal, and the cages and venturis were stacked on the roof of the boilerhouse.
- December 5 -- The remaining bags were removed, except for the six that were replaced in November, and twenty bags (which were on hand as spares) were installed.
- December 6 -- Site cleanup (from the bags removal) and data reduction were conducted.
- December 7 -- Site cleanup and data reduction were conducted.
- December 8 -- Data reduction was performed. The cages and venturis were brought down from the roof of the boilerhouse and stacked in the Fuel Preparation Facility in preparation for installing the first shipment of bags.
- December 9 (Saturday) -- The first shipment of bags were installed on 113 of the cages. The venturis were attached and the bags/cages were installed in the baghouse.
- December 11 -- The remaining 57 bags were installed on the cages.
- December 12 -- The venturis were attached on the remaining cages, and the bags/cages were installed in the baghouse. Limestone was put into the duct upstream of the baghouse to condition the bags.
- December 13 -- The deposition test was started. The boiler was operated continuously with damper settings of <u>100/100/50/0 and mill air flow of ~375 acfm.</u>

- December 14 -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flow of ~375 acfm.
- December 15 -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flow of ~375 acfm.
- December 16 (Saturday) -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flow of ~375 acfm.
- December 17 (Sunday) -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flow of ~375 acfm.
- December 18 -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flow of ~375 acfm. Sootblowing frequency increased from every two hours to every 1.5 hours.
- December 19 -- The boiler was shut down at 8:00 am after 136 hours of continuous operation. The boiler outlet pressure decreased from ~1.0" W.C. to -1.5" at 7:00 am to -1.8" at 8:00 am. The entrance into the convective pass was nearly plugged.
- December 20 -- Photographs of the ash deposition/accumulation in the boiler were taken. The boiler was cleaned and 780 and 215 lb of ash were removed from the furnace and breaching, respectively.
- December 21 -- Equipment repair was conducted. A steam regulator/valve was replaced.
- December 22 -- Christmas Holiday
- December 25 -- Christmas Holiday
- December 26 -- Christmas Holiday
- December 27 -- Christmas Holiday
- December 28 -- Christmas Holiday
- December 29 -- Christmas Holiday

January '96

During January, activities focused on conducting a third long-term test to investigate deposition (the first was conducted in November 1995; the second was conducted in December 1995), troubleshooting problems with the baghouse/bagfilters, and performing data reduction. A day-by-day synopsis of the Penn State boiler operation for January follows:

- January 1 -- Holiday
- January 2 through 5 -- Preparations were made for the third continuous deposition test to be started Monday, January 8 which included installing a new steam valve for the convective pass sootblower, replacing piping (nipple) to eliminate steam leaks, and installing a floor ash sparge system. Additional activities included reducing data, analyzing samples, and compiling data summaries.
- January 8 -- The third deposition test was started. The test was to begin at midnight (Sunday, January 7) but was delayed until 1600 hours (military time) due to a major snowstorm. A state snow emergency was in effect from 10:00 p.m. Sunday until noon Monday. The boiler was firing 100% coal at a rate of 18.6 lb/m starting at ~2300 hours.
- January 9 -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flow of ~370 to 400 acfm. The coal feed rate was

changed to 19.8 lb/m (to maintain a firing rate of 15.6 MM Btu/h) at 1630 hours after a new coal calorific value was received.

- January 10 -- The boiler came off line at 0130 hours due to low feedwater level in the steam drum. Penn State's steam plant personnel were making adjustments on the East Campus Steam Plant boilers and insufficient feedwater to the demonstration boiler resulted. The demonstration boiler was brought back on line and was firing 100% coal at ~0430 hours at a rate of 19 lb/m.

  The steam back pressure regulator valve (which regulates the steam flow from the boiler into the University's steam distribution line and hence the steam drum pressure) was not maintaining the desired ~200 psig pressure. The pressure was 120 to 185 psig resulting in steam flows exceeding 15,000 lb/h. Since the test was a deposition test, it was decided to continue operating but note the conditions the steam was produced at so that the boiler derating results would not be biased.

  The boiler was shut down at 1130 hours due to no coal available. A coal delivery was received from Bradford coal at ~1500 hours and the boiler was firing 100% coal at 1800 hours at a rate of 19.8 lb/m.
- January 11 -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flow of 365 to 395 acfm. The steam pressure was increased to ~210 psig and maintained at ~200 psig for the duration of the test after tapping on the back pressure valve.
- January 12 -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flow of 370 to 400 acfm except for one hour from 1700 to 1800 hours. The main coal storage hopper plugged resulting in a loss of coal feed. The boiler was back at 100% coal firing at 1800 hours. It was observed that some deposits burned off when bringing the boiler back on line.

  A hand-held lance, operated with compressed air, was constructed to remove ash deposits from the tubes at the convective pass entrance in order to keep the entrance clear and prolong boiler operation. The lance was inserted into a sight port located on the boiler sidewall directly across from the convective pass entrance with minimal success.
- January 13 (Saturday) -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flow of 370 to 395 acfm.
- January 14 (Sunday) -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flow of 375 to 400 acfm.
- January 15 -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flow of 375 to 400 acfm. Deposition became noticeable in convective pass and the boiler outlet pressure increased from ~-1.0 to -1.3" H_2O.
- January 16 -- The boiler was operated continuously with damper settings of 100/100/50/0 and mill air flow of 380 to 405 acfm until 1730 hours. The boiler outlet pressure increased to -1.8 to -1.9" H_2O at ~0500 hours and the gauge went off scale (-2.0" H_2O) at 1300 hours. The convective pass entrance was nearly plugged but the ID fan amperage (which is an indication of deposition in the convective pass) remained relatively unchanged. The boiler was shut down at 1730 hours due to a hot spot appearing on the back wall. A total of 176

hours of coal firing were obtained during this test with the last 95.5 hours continuous.

- January 17 -- Photographs of the ash deposition/accumulation in the boiler were taken and are attached. The boiler was cleaned and 858.3 and 82.5 lb of ash were removed from the furnace and breaching, respectively.
  Data reduction was performed.
- January 18 -- Activities included performing data reduction, hauling a load of fly ash to the Bradford ash disposal site, and removing and cleaning components of the back pressure regulator valve.
- January 19 -- Preparations for conducting a fourth continuous deposition test starting on January 22 were made which included repairing water lines (for conditioning the fly ash) on the ash screw and cleaning gas sample lines in the emissions monitoring system. In addition, data reduction was conducted.
- January 22 -- The third deposition test was started. The test was to begin at midnight (Sunday, January 21) but was delayed until 1530 hours due to water softener repair (on Penn State's power plant equipment). The boiler was operated with damper settings of 100/100/50/0. Coal feed was lost at 2100 hours due to the main coal hopper plugging. The boiler was brought back on line and data were recorded starting at 2230 hours.
- January 23 -- Fly ash was observed being emitted from the stack during sootblowing at 0400 hours. The boiler was shut down at 0700 hours.
  Limestone was fed into a port upstream of the baghouse in order to identify problem bagfilters. A ring of limestone was observed around two venturis. The two bagfilters were removed and inspected. No problems with them were noted. All the bagfilters were on the cages. All of the venturis were tightened and the baghouse top was closed.
  The boiler was brought on line at 2300 hours on natural gas. Natural gas was fired for several hours before switching to coal in order to heat the baghouse.
- January 24 -- Coal was introduced to the boiler at ~0330 hours and 100% coal firing was started at 0400 hours. Fly ash was again observed being emitted from the stack and the boiler was shut down at 0530 hours.
  Discussion were held with Air Engineering Services (AES), the local representative through which the baghouse was purchased, to order gaskets for the venturis and material to conduct a blacklight test (to determine if there were cracked welds on the tubesheet).
  Date reduction was performed.
- January 25 -- A order was placed for venturi gaskets and the materials for a blacklight test (fluorescent powder and blacklight). Activities included equipment maintenance and repair (i.e., plugging leaks in the transfer fan, steam valve leak). Data reduction was also performed.
- January 26 -- Data reduction and equipment maintenance and repair were conducted (i.e., steam valve leak).
- January 29 -- Data reduction and equipment maintenance and repair were conducted (i.e., plugging a leak in the boiler access door).
- January 30 -- Data reduction and routine equipment maintenance were conducted.

- January 31 -- The baghouse was inspected and found that the gasket between the tubesheet and two baghouse walls (inlet and outlet sides) was missing. High-temperature silicone was applied and allowed to dry overnight.

February '96

During February, activities focused on conducting a forth and final long-term test with cyclical load (firing 12 hrs @ 15.5 MBtu/hr and 12 hrs @ 12 MBtu/hr) to investigate ash deposition /management, sample analysis, and data reduction. Plots of coal combustion efficiency, NOx and CO emissions as a function of time for testing conducted from February 7 through February 19, 1996 are attached. A summary of the fourth deposition test results is also attached. On February 19, the subject Task 5 Demonstration testing was completed with cumulative (including all the short and long -term tests during July '95 through February '96) 1,002.5 hours of 100% micronized coal firing. A day-by-day synopsis of the Penn State boiler operation for February follows:

- February 1 -- The RSFC burner with the movable-block swirl generating arrangement was tested firing natural gas under the direction of ABB/CE personnel. The burner was removed at the end of the day and ~65% of the primary and secondary air areas were closed off by welding plates over the air inlets.
- February 2 -- EFRC and ABB/CE personnel were informed by Office of Physical Plant (OPP) personnel that the gas company (Columbia Gas) was implementing a natural gas curtailment effective Saturday, February 3, 1996 at 8:00 am due to very cold weather. It was the intention to operate the boiler for ABB/CE on Saturday, and possibly Sunday, to obtain performance data. However, after receiving word about the gas curtailment, it was decided to operate the boiler through the night and shut down prior to the 8:00 am deadline.

  The burner was reinstalled and testing continued firing natural gas. The burner was removed at noon and additional open combustion air areas were covered. Rather than incrementally closing off air inlet area, it was decided to close off the maximum possible area that could be tolerated before the welder went off work. As open area was needed, the burner would be removed and plates ground off the air inlets. No significant improvement was observed with the movable-block swirler.
- February 5 -- The natural gas curtailment was still in effect. Activities focused on analyzer repair and equipment maintenance.
- February 6 -- The natural gas curtailment was still in effect. Activities focused on analyzer repair and equipment maintenance.
- February 7 -- The natural gas curtailment was lifted. The RSFC was reinstalled in order to conduct a final continuous/deposition test planned to begin on February 12, 1996. The boiler system was fired using natural gas for several hours in order to heat the system. Micronized coal was fired for ~1.5 hours to check for fly ash emissions from the system. No ash was observed.

- February 8 -- The boiler was fired on coal for a second day to check for fly ash emissions. Ash was observed emitting from around the cyclone sampling port prior to the baghouse. The leak was fixed and the system readied for the continuous/deposition test.
- February 9 -- Final preparations were completed for the continuous/deposition test to start on February 12.
- February 12 -- Continuous/deposition test #4 was started at 0000 hr (military time; Sunday night midnight). The boiler was firing 100% coal at 0500 hr with damper settings of 100/100/50/0 (primary air/secondary air/tertiary air/radial damper) and 19 lb coal/m (~15.2 MM Btu/h).

  The hand-held air lance that was constructed last month to remove ash deposits from the tubes at the convective pass entrance was modified. The end was modified by reducing the number of openings for the compressed air from four (1 axial and 3 radial) to one (radial).
- February 13 -- The boiler was operated continuously with damper settings of 100/100/50/0. The firing was reduced to 12.0 MM Btu/h (15 lb coal/m) at 0830 and operated at the lower load for eight hours to simulate reduced steam demand. At 1630 hours the firing rate was increased to 15.6 MM Btu/h (19.5 lb coal/m).
- February 14 -- The boiler was operated continuously with damper settings of 100/100/50/0. The firing was reduced to 12.0 MM Btu/h at 0830 and operated at the lower load for eight hours. At the lower firing rate the flame was longer and impinged on the back wall. The mill air flow was reduced from ~380 acfm to ~350 acfm and the O_2 concentration was increased from ~3.7% to 4.2% to reduce the flame length. At 1645 hours the firing rate was increased to 15.6 MM Btu/h.

  The hand-held air lance was not able to remove ash deposits building on the tubes at the convective pass entrance.
- February 15 -- The boiler was operated continuously with damper settings of 100/100/50/0. The firing was reduced to 12.0 MM Btu/h at 0830 and operated at the lower load for eight hours. To shorten the flame, the O_2 concentration was increased from 3.7% to 5.3% . At 1630 hours the firing rate was increased to 15.6 MM Btu/h.

  The boiler was shut down at 2300 hr because a screwdriver was dropped into the Redler conveyor (conveyor located between the cage mill and surge bin) while trying to unplug the cage mill of packed coal. Portions of the conveyor were disassembled in order to find and remove the screwdriver to ensure that it would not pass through the coal feed system in the TCS mill.
- February 16 -- The screwdriver was retrieved, the Redler reassembled, and the boiler was fired with 100% coal at a firing rate of 15.6 MM Btu/h at 0400 hours with damper settings of 100/100/50/0. The firing rate was reduced to 12.0 MM Btu/h at 0830 hr and operated at the lower load for eight hours. To shorten the flame, the O_2 concentration was increased from 3.7% to 5.3% . The coal feed rate was increased from 15 lb/m to 17 lb/m at 1630 hr and to 19.5 lb/m (15.6 MM Btu/h) at 1830 hr.
- February 17 (Saturday) -- The firing rate was reduced to 12.0 MM Btu/h at 0830 hr and the dampers changed to 100/100/28/0 in order to reduce the length of the flame. Because of a significant buildup of ash on the

convective pass entrance, it was decided to maintain the lower firing rate for the duration of the testing. The O_2 concentration was increased from 3.6% to 5.0%.

The boiler was shutdown at 2230 hr due to ash plugging the convective pass entrance. The continuous/deposition test length was a total of 133.6 hours with 90.8 hours accrued from 02/12/96 through 02/16//96 and 42.8 hours from 02/16/96 and 02/17/96. Approximately 984 total hours of 100% micronized coal-fired operation was obtained in Task 5.0 from July 1995 to February 12, 1996.

- February 18 (Sunday) -- Photographs of the ash deposits were taken and copies are attached. The ash was removed from the firebox and breaching, the ducting connecting the boiler outlet with the heat pipe heat exchanger. A total of 479.1 lb was removed, 381.5 lb from the firebox and 97.6 from the breaching.

  The boiler was brought back on line in order to obtain the 1,000-hour milestone firing 100% micronized coal. The boiler was fired at 20 lb coal/m with damper settings of 100/100/28/0.
- February 19 -- The boiler was continuously operated until 1630 hours which produced 1,002.5 cumulative hours firing 100% micronized coal during Task 5.0 testing. During the last day of operation, the coal feed was reduced to 19 lb/m at 0130 hr and to 15 lb/m (12.0 MM Btu/h) at 0730 hr.
- February 20 - 29 -- Activities included sample analysis and data reduction.

March '96

During March, activities included sample analysis and data reduction from the forth continuous/deposition test. Continued compiling and reducing Task 5.0 data /results and started working on Task 5 report.

A technical paper (Attachment A) "Demonstration of Microfine Coal Firing with the RSFC Burner in a Gas/Oil Designed Industrial Boiler" was presented at 21st International Technical Conference on Coal Utilization & Fuel Systems, held in Cleartwater, Florida, during March 18 -21.

April '96

During April, activities included data/results interpretation from the Task 5 1000 hrs demonstration testing. Continued working on Task 5 Report. The abstract was submitted for "First Joint Power and Fuel Systems Contractors Conference" to be held in Pittsburgh, PA., during July 9 -11, 1996.

May '96

Continued working on Task 5 Report. A technical paper (Attachment B) "Firing Microfine Coal in the RSFC Burner for 1000 Hours in a Gas/Oil Designed Industrial Boiler" was prepared for the "First Joint Power and Fuel Systems Contractors Conference" to be held in Pittsburgh, PA., during July 9 -11, 1996.

June '96
Continue working on Task 5 Report. Prepared a technical presentation for the next month (July 9 -11, 1996) DOE/PETC Contractors Conference.

Summary of micronized coal-fired testing and all the graphs of coal efficiency and emissions as function of time during the Task 5 testing are in Appendix C and D, respectively.

6.3 Next Quarter's Plan -

During the next quarter we plan to continue and complete preparation of the Task 5 Report. Also prepare and submit a commercialization plan (Task 4) to DOE/PETC.

Attachment A

DEMONSTRATION OF MICROFINE COAL FIRING WITH THE RSFC BURNER IN A GAS/OIL DESIGNED INDUSTRIAL BOILER

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Presented at:

The 21st International Technical Conference on
COAL UTILIZATION & FUEL SYSTEMS

March 18 - 21, 1996
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ABSTRACT

This paper provides initial indications of performance of ABB CE Services's low NOx, Radially Stratified Flame Core (RSFC) burner, in the subject case having the capability of firing natural gas and/or microfine pulverized coal in a boiler designed for oil and natural gas firing. The RSFC burner tested represents a scaled up version of a burner developed and patented by the Massachusetts Institute of Technology (M.I.T.). The work described in this paper has been carried out under a U.S. Department of Energy, Pittsburgh Energy Center Technology Center (DOE-PETC) sponsored project with ABB Power Plant Laboratories (ABB PPL) as the prime contractor and Penn State University, specifically the Energy and Fuels Research Center, working as a subcontractor to ABB PPL. The burner was fired in Penn State's 15,000 lb/hr steam, Tampella Keeler boiler, which has been specifically designated for carrying out R&D work. Most of the information presented in this paper has been generated during Task 5 of the DOE-PETC Project which represents the long term testing phase of the project.

BACKGROUND / INTRODUCTION

The objective of the DOE-PETC sponsored project has been to determine the technical and economic feasibility of firing microfine pulverized coal in an oil/natural gas designed boiler. Specific targets were set at 0.6 lb NOx/million Btu (~450 ppm) and 98% combustion efficiency.

The DOE-PETC project has been in progress for several years, and during much of the time work has centered around development and testing of the High Energy Advanced Coal Combustor (HEACC). The HEACC has been described in previous papers (Rini, et. al., 1987, 1988; Toqan, et al., 1988).

During 1994 ABB PPL began working, as part of an internally-funded project, to scale up the low NOx, RSFC burner in partnership with M.I.T.; the initial focus was on firing natural gas and No. 6 fuel oil. Earlier results (DOE-PETC Project:Task 3) from testing the HEACC on microfine coal at Penn State had shown it to meet the NOx target, but to fall short of the combustion efficiency target. Given the knowledge base that both M.I.T. and ABB PPL had compiled when firing natural gas, oil and pulverized coal and the operating principle of the RSFC burner, it was believed that it could provide improved combustion efficiencies over that of the HEACC in the Penn State boiler while maintaining the target NOx levels when firing microfine coal. During M.I.T's previous testing of the RSFC burner on pulverized coal, excellent results were achieved, which further indicated that improvements in combustion efficiency should be possible if the RSFC burner were installed in the Penn State boiler. It should be noted that the bulk residence time in the M.I.T. Combustion Research Facility (CRF), where the RSFC burner was tested, was significantly greater, at about 2.5 seconds, than the residence time in the Penn State boiler, which is on the order of 0.7 seconds.

A decision was made to switch from testing the HEACC burner, under the long term testing phase (Task 5) of the project, to installing and testing the RSFC burner. It was also agreed that ABB PPL would design, build and provide the properly sized RSFC burner at no cost to the DOE-PETC project.

Task 5 represents the final phase of the project with the previously completed tasks as follows:

1.0 A review of current state-of-the-art coal firing system components.
2.0 Design and experimental testing of a prototype HEACC.
3.0 Installation and testing of a HEACC system in a simulated commercial retrofit application.
4.0 Economic evaluation of the HEACC concept for retrofit applications.
5.0 Long term demonstration under simulated commercial user demand conditions.

Results of Tasks 1 through 4 have been summarized in previous technical publications (Patel, et. al.,1995; Jennings, et. al., 1993, 1994; Rini, et al.,1993).

This paper provides initial information from the long term testing task, wherein micro-fine pulverized coal was fired, and it also provides information on the performance of the RSFC burner when firing natural gas.

DESCRIPTION OF THE RSFC BURNER

Many burners employ swirling flows to enhance mixing in the near-burner flow field. The RSFC burner is, however, different in that swirling flow is used to create the opposite effect, namely delay of mixing in the near-burner zone (Borio, et. al., 1995). It is this combination of a near-burner, high temperature, fuel rich core followed by a downstream, fuel lean combustion zone that are responsible for the low NOx generated by the RSFC burner.

The delay of mixing is brought about through stratification between the fuel jet and the surrounding, swirling combustion air. The key phenomena upon which this stratification depends are turbulence and turbulent mixing dampening at the flame/air interface. In the RSFC multi-annular burner, the fuel enters in the center of an inner air annulus with low mass flows which are strongly swirling. Turbulence dampening results from a swirl-induced centrifugal force field acting on a radial density gradient set up by the density difference between the hot burning fuel core and the surrounding, cooler combustion air. This results in a radially stratified flow in which relatively cool, dense combustion air remains at the outside of a hot, less dense core for an extended mixing length. A typical low NOx RSFC flow field is depicted in Figure 1. The concept of radial stratification originated with the work of Rayleigh (Beér and Chigier, 1972), and was brought to practical application by Beér, et al. (1970). This phenomena has been applied at M.I.T. to design the radially stratified flame core burner now known as the RSFC burner.

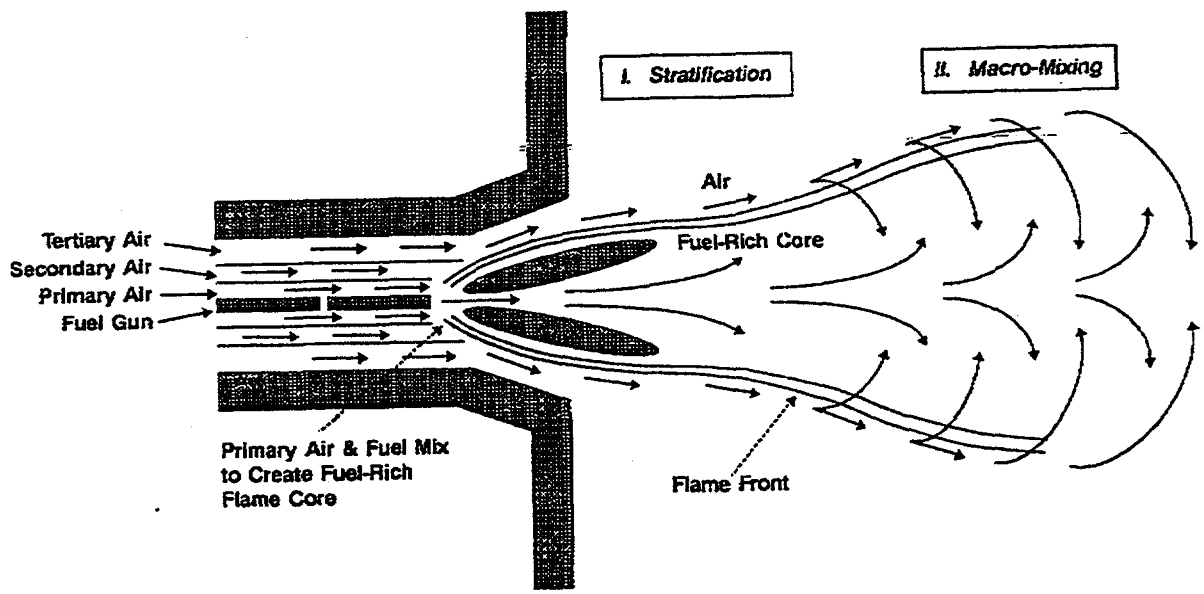


Figure 1 Typical Low NOx RSFC Flow Field

Using the principle of turbulence dampening by the suitable combination of the inertial force (centrifugal force) and a positive radial density gradient in a rotating burner air flow (Toqan, et al., 1992), the RSFC burner has been under development at M.I.T. since 1989. Figure 2 shows a schematic of the M.I.T. RSFC burner and the three independently-controlled air annuli. Swirl number and mass air fractions were individually controllable on the M.I.T. RSFC burner.

The RSFC burner that was designed and built for testing in the Penn State boiler is, operationally, the similar to the M.I.T. burner, but with different swirlers and the ability to co-fire or fire independently natural gas and pulverized coal at firing rate of about

18×10^6 Btu/hr and 16×10^6 Btu/hr, respectively. Figure 3 shows a schematic representation of the RSFC burner tested at Penn State. Natural gas is fired from an annulus around the coal nozzle. Dampers in the tangential air inlet scoops can be used to control air flow and swirl number.

DEMONSTRATION TESTING

Objective

The objective of this phase of the project was to characterize burner and boiler performance under long term testing conditions that were representative of typical industrial boiler operation.

Facilities

The boiler in which tests were carried out at Penn State is a Tampella Keeler Model DS-15, D-Type watertube boiler capable of producing 15,000lb/hr of saturated steam at 300 psig. Significantly, while being an actual commercial boiler, the arrangement is such that the Energy and Fuels Research Center at Penn State has control over boiler operation for R & D purposes with the steam being used by the Universities heating plant. The boiler was designed for firing natural gas and fuel oil and has a volumetric heat release rate of 50,000 Btu/ft^3-hr. The boiler has a refractory front wall and hearth with tangent waterwall tubes on the walls and roof. Combustion gases from the furnace chamber enter the convection pass through the right rear of the boiler. Openings between tubes at the convective pass entrance range from 2 to 6 inches. Prior to demonstration testing, a convective pass, steam operated, soot blower was modified to extend soot blower coverage close to the convective pass entrance. Additionally, an air sparge system was installed on the hearth of the boiler with the expectation that it would help to resuspend ash that had dropped to the floor and facilitate its removal from the furnace. Four sight ports are located on the left side of the boiler and three in the back of the boiler. This allowed excellent observations of flame shape and ash deposition on waterwalls. The ignitor is a Class 3 system meaning that following a short time interval after the main fuel is ignited the ignitor shuts off. The ignitor cannot be used as a flame support while coming up in furnace load. The ignitor has been installed through the burner quarl.

The coal preparation, handling and storage system has been described in previous papers (Patel, et. al., 1995, Jennings, et. al., 1994). However, it is significant to note that some changes were made to the coal system prior to the startup of the demonstration testing. The original system was susceptible to problems when coal moisture became excessive, not to mention the problems with ice chunks during winter operation. Problems with ice were resolved by arranging for covered storage of the coal. Coal moisture-related problems showed up as the inability to maintain consistent flow from the surge bin. The existing surge bin was replaced with one

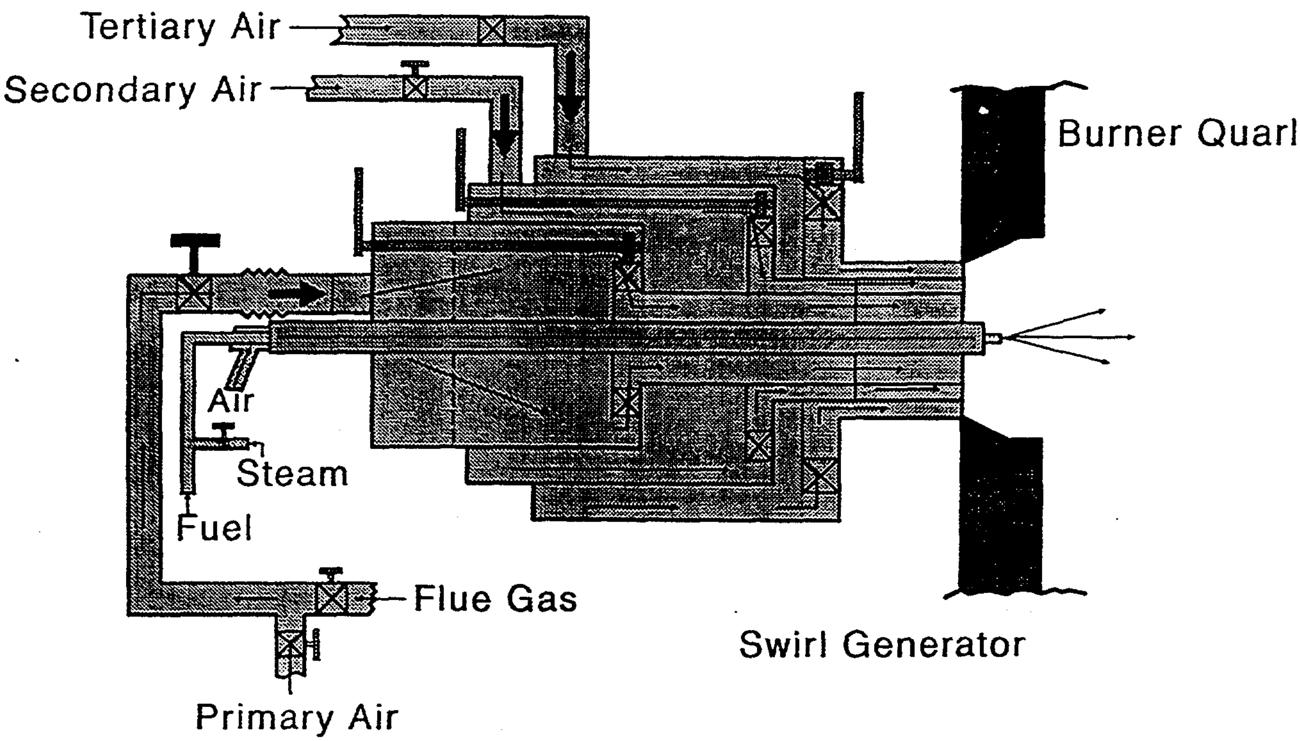


Figure 2 Schematic of M.I.T. Laboratory Prototype Low NOx RSFC Burner

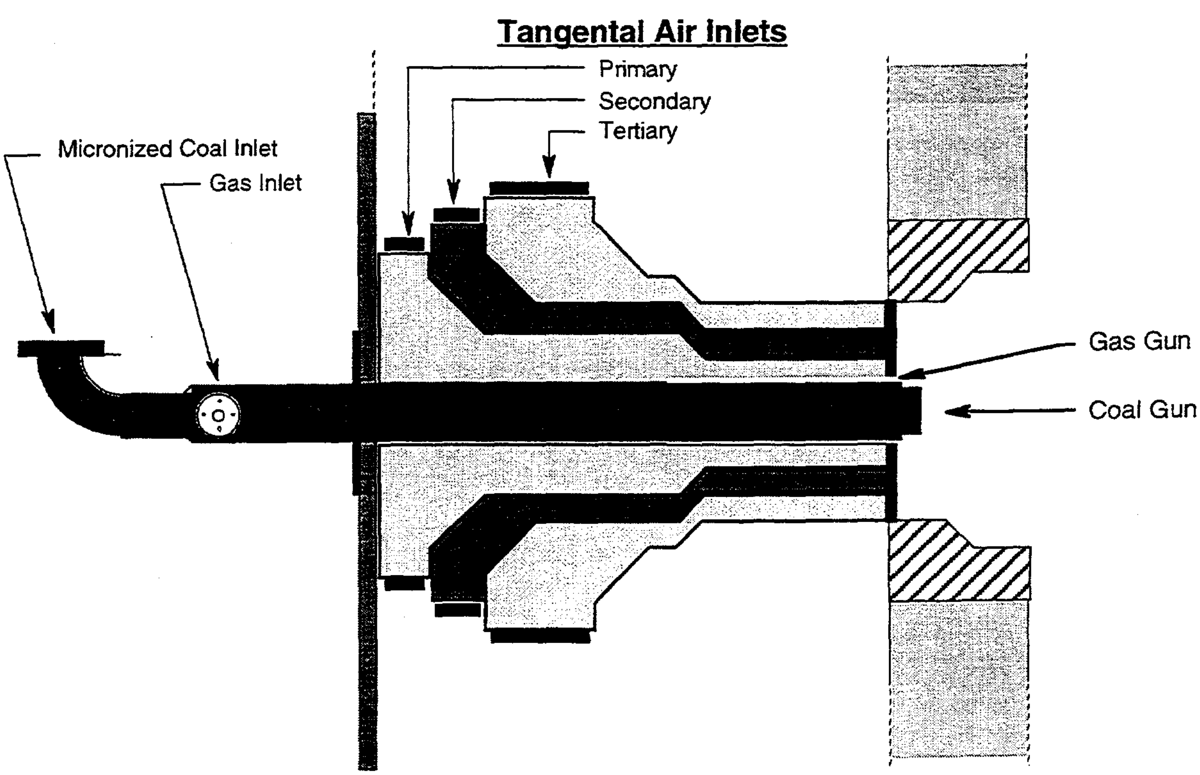


Figure 3 Schematic of RSFC Burner Tested at Penn State

having a mass flow design to facilitate consistent coal flow out of the bin. The volumetric feeder was replaced with a gravimetric feeder to prevent fluctuations in coal feed rate because of size-related changes to bulk density. A schematic of the present coal preparation and firing complex is shown in Figure 4.

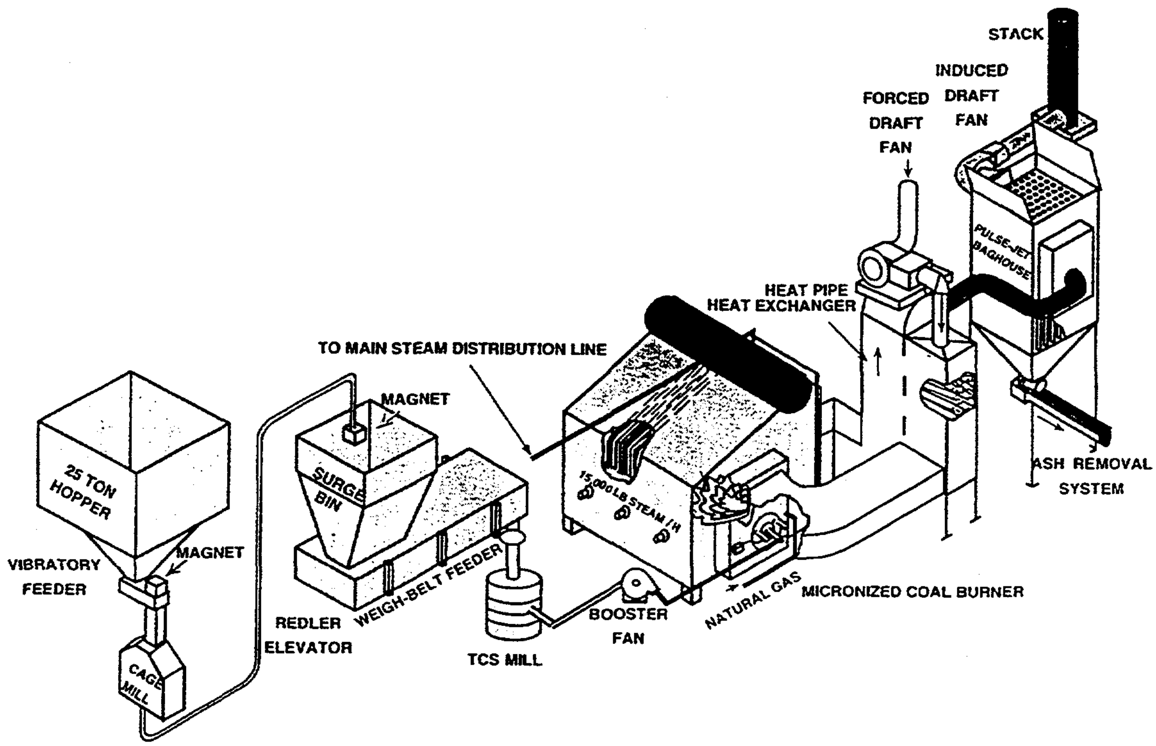


Figure 4 Micronized Coal Combustion System at Penn State

Test Plan

As noted earlier a decision was made to conduct demonstration testing with the RSFC burner instead of the HEACC. The test plan consisted of four (4) key areas as follows:

1. Establishing the effect of burner operational parameters within the envelope of the Penn State boiler.

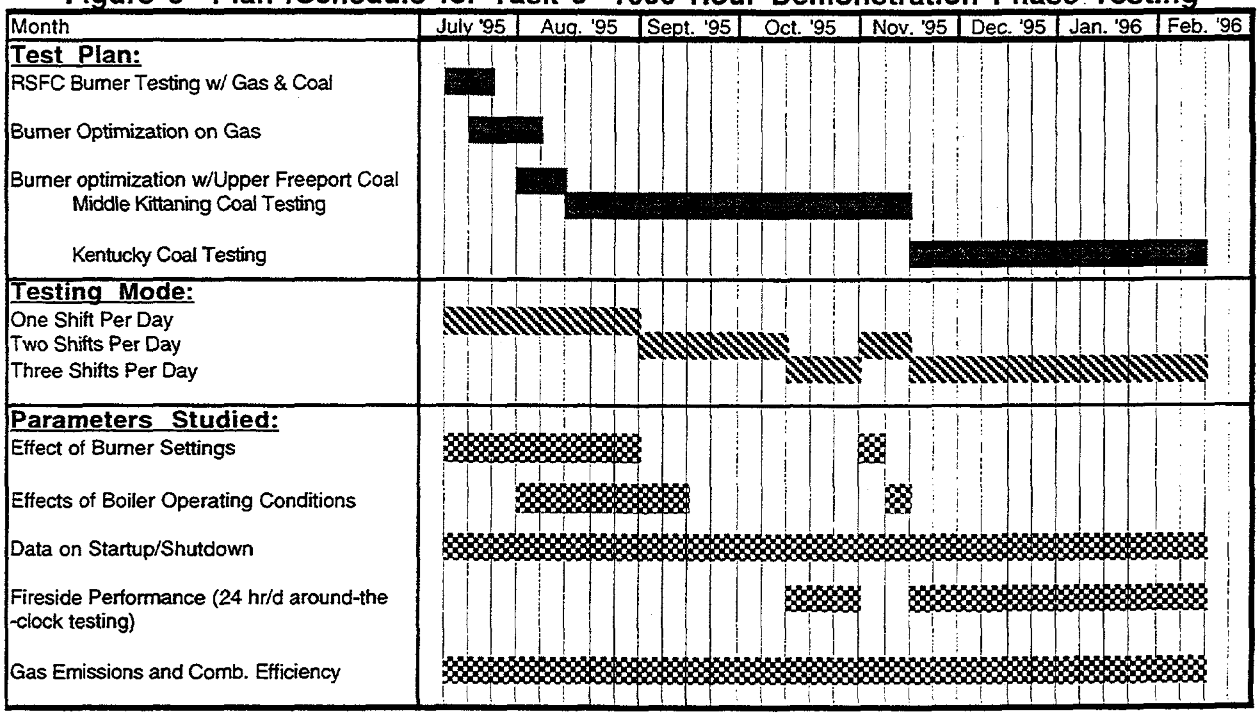
2. Establishing the effect of boiler operational parameters on burner performance.

3. Characterizing burner and boiler operation under startup and shutdown operation and switching from natural gas to coal and the reverse.

4. Establishing the effects of ash deposition on burner and boiler performance and assessment of ash management.

Figure 5 depicts the areas identified above in a schedular fashion.

Figure 5 Plan /Schedule for Task 5 -1000 Hour Demonstration Phase Testing



Since a new burner (RSFC) was being installed in the Penn State furnace it seemed reasonable to devote some time toward characterizing its performance within the boundary conditions described by this furnace. For example the bulk residence time within the combustion chamber is on the order of 0.7 seconds, a very significant decrease over that which would be available in most coal fired boilers. It would be important to establish some relationship between NOx and combustion efficiency within this boiler. Key burner parameters were mass flow distribution of air through the various annuli, swirl number and fuel gun position.

The second key area within the test plan concerned itself with boiler and/or other system related parameters such as excess air, boiler load, transport air/coal ratio, cleanliness of the waterwalls, and fuel fineness.

The third key area dealt with startup and shutdown sequences with attention being paid to the ignitor, scanner and associated controls. The burner is a dual fuel (natural gas and coal) burner and the normal startup sequence involves lighting off on natural gas at about 3×10^6 Btu/hr and then transitioning to coal. Shutdown procedure is to transition from 100% coal to co-firing coal and natural gas, and then to 100% natural gas. Once back on 100% natural gas the furnace can be easily shut off.

The fourth area involved around-the-clock-testing, the primary purpose being to determine the effects of ash deposition on boiler operation and burner performance and, in particular, to determine what would finally dictate that testing must cease.

Coals Tested

Three different coals were tested as part of the Task 5 demonstration testing period. Upper Freeport was used exclusively during the beginning of the demonstration testing for purposes of assessing the effect of changing burner operational parameters. Middle Kittanning and Kentucky coals were used during the around-the-clock-testing periods when ash deposition effects were the focus of the testing. Table 1 shows the analysis of the coals mentioned as well as the coals that had been tested under earlier Tasks in the project with the HEACC. All of the coals are low ash with respectably high fusibility temperatures, the idea being to minimize impacts of ash on boiler operation.

Table 1 Selected Analysis of the Coals

Analysis	HEACC (Task 3) Used for 400 hr Testing		RSFC (Task 5) Used for 1,000 hrs Testing		
	Brookville	Kentucky	Upper Freeport	Middle Kittanning	Kentucky
Proximate, Wt%					
Moisture	8.2	6.3	4.3	3.8	4.5
Volatile Matter	33.1	33.3	30.6	29.8	33.4
Fixed Carbon	55.8	55.4	58.9	62.2	58.8
Ash	2.9	4.5	6.2	4.2	3.3
HHV, Btu/lb	13,250	13,010	13,430	14,010	13,700
Ash Fusion Temp. °F					
IDT	2,820	2,803	-	2,432	2,544
ST	+3,000	+3,000	-	2,506	2,800
FT	+3,000	+3,000	-	+2,800	+2,800

Test Results

Short Term

In July 1995, the RSFC burner was installed in the Penn State boiler and a series of short term (4 to 12 hrs) tests were conducted first with natural gas and then with coal (Upper Freeport and Middle Kittanning). The goal during the short term testing was to address the first three areas identified in the Test Plan, namely (1) assessment of burner settings on NOx and CO, (2) the effect of boiler operating conditions on NOx and CO and (3) to establish reliable startup and shut down procedures and assess the performance of ignitor and flame scanner operation.

Burner settings involved varying swirl numbers and mass flows of the various combustion air annuli and fuel gun position. Boiler operating parameters involved changes in excess air, boiler load, coal fineness, cleanliness of furnace walls and the ratio of transport air to coal flow. Startup and shutdown procedures involved assessment of ignitor and scanner performance as well as co-firing (natural gas and coal) since startup was always on natural gas with a transition to 100% coal (if coal firing was desired) and transition back to natural gas before shutdown.

For natural gas firing burner settings were examined which gave the lowest NOx commensurate with acceptable CO levels. For coal firing NOx was balanced against combustion efficiency. Excess air was evaluated relative to its effect on achieving the best balance between NOx and CO or combustion efficiency, depending on the fuel being tested. When firing coal the additional parameters included coal fineness and transport air to coal ratios.

For natural gas firing optimum excess oxygen levels were found to be on the order of 1.5% to 2.5%. For coal firing optimum excess oxygen levels were found to be on the order of 3.0% to 4.0%.

Interestingly, the TCS mill (Patel, et. al., 1995) was able to be successfully operated at a higher speed (without exceeding a safe temperature) giving slightly finer coal than when firing with the HEACC. A typical $D_{(V,0.5)}$ (i.e., 50% less than) values of coal particle size when firing the RSFC burner were ~17 to 22 microns while when firing the HEACC the values were between ~25 to 30 microns . A lower pressure drop through the coal gun, in the case of the RSFC burner, is speculated as the reason for the difference.

When firing natural gas with the RSFC burner the condition of the boiler tube walls was important. With clean tubes NOx levels ranged from 45 to 55 ppm, while NOx values of 60 to 70 ppm were achieved at the same conditions when the tubes were dirty from previously firing coal. This was not observed when testing the HEACC which gave NOx levels of 140 to 190 ppm under clean or dirty conditions. It was a reproducible phenomena with the RSFC burner. Table 2 summarizes selected emissions and burner information for the RSFC burner and the HEACC when firing gas and coal.

When firing coal NOx levels ranged from roughly 300 to 600 ppm for both the RSFC burner and the HEACC. The RSFC burner has shown a slightly greater variation in NOx, perhaps owing to it's greater adjustability. It seems reasonable to conclude that based on the short term data (which is all that exists on the HEACC) NOx levels for the two burners are comparable in the Penn State boiler. Differences in combustion efficiency are more apparent, however. Figure 6 is a plot of NOx for each of the burners, for short term tests only and with all data points taken at full load. The RSFC burner is seen to have combustion efficiencies ranging from slightly over 93% to almost 98% while the HEACC shows combustion efficiencies ranging from 90% to slightly over 96%. The highest combustion efficiency attained for the highest acceptable NOx level (450ppm) for the RSFC burner was slightly over 97% while for the HEACC the comparable value is somewhat over 95%. Given that the combustion

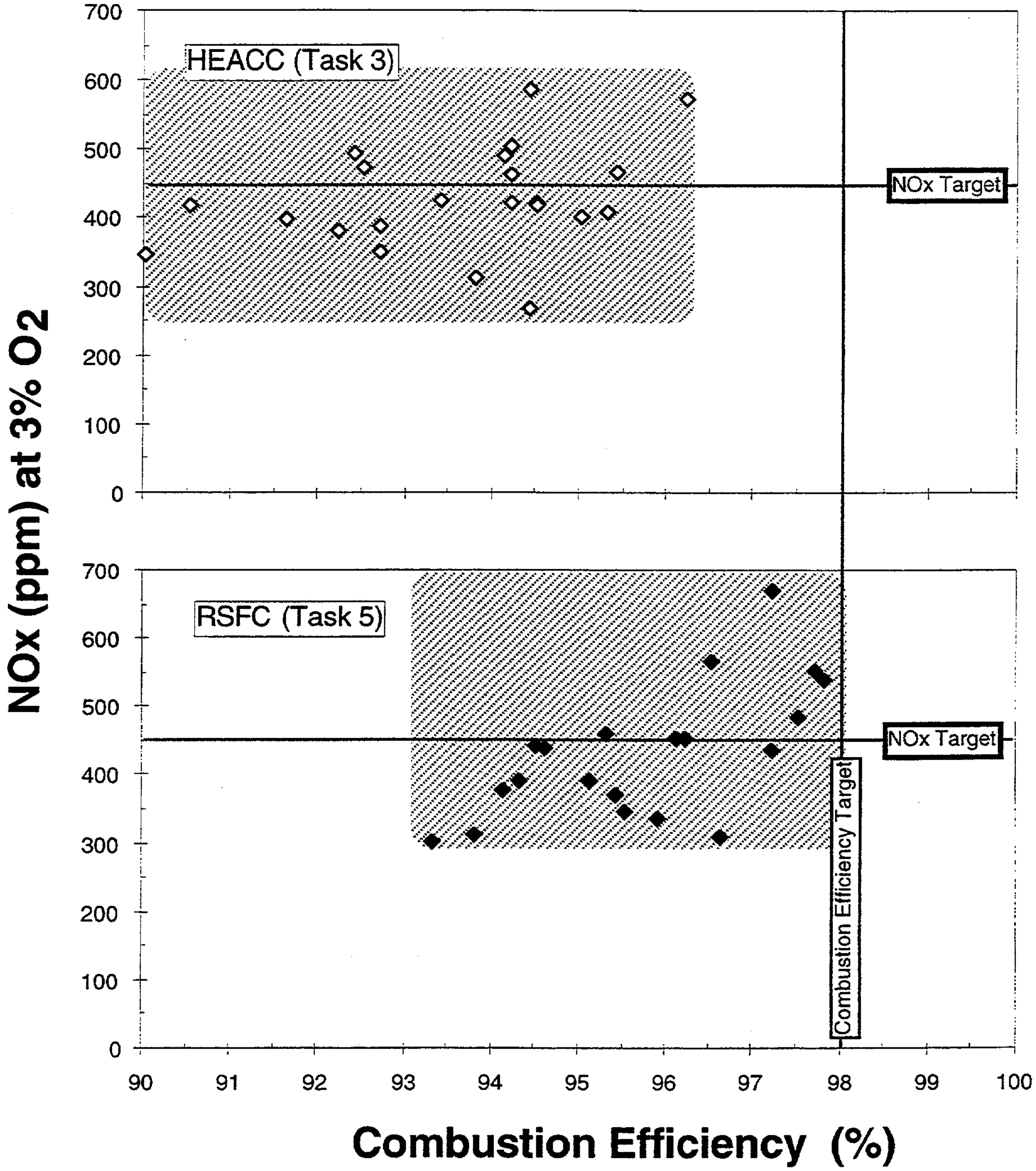


Figure 6 NOx vs Combustion Efficiency for HEACC and RSFC burners In Penn State Boiler Firing Microfine Coal at Full Load.

Table 2 Comparision of HEACC vs RSFC Micronized Coal Burner

Short Term Test Results	HEACC (Task 3)	RSFC (Task 5)
• Natural Gas Testing		
w/clean walls		
NOx (ppm)	140 - 200	45 - 55
CO (ppm)	10 - 40	40 - 60
w/dirty walls (ash depo.)		
NOx (ppm)	140 - 200	60 - 70
CO (ppm)	10 - 40	45 - 60
• Coal Firing Results		
% Comb. Efficiency	90 -96	93 -97.8
NOx (ppm)	300 - 600	300 - 600
Burner Pressure Drop (inches H2O)	~ 8	4 - 6.5
• Flame Shape	Fixed	Adjustable
• Flame Stability	Moderate	Excellent

NOx and CO values are expressed @ 3% O2

efficiency target (98%) was missed during previous testing (Task 3) the increase in combustion efficiency for the RSFC burner was considered a significant improvement. Results during long term testing (next section) will show that combustion efficiencies generally increased with time.

Reliable RSFC burner lightoff was accomplished on natural gas with a strong scanner signal and transition to coal was usually begun within 15 minutes. Firing on 100% coal was usually achieved in about one hour. Flame stability was excellent on natural gas or coal. Co-firing of natural gas and coal, a necessary sequence during every startup and shut down, was accomplished without a problem.

Long Term

As previously noted under "Test Plan", part of the demonstration testing was devoted to around-the-clock trials with the focus on the effects of ash deposition. The goal during this phase of the testing was to determine how long the boiler could operate before an ash-related constraint would prevent further operation. Earlier testing during Task 3 showed that some of the more likely constraints would be excessive flue gas temperatures entering the bag filter (limited to 400 °F) and blockage of the convective pass entrance.

Around-the-clock testing was conducted at full load with the Middle Kittanning and the Kentucky coals and at a combination of full and partial load testing for the Kentucky coal. The long term data is still in the process of being plotted and analyzed, but some observations can be made at this time.

The longest long term test at full load was conducted during mid-December with the Kentucky coal. Information generated from this test is discussed in this paper.

The Kentucky coal was burned for 136 continuous hours at full load, which is equivalent to an average heat input of 15.6 million Btu/hr. After operating for 136 hours the convective pass entrance became sufficiently blocked so that the ID fan could no longer maintain a slightly negative furnace pressure and the test had to be terminated. Although the convective pass soot blower was operated about once every two hours it was unable, over time, to keep the convective pass entrance adequately clean. Following shutdown of the furnace and after sufficient cooling time an inspection was carried out inside the furnace. The entrance to the convective pass was indeed severely blocked. There was also a considerable amount of ash on the floor, most of it being near the bottom of the sidewalls. It seems reasonable to assume that most of the ash on the floor probably came from deposits which formed on the waterwalls and sloughed off onto the floor. About 93 tons of coal were fired during this long term test. With an average ash content of 3.3% the total amount of ash put into the furnace was 6140 lb. When the ash was removed from the furnace its weight was ~780 lb; this means that about 13% of the ash put into the furnace ended up on the waterwall tubes and the floor with the remainder being carried through as fly ash. Given the high fusibility temperatures of the Kentucky coal (see Table 1), highly sintered deposits would not be expected, nor were they observed. In fact the ash deposits were of a rather friable nature and would be easily removed with a soot blower. Any time the boiler had to be shut down, even for very short time durations, the ash deposits easily sloughed off the waterwall tube surfaces. However, the boiler has no soot blowers in the radiant section of the furnace.

Convective pass temperatures at the beginning of the test (once full load was established) were on the order of 1000 °F while at the end of the test (after 136 hr) they were averaging close to 1300 °F, see Figure 7. Steam production was on the order of 12,000 lb/hr, representing a 20% decrease from the 15,000lb/hr steam production that is available on natural gas. This 20% reduction was required with the HEACC also and is needed to prevent excessively high flue gas temperatures (greater than 400 °F) from entering the bag filter. It is accepted that there will be some derating necessary when firing coal.

With regard to NOx levels and combustion efficiency it should be noted that the RSFC burner has the ability to adjust the flame shape which is an important feature when it is recognized that combustors come in all sizes and shapes. Simply stated, longer flames will produce lower NOx levels while shorter flames will produce higher combustion efficiencies. Longer flames produce lower NOx because they occupy a longer residence time in the fuel rich core where fuel nitrogen has a greater opportunity to then be converted to molecular nitrogen. If the flames are too long and impinge the back wall (in the case of the Penn State boiler) before combustion is completed combustion efficiencies will suffer. Short flames tend to produce higher combustion efficiencies because they are more intense and they will not impinge the back wall before combustion is completed. The challenge, of course, is to find a happy balance between the two extremes where flame length is long enough to give the low NOx, but not so long that flame impingement causes a reduction in combustion efficiency. This is particularly challenging when burning coal in a small furnace designed for oil and natural gas where bulk residence times are on the order of 0.7 seconds.

Since the HEACC was able to meet the NOx target of 450 ppm, but not the combustion efficiency target of 98%, the emphasis was on trying to increase the combustion efficiency without adversely affecting NOx. Therefore, burner settings were established where combustion efficiencies were maximized while holding to the target of 450 ppm NOx. Initial NOx levels were on the order of 370 ppm and early combustion efficiencies, as determined through analysis of particulate samples, were around 97%. However, with increased running time NOx and combustion efficiencies generally increased. Increases in combustion efficiencies were welcome, but increases in NOx were not. It would appear that the accumulation of ash deposits were responsible for this change in NOx and combustion efficiency with time. It seems reasonable to assume that increases in flame temperatures would occur as deposits increased and provided greater resistance to heat transfer to the waterwall tubes. Higher temperatures would work in favor of increased combustion efficiency and toward higher thermal NOx. For the duration of the test, NOx levels ranged from a low of 365 ppm and a high of 600 ppm with the average NOx value of about 480 ppm, somewhat over the target of 450 ppm. During the same period, the combustion efficiencies ranged from a low of 96.9% to a high of 98.5 % with an average value of 97.8%, nearly making the target of 98%. Burner settings were not changed during this long term test, nor was it the intent to change any of the other operating parameters such as excess air, transport air, coal feed rate, etc. However there were fluctuations in excess air; oxygen in the flue gas ranged from roughly 3.0% to 4.0% with a number of excursions from 2.5% to 4.5%. Fluctuations occurred in other areas also and these are being analyzed to determine what effect they may have on NOx and/or combustion efficiency.

Figure 8 shows a plot of NOx and combustion efficiency over the entire 136 hours of testing. It is particularly interesting to observe that NOx dropped to roughly the target level of 450 ppm after about 90 hours of operation; this occurred without purposely making any changes to the burner or operating conditions. It is interesting because formerly stated speculation regarding the effects of ash deposits on NOx and combustion efficiency seems to not hold true during the last 46 hours of this long term test. A good answer for why this has occurred does not currently exist, but all corresponding data is being compiled and analyzed to try and explain what happened.

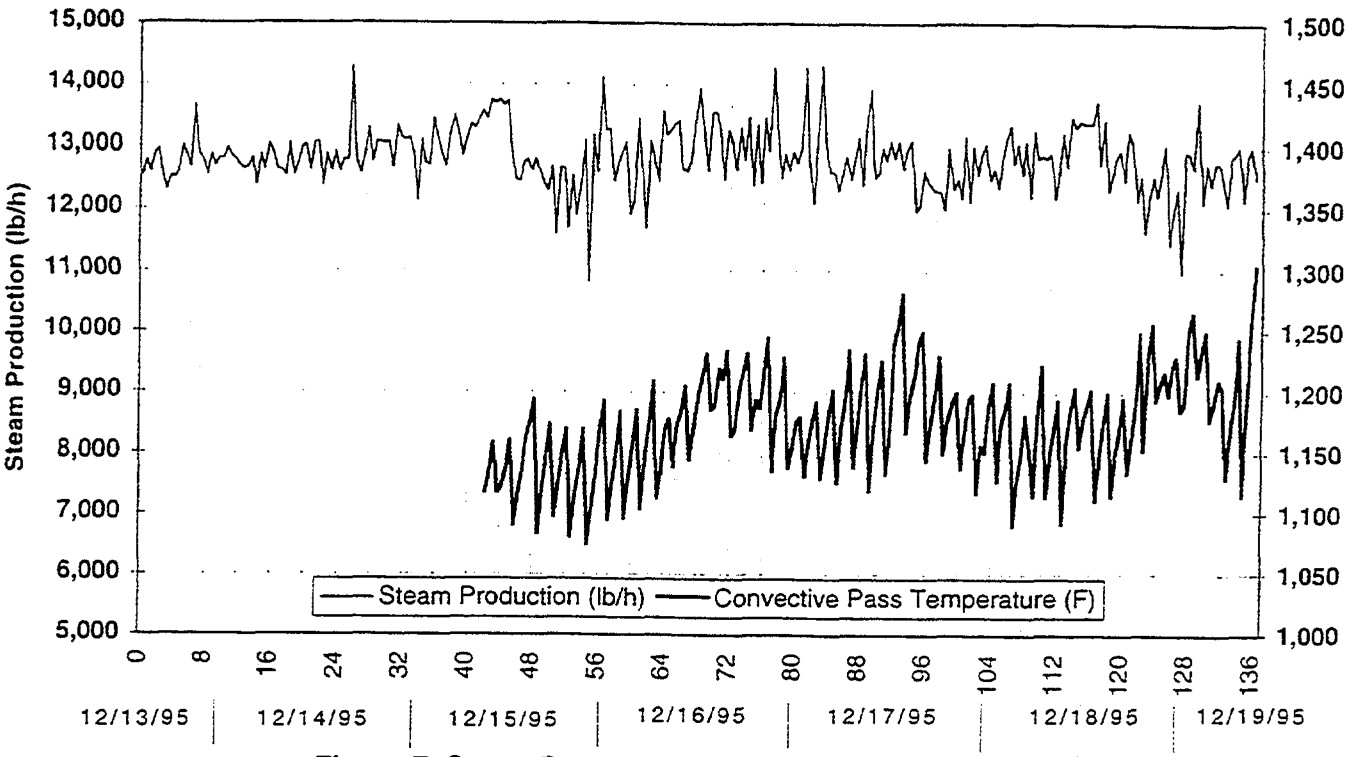


Figure 7 Steam Production and Convective Pass Temperature During the Continuos Test on Kentucky Coal

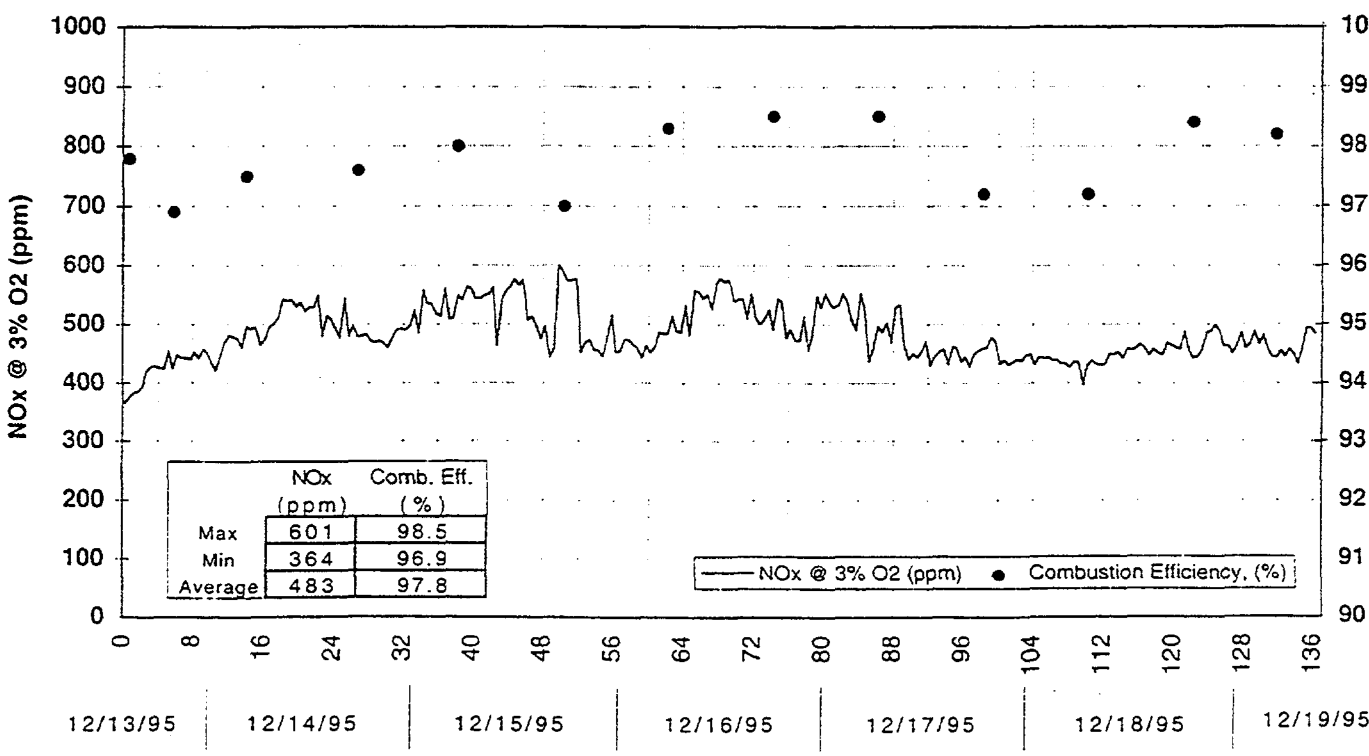


Figure 8 Combustion Efficiency and NOx During the Continuos Test on Kentucky Coal

Results from the long term test are very encouraging from the standpoint of NOx and combustion efficiency insofar as the original targets are concerned. Earlier testing with the HEACC gave combustion efficiencies on the order of 95% under short term (no longer than 12 hours) testing. Even assuming that the combustion efficiency would have improved by about 1% during long term testing would not have provided as high a value as was obtained with the RSFC burner. It should also be noted that some burner adjustments would have to be made to the RSFC burner to allow the target NOx levels to be achieved over the long term test and that such a change could slightly decrease combustion efficiencies.

Ash management when burning coal in an oil/gas designed boiler remains a critical concern. If the intent is to run the boiler continuously, i.e. without shutting down on weekends and cleaning out the ash, then judging from experience on the Penn State boiler and even when using a very good coal it does not appear possible to run a boiler of this size for more than about 6 days. Larger boilers with lower volumetric heat release rates may be able to run longer. More will be said about this in future papers. Flame stability and scanner signal strength were excellent during the entire 136 hour test.

CONCLUDING COMMENTS

- Short term testing (less than 12 continuous hours) has shown the RSFC burner to be able to achieve NOx levels in the Penn State boiler ranging from 350 to 450 ppm while achieving combustion efficiencies of 96.5% to 97.5%. The HEACC had comparable values of 350 to 450 ppm NOx and 94% to 95% combustion efficiencies. The RSFC burner has shown its ability to attain higher combustion efficiencies under comparable conditions.

- Long term testing has shown a tendency toward increasing both NOx and combustion efficiency with time. It is believed that the growth of ash deposits on waterwall tubes causes temperatures to increase which adversely affect thermal NOx and work in favor of increasing combustion efficiency.

- Based on long term results in the Penn State boiler management of ash deposits and ash removal when burning coal in a boiler designed for oil and gas is a concern if the boiler is to be operated for periods greater than about one week. For the long term test of 136 hours, about 16% of the ash in the as-fired coal was retained in the radiant section of the furnace with no means of removal other than manual removal when the boiler was taken off line.

- When firing coal the Penn State boiler must be operated at about 80% of its rated capacity to avoid producing excessively high temperatures entering the bag filter.

CONCLUDING COMMENTS (continued)

- Burner startup and shutdown as well as flame stability and scanner signal strength during long term testing were all excellent.

- The Penn State boiler with a volumetric heat release rate of 50,000 Btu/ft^3-hr, a bulk residence time of 0.7 seconds and a design steam production rate of 15,000 lb/hr represents the most challenging end of the spectrum for retrofitting coal in an oil/gas designed boiler.

ACKNOWLEDGEMENTS

We appreciatively acknowledge the DOE-PETC for the financial support of this program under Contract No. DE-AC 22-91PC91160. John Winslow and Douglas Gyorke (DOE-PETC) are acknowledged for their support of this work.

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Attachment B

FIRING MICROFINE COAL IN THE RSFC BURNER FOR 1000 HOURS IN A GAS/OIL DESIGNED INDUSTRIAL BOILER

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Presented at:

FIRST JOINT POWER AND FUEL SYSTEMS
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July 9 - 11, 1996
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INTRODUCTION

This U.S. Department of Energy, Pittsburgh Energy Technology Center (DOE-PETC) sponsored project has been in progress for several years at ABB Power Plant Laboratories (ABB PPL) in cooperation with the Energy and Fuels Research Center of The Penn State University. During much of the time work has centered around development and testing of the High Energy Advanced Coal Combustor (HEACC). The HEACC has been described in previous papers (Rini, et. al., 1987, 1988; Toqan, et al., 1988).

The objective of the project has been to determine the technical and economic feasibility of firing microfine pulverized coal in an oil/natural gas designed boiler. Specific targets were set at 0.6 lb NOx/million Btu (~450 ppm) and 98% combustion efficiency.

During 1994 ABB PPL began working, as part of an internally-funded project, to scale up the low NOx, RSFC burner in partnership with M.I.T.; the initial focus was on firing natural gas and No. 6 fuel oil. Earlier results (DOE-PETC Project:Task 3) from testing the HEACC on microfine coal at Penn State had shown it to meet the NOx target, but to fall short of the combustion efficiency target. Given the knowledge base that both M.I.T. and ABB PPL had compiled when firing natural gas, oil and pulverized coal and the operating principle of the RSFC burner, it was believed that it could provide improved combustion efficiencies over that of the HEACC in the Penn State boiler while maintaining the target NOx levels when firing microfine coal. During M.I.T's previous testing of the RSFC burner on pulverized coal, excellent results were achieved, which further indicated that improvements in combustion efficiency should be possible if the RSFC burner were installed in the Penn State boiler. It should be noted that the bulk residence time in the M.I.T. Combustion Research Facility (CRF), where the RSFC burner was tested, was significantly greater, at about 2.5 seconds, than the residence time in the Penn State boiler, which is on the order of 0.7 seconds.

A decision was made to switch from testing the HEACC burner, under the long term testing phase (Task 5) of the project, to installing and testing the RSFC burner. It was also agreed that ABB PPL would design, build and provide the properly sized RSFC burner at no cost to the DOE-PETC project.

Task 5 represents the final phase of the project with the previously completed tasks as follows:

1.0 A review of current state-of-the-art coal firing system components.
2.0 Design and experimental testing of a prototype HEACC.
3.0 Installation and testing of a HEACC system in a simulated commercial retrofit application.
4.0 Economic evaluation of the HEACC concept for retrofit applications.
5.0 Long term demonstration under simulated commercial user demand conditions.

Results of Tasks 1 through 4 have been summarized in previous technical publications (Patel, et. al.,1995; Jennings, et. al., 1993, 1994; Rini, et al.,1993).

This paper provides information from the long term testing (Task 5), wherein micro- fine pulverized coal was fired, and it also provides information on the performance of the RSFC burner when firing natural gas.

DESCRIPTION OF THE RSFC BURNER

Many conventional burners employ swirling flows to enhance mixing in the near-burner flow field. The RSFC burner is, however, different in that swirling flow is used to create the opposite effect, namely delay of mixing in the near-burner zone (Borio, et. al., 1995). It is this combination of a near-burner, high temperature, fuel rich core followed by a downstream, fuel lean combustion zone that are responsible for the low NOx generated by the RSFC burner.

A typical low NOx, RSFC flow field is depicted in Figure 1. The concept of radial stratification originated with the work of Rayleigh (Beér and Chigier, 1972), and was brought to practical application by Beér, et al. (1970). This phenomena has been applied at M.I.T. to design the radially stratified flame core burner now known as the RSFC burner (Toqan, et al., 1992).

The RSFC burner that was designed and built for testing in the Penn State boiler is, operationally, similar to the M.I.T. burner, but with different swirlers and the ability to co-fire or fire independently natural gas and pulverized coal at a firing rate of about 18×10^{6} Btu/hr and 16×10^{6} Btu/hr, respectively (Patel, et. al., 1996). Figure 2 shows a schematic representation of the RSFC burner tested at Penn State. Natural gas is fired from an annulus around the coal nozzle. Dampers in the tangential air inlet scoops can be used to control air flow and swirl number.

DEMONSTRATION TESTING

Objective

The objective of this phase of the project was to characterize burner and boiler performance under long term testing conditions that were representative of typical industrial boiler operation.

Facilities

The boiler in which tests were carried out at Penn State is a Tampella Keeler Model DS-15, D-Type watertube boiler capable of producing 15,000lb/hr of saturated steam at 300 psig. Significantly, while being an actual commercially supplied boiler, the arrangement is such that the Energy and Fuels Research Center at Penn State has control over boiler operation for R & D purposes with the steam being used by the Universitiy's heating plant. The boiler was designed for firing natural gas and fuel oil and has a volumetric heat release rate of 50,000 Btu/ft^3-hr. The boiler, coal preparation, handling and storage systems have been described in previous papers (Patel, et. al., 1996). A schematic of the coal preparation and firing complex is shown in Figure 3.

Test Plan

As noted earlier a decision was made to conduct demonstration testing with the RSFC burner instead of the HEACC. The test plan consisted of four (4) key areas as follows:

1. Establishing the effect of burner operational parameters within the envelope of the Penn State boiler.
2. Establishing the effect of boiler operational parameters on burner performance.
3. Characterizing burner and boiler operation under startup and shutdown operation and switching from natural gas to coal and the reverse.
4. Establishing the effects of ash deposition on burner and boiler performance and assessment of ash management.

Figure 4 depicts the areas identified above in a schedular fashion.

Coals Tested

Three different coals were tested as part of the Task 5 demonstration testing period. Upper Freeport was used exclusively during the beginning of the demonstration testing for purposes of assessing the effect of changing burner operational parameters. Middle Kittanning and Kentucky coals were used during the around-the-clock-testing periods when ash deposition effects were the focus of the testing. Table 1 shows the analysis of the coals mentioned as

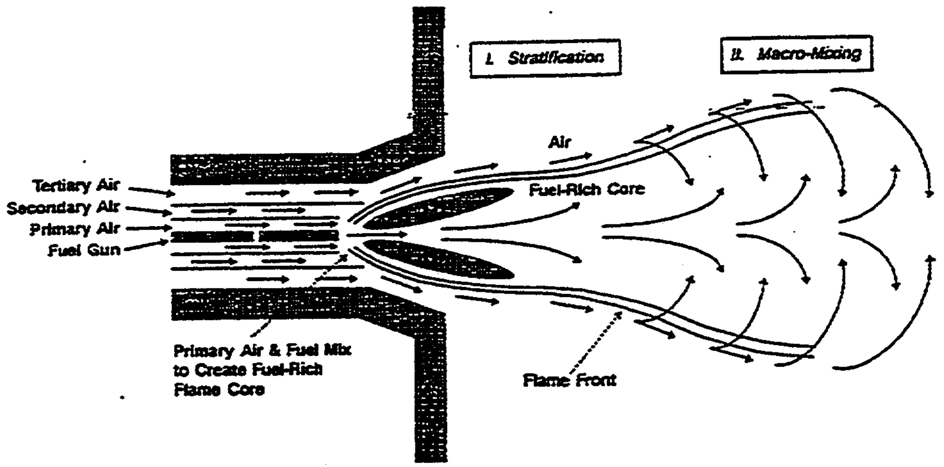

Figure 1 Typical Low NOx RSFC Flow Field

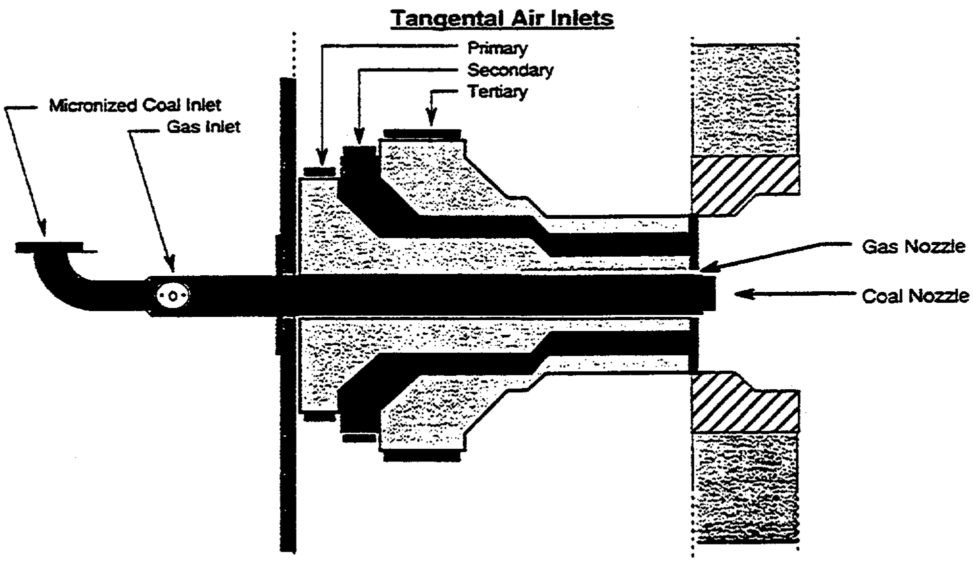

Figure 2 Schematic of RSFC Burner Tested at Penn State

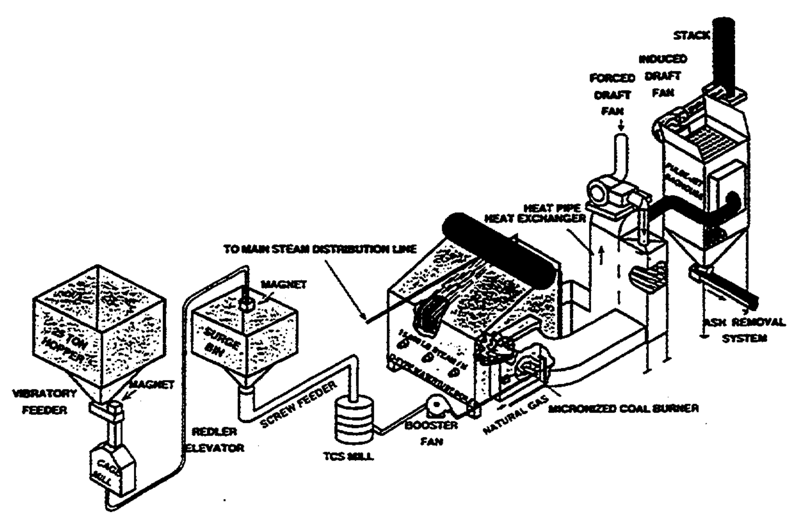

Figure 3 Micronized Coal Combustion System at Penn State

well as the coals that had been tested under earlier Tasks in the project with the HEACC. All of the coals are low ash with respectably high fusibility temperatures, the idea being to minimize impacts of ash on boiler operation.

Figure 4 Plan /Schedule for Task 5 -1000 Hour Demonstration Phase Testing

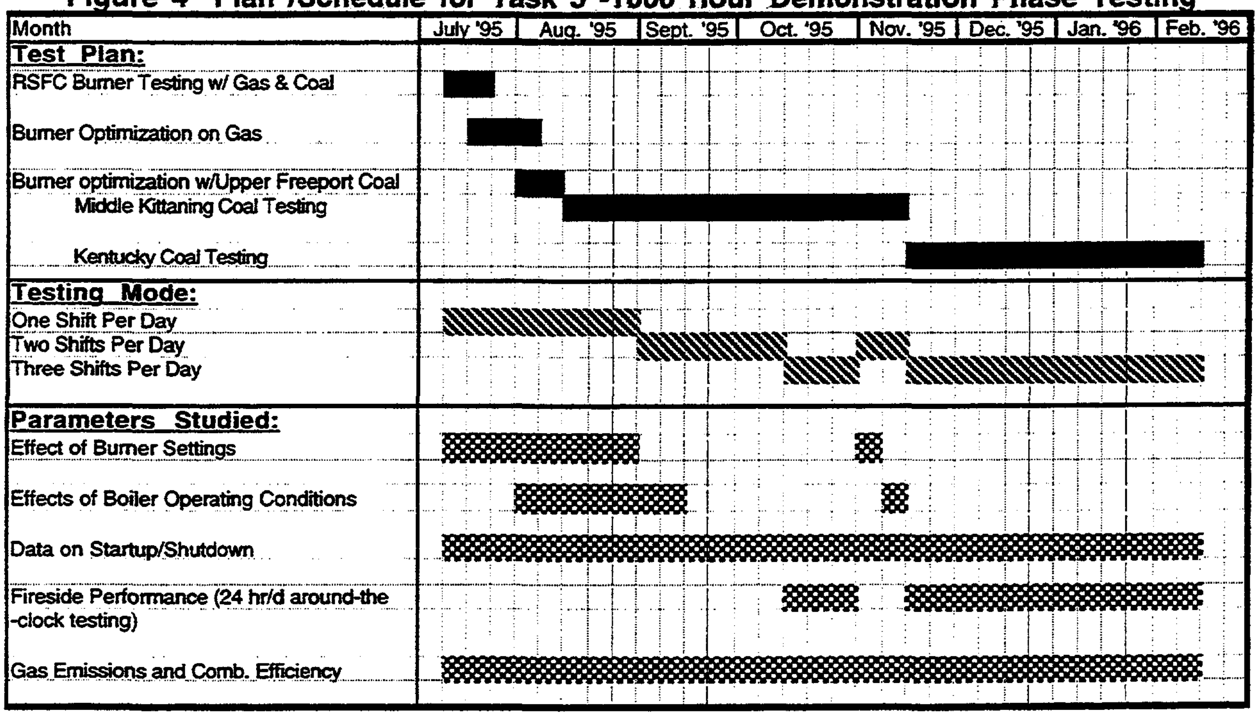

Table 1 Selected Analysis of the Coals

Analysis	HEACC (Task 3) Used for 400 hr Testing		RSFC (Task 5) Used for 1,000 hrs Testing		
	Brookville	Kentucky	Upper Freeport	Middle Kittanning	Kentucky
Proximate, Wt%					
Moisture	8.2	6.3	4.3	3.8	4.5
Volatile Matter	33.1	33.3	30.6	29.8	33.4
Fixed Carbon	55.8	55.4	58.9	62.2	58.8
Ash	2.9	4.5	6.2	4.2	3.3
HHV, Btu/lb	13,250	13,010	13,430	14,010	13,700
Ash Fusion Temp. °F					
IDT	2,820	2,803	-	2,432	2,544
ST	+3,000	+3,000	-	2,506	2,800
FT	+3,000	+3,000	-	+2,800	+2,800

Test Results

Short Term

In July 1995, the RSFC burner was installed in the Penn State boiler and a series of short term (4 to 12 hrs) tests were conducted first with natural gas and then with coal (Upper Freeport and Middle Kittanning). The goal during the short term testing was to address the first three areas identified in the Test Plan, namely (1) assessment of burner settings on NOx and CO, (2) determine the effect of boiler operating conditions on NOx and CO and (3) establish reliable startup and shut down procedures and assess the performance of ignitor and flame scanner operation.

For natural gas firing optimum excess oxygen levels were found to be on the order of 1.5% to 2.5%. For coal firing optimum excess oxygen levels were found to be on the order of 3.0% to 4.0%.

When firing natural gas with the RSFC burner the condition of the boiler tube walls was important. With clean tubes NOx levels ranged from 45 to 55 ppm, while NOx values of 60 to 70 ppm were achieved at the same conditions when the tubes were dirty from previously firing coal. This was not observed when testing the HEACC which gave NOx levels of 140 to 190 ppm under clean or dirty conditions. It was a reproducible phenomena with the RSFC burner. Table 2 summarizes selected emissions and burner information for the RSFC burner and the HEACC when firing gas and coal.

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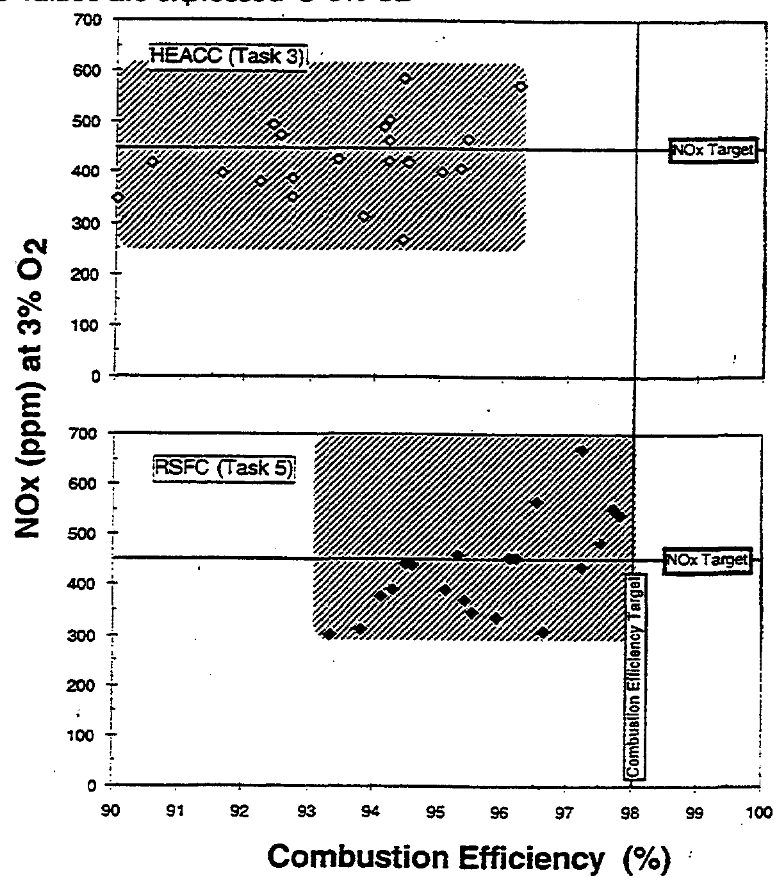


Figure 5 NOx vs Combustion Efficiency for HEACC and RSFC Burner in Penn State Boiler Firing Microfine Coal at Full Load

Long Term

As previously noted under "Test Plan", part of the demonstration testing was devoted to around-the-clock trials with the focus on the effects of ash deposition. The goal during this phase of the testing was to determine how long the boiler could operate before an ash-related constraint would prevent further operation. Earlier testing during Task 3 showed that some of the more likely constraints would be excessive flue gas temperatures entering the bag filter (limited to 400 °F) and blockage of the convective pass entrance.

Around-the-clock testing was conducted at full load with the Middle Kittanning and the Kentucky coals and at a combination of full and partial load testing for the Kentucky coal. The longest long term test at full load was conducted during mid-December with the Kentucky coal. Information generated from this test is discussed in this paper.

The Kentucky coal was burned for 136 continuous hours at full load, which is equivalent to an average heat input of 15.6 million Btu/hr. After operating for 136 hours the convective pass entrance became sufficiently blocked so that the ID fan could no longer maintain a slightly negative furnace pressure and the test had to be terminated. Although the convective pass soot blower was operated about once every two hours it was unable, over time, to keep the convective pass entrance adequately clean. Following shutdown of the furnace and after sufficient cooling time an inspection was carried out inside the furnace. The entrance to the convective pass was indeed severely blocked. There was also a considerable amount of ash on the floor, most of it being near the bottom of the sidewalls. It seems reasonable to assume that most of the ash on the floor probably came from deposits which formed on the waterwalls and sloughed off onto the floor. About 93 tons of coal were fired during this long term test. With an average ash content of 3.3% the total amount of ash put into the furnace was 6140 lb. When the ash was removed from the furnace its weight was ~780 lb; this means that about 13% of the ash put into the furnace ended up on the waterwall tubes and the floor with the remainder being carried through as fly ash. Given the high fusibility temperatures of the Kentucky coal (see Table 1), highly sintered deposits would not be expected, nor were they observed. In fact the ash deposits were of a rather friable nature and would be easily removed with a soot blower. Any time the boiler had to be shut down, even for very short time durations, the ash deposits easily sloughed off the waterwall tube surfaces. However, the boiler has no soot blowers in the radiant section of the furnace.

Convective pass gas temperatures at the beginning of the test (once full load was established) were on the order of 1000 °F while at the end of the test (after 136 hr) they were averaging close to 1300 °F, see Figure 6. Steam production was on the order of 12,000 lb/hr, representing a 20% decrease from the 15,000lb/hr steam production that is available on natural gas. This 20% reduction was required with the HEACC also and is needed to prevent excessively high flue gas temperatures (greater than 400 °F) from entering the bag filter. It is accepted that there will be some derating necessary when firing coal.

With regard to NOx levels and combustion efficiency it should be noted that the RSFC burner has the ability to adjust the flame shape which is an important feature when it is recognized that combustors come in all sizes and shapes. Simply stated, longer flames will produce lower NOx levels while shorter flames will produce higher combustion efficiencies. Longer flames produce lower NOx because they occupy a longer residence time in the fuel rich core where fuel nitrogen has a greater opportunity to then be converted to molecular nitrogen. If the flames are too long and impinge the back wall (in the case of the Penn State boiler) before combustion is completed combustion efficiencies will suffer. Short flames tend to produce higher combustion efficiencies because they are more intense and they will not impinge the back wall before combustion is completed. The challenge, of course, is to find a happy balance between the two extremes where flame length is long enough to give the low NOx, but not so long that flame impingement causes a reduction in combustion efficiency. This is particularly challenging when burning coal in a small furnace designed for oil and natural gas where bulk residence times are on the order of 0.7 seconds.

Since the HEACC was able to meet the NOx target of 450 ppm, but not the combustion efficiency target of 98%, the emphasis was on trying to increase the combustion efficiency without adversely affecting NOx. Therefore, burner settings were established where combustion efficiencies were maximized while holding to the target of 450 ppm NOx. Initial NOx levels were on the order of 370 ppm and early combustion efficiencies, as determined through analysis of particulate samples, were around 97%. However, with increased running time NOx and combustion efficiencies generally increased. Increases in combustion efficiencies were welcome, but increases in NOx were not. It would appear that the accumulation of ash deposits were responsible for this change in NOx and combustion efficiency with time. It seems reasonable to assume that increases in flame temperatures would occur as deposits increased and provided greater resistance to heat transfer to the waterwall tubes. Higher temperatures would work in favor of increased combustion efficiency and toward higher thermal NOx. For the duration of the test, NOx levels ranged from a low of 365 ppm and a high of 600 ppm with the average NOx value of about 480 ppm, somewhat over the target of 450 ppm. During the same period, the combustion efficiencies ranged from a low of 96.9% to a high of 98.5 % with an average value of 97.8%, nearly making the target of 98%. Burner settings were not changed during this long term test, nor was it the intent to change any of the other operating parameters such as excess air, transport air, coal feed rate, etc. However there were fluctuations in excess air; oxygen in the flue gas ranged from roughly 3.0% to 4.0% with a number of excursions from 2.5% to 4.5%. Fluctuations occurred in other areas also and these are being analyzed to determine what effect they may have on NOx and/or combustion efficiency.

Figure 7 shows a plot of NOx and combustion efficiency over the entire 136 hours of testing. It is particularly interesting to observe that NOx dropped to roughly the target level of 450 ppm after about 90 hours of operation; this occurred without purposely making any changes to the burner or operating conditions. It is interesting because formerly stated speculation regarding the effects of ash deposits on NOx and combustion efficiency seems to not hold true during the last 46 hours of this long term test. A good explanation for why this has occurred does not currently exist, but all corresponding data is being compiled and analyzed to try and explain what happened.

Results from the long term test are very encouraging from the standpoint of NOx and combustion efficiency insofar as the original targets are concerned. Earlier testing with the HEACC gave combustion efficiencies on the order of 95% under short term (no longer than 12 hours) testing. Even assuming that the combustion efficiency would have improved by about 1% during long term testing, it would not have provided as high a value as was obtained with the RSFC burner. It should also be noted that some burner adjustments would have to be made to the RSFC burner to allow the target NOx levels to be achieved over the long term test and that such a change could slightly decrease combustion efficiencies.

Ash management when burning coal in an oil/gas designed boiler remains a critical concern. If the intent is to run the boiler continuously, i.e. without shutting down on weekends and cleaning out the ash, then judging from experience on the Penn State boiler and even when using a very good coal it does not appear possible to run a boiler of this size for more than about 6 days. Larger boilers with lower volumetric heat release rates may be able to run longer. Flame stability and scanner signal strength were excellent during the entire 136 hour test.

CONCLUDING COMMENTS

- NOx levels when firing natural gas with the RSFC burner ranged from 45 to 55 ppm for a clean furnace and 60 to 70 ppm for a dirty furnace compared to values of 140 to 200 ppm for the HEACC under clean or dirty conditions.

- Short term testing (less than 12 continuous hours) has shown the RSFC burner to be able to achieve NOx levels in the Penn State boiler ranging from 350 to 450 ppm while achieving combustion efficiencies of 96.5% to 97.5%. The HEACC had comparable NOx values, 350 to 450 ppm, and lower combustion efficiencies 94% to 95%. The RSFC burner has shown its ability to attain higher combustion efficiencies under comparable conditions.

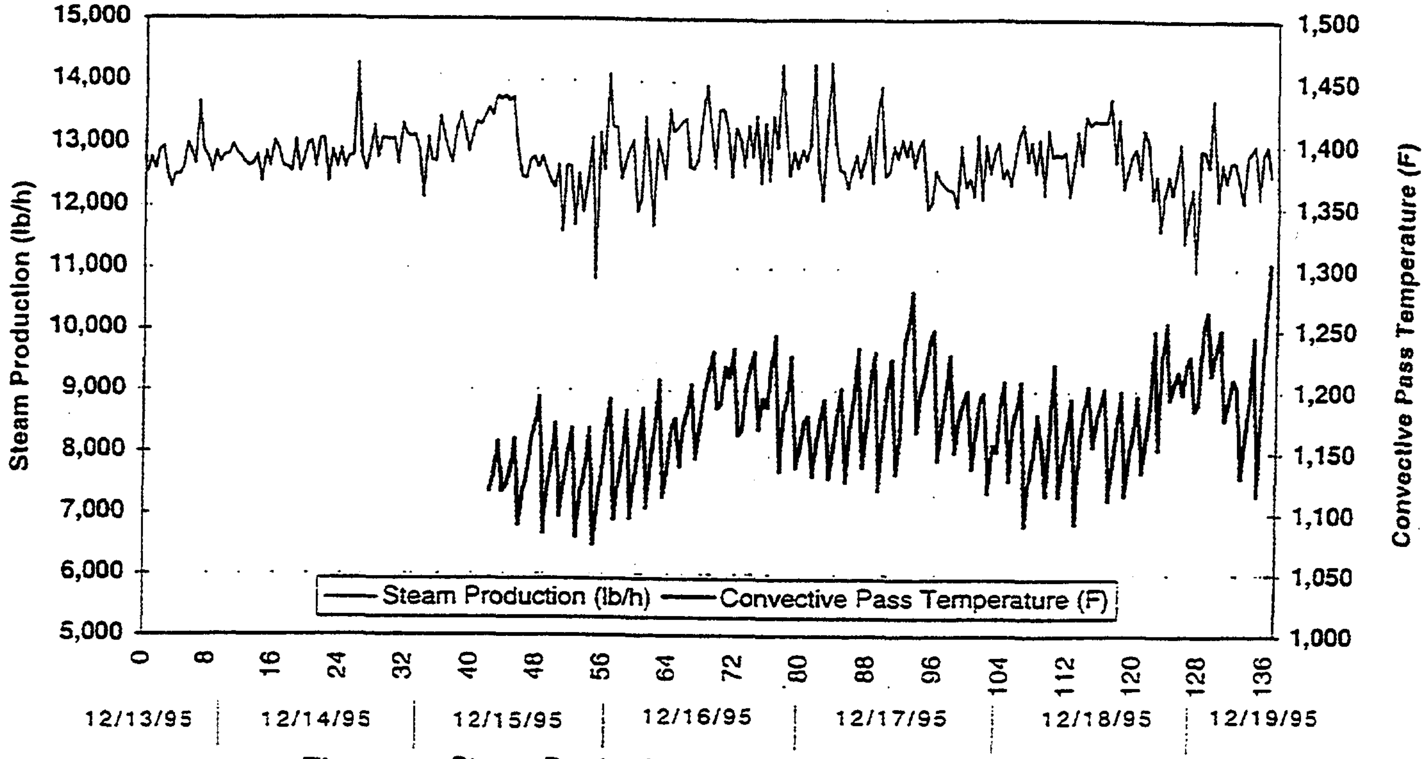
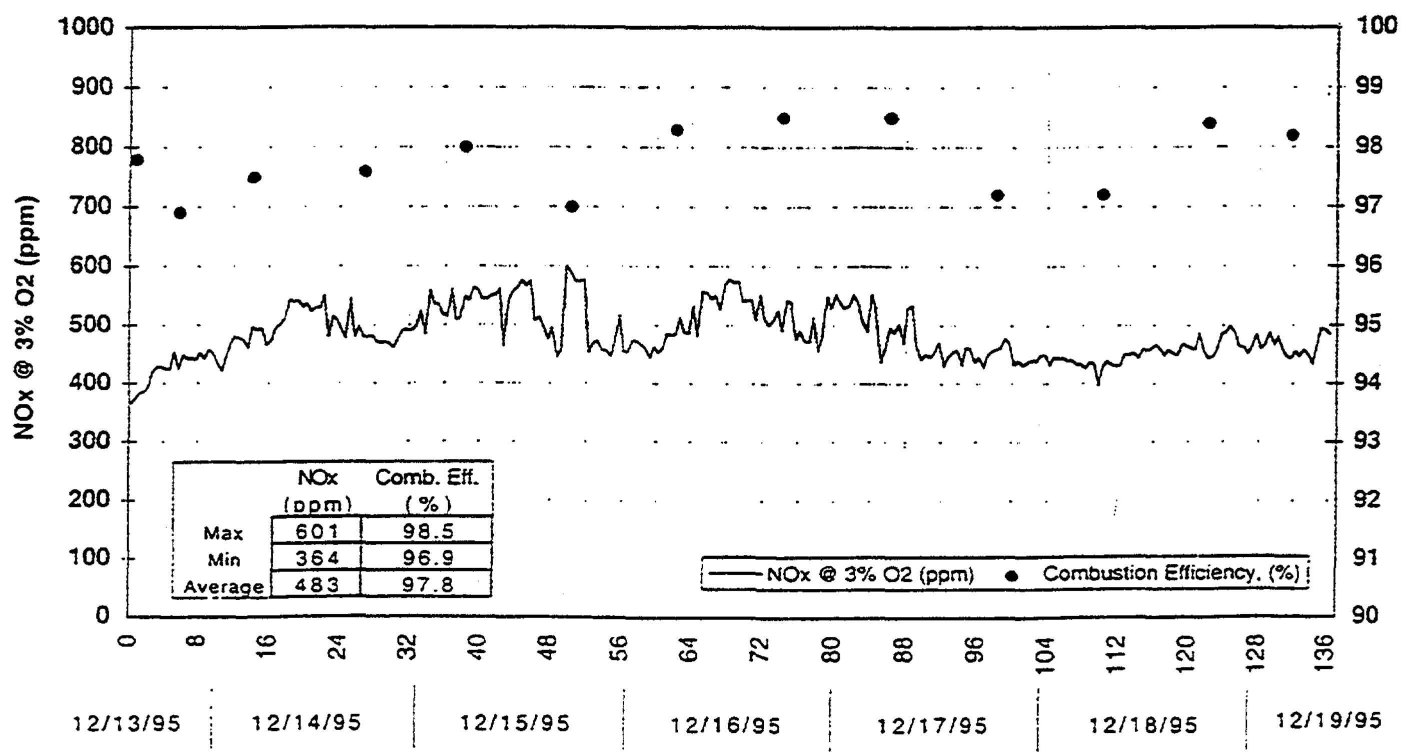


Figure 6 Steam Production and Convective Pass Temperature During the Continuos Test on Kentucky Coal



	NOx (ppm)	Comb. Eff. (%)
Max	601	98.5
Min	364	96.9
Average	483	97.8

Figure 7 Combustion Efficiency and NOx During the Continuos Test on Kentucky Coal

CONCLUDING COMMENTS (continued)

- Long term testing has shown a tendency toward increasing both NOx and combustion efficiency with time. It is believed that the growth of ash deposits on waterwall tubes causes temperatures to increase which adversely affect thermal NOx and work in favor of increasing combustion efficiency.

- Based on long term results in the Penn State boiler management of ash deposits and ash removal when burning coal in a boiler designed for oil and gas is a concern if the boiler is to be operated for periods greater than about one week. For the long term test of 136 hours, about 16% of the ash in the as-fired coal was retained in the radiant section of the furnace with no means of removal other than manual removal when the boiler was taken off line.

- When firing coal the Penn State boiler must be operated at about 80% of its rated capacity to avoid producing excessively high temperatures entering the bag filter.

- Burner startup and shutdown as well as flame stability and scanner signal strength during long term testing were all excellent.

- The Penn State boiler with a volumetric heat release rate of 50,000 Btu/ft^3-hr, a bulk residence time of 0.7 seconds and a design steam production rate of 15,000 lb/hr represents the most challenging end of the spectrum for retrofitting coal in an oil/gas designed boiler.

ACKNOWLEDGEMENTS

We appreciatively acknowledge the DOE-PETC for the financial support of this program under Contract No. DE-AC 22-91PC91160. Douglas Gyorke and John Winslow (DOE-PETC) are acknowledged for their support of this work. Technical advice and consultation with Majed Toqan and Jonas Beér is acknowledged and appreciated.

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Appendix C. Summary of Micronized Coal-Fired Testing

TEST/DESCRIPTION:	8/9/95	8/9/95	8/23/95	8/24/95	8/25/95	8/28/95	8/29/95	8/30/95	8/31/95	9/5/95	10/9/95
	Low-NOx	High Comb. Eff									
	Prim. Closed	Prim. Open	Prim. Open	Prim. Open	Prim. Closed	Prim. Open	Prim. Open	Prim. Open	Prim. Open	Prim. Open	Prim. 100%
	Sec. Closed	Sec. Closed	Sec. 70%	Sec. Open	Sec. Closed	Sec. Open	Sec. Open	Sec. Open	Sec. Open	Sec. 50%	Sec. 100%
	Tert. Open	Tert. Closed	Ter. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%
	Gas Gun -8.5"	Gas Gun -8.5"	Gas Gun 3"	Gas Gun -9"	Gas Gun -9"	Gas Gun -9"	Gas Gun -9"	Gas Gun -9"	Gas Gun -9"	Gas Gun -9"	Radial 0%
	C. Gun 42.25"	C. Gun 42.25"	C. Gun 32"	C. Gun -10.5"	C. Gun -11"	C. Gun -10.5"	C. Gun -10.5"	C. Gun -10.5"	C. Gun -10.5"	C. Gun -10.5"	Gas Gun-9
WATER/STEAM SIDE											C. Gun -9.5
Steam flow rate; lb/h	13,466	14,367	13,467	14,417	14,378	14,039	13,938	14,139	13,601	13,122	13,218
Water temperature into boiler; °F	218	219	208	207	207	206	206	208	207	199	209
Drum pressure; psig	191	186	187	183	187	187	183	186	186	191	193
Calorimeter temperature; °F	313	312	302	301	301	300	301	302	302	301	300
Steam temperature; °F	386	384	373	371	372	372	371	373	372	374	372
Steam quality; %	100.1	100.1	99.5	99.5	99.5	99.4	99.5	99.5	99.5	99.4	99.4
Blowdown rate; lb/h	3,027	2,985	2,994	2,967	2,999	2,997	2,966	2,989	2,988	3,030	3,041
AIR,FUEL, FLUE GAS SIDE											
Coal flow rate; lb/h, MMBtu/h	1,140;15.7	1,140;15.7	1,140;15.7	1,140;15.7	1,140;15.8	1,140;15.8	1,140;15.8	1,140;15.8	1,140;15.8	1,098;15.3	1,140;15.7
Boiler outlet temperature; °F	588	607	549	539	594	562	561	566	571	571	569
Gas temperature leaving air heater; °F	403	414	378	378	400	386	389	390	391	389	388
Air temperature entering air heater; °F	177	183	175	171	166	168	177	173	175	171	162
Air temperature leaving air heater; °F	427	436	404	395	421	406	406	406	411	403	400
Air temperature into boiler; °F	404	415	382	377	399	383	387	385	389	377	375
Ash content of particulate; %	47.55	61.61	30.82	49.94	45.02	47.90	50.20	53.13	50.95	61.08	40.50
Coal combustion efficiency; %	94.1±1.2	97.2±0.5	89.2±1.3	95.3±0.6	94.5±0.6	94.3±1.1	95.4±0.2	95.9±0.8	95.5±0.4	97.5±0.8	93.3±0.7
Combustion air flow; lb/h	14,615	14,011	14,403	14716	14,442	14,693	14,694	14,935	14,639	14,031	14,623
Boiler draft; in H2O	0.04	0.03	0.05	-0.04	-0.01	-0.02	-0.03	-0.03	-0.04	-0.02	0.06
Boiler efficiency; %	83.42	85.72	80.34	84.7	83.46	83.84	84.77	85.01	84.46	86.21	82.39
Mill air flow rate; acfm,lb/h	341;1,480	326;1,393	356;1,555	360;1,572	359;1,574	388;1,701	356;1,549	390;1,688	392;1,722	369;1,629	379; 1,706
Mill outlet temperature; °F	231	243	211	206	206	197	201	220	188	230	222
EMISSIONS											
O2; %	3.5	2.7	3.4	3.8	3.3	3.5	3.6	3.8	3.5	3.5	3.5
CO; ppm;lb/MMBtu@3%O2	238;0.21	149;0.12	258;0.23	146;0.13	178;0.15	129;0.12	166;0.15	114;0.10	118;0.11	119;0.10	224; 0.20
CO2; %	15.8	16.5	15.6	15.0	15.3	15.4	15.4	15.3	15.6	15.9	14.9
SO2; ppm;lb/MMBtu@3%O2	512;1.04	552;1.03	583;1.16	485;1.01	529;1.05	474;0.97	511;1.04	538;1.13	478;0.99	540;1.08	541; 1.10
NOx; ppm;lb/MMBtu@3%O2	371;0.54	684;0.92	281;0.40	443;0.66	439;0.63	385;0.56	361;0.53	325;0.49	341;0.51	474;0.68	298; 0.44
MISCELLANEOUS DATA											
Maximum load (based on 14,700 lb steam/h); %	91.6	97.7	91.6	98.1	97.8	95.5	94.8	96.2	92.5	89.3	89.9

Footnote: Highlighted columns are subperiods within test periods.

TEST/DESCRIPTION:	10/11/95	10/11/95	10/12/95	10/12/95	10/13/95	10/13/95	10/16/95	10/16/95	10/16/95	10/16/95	10/16/95
			Test #1	Test #2	Test #3	Test #4	Test #5	Test #6	Test #7	Test #8	Test #9
	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 50%	Prim. 50%	Prim. 50%	Prim. 50%	Prim. 0%
	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%
	Tert. 50%	Tert. 50%	Tert. 40%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%
	Radial 0%	Radial 25%	Radial 0%	Radial 100%	Radial 25%	Radial 50%	Radial 0%	Radial 100%	Radial 25%	Radial 50%	Radial 0%
	Gas Gun-9	Gas Gun-9	Gas Gun-9	Gas Gun-9	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5
WATER/STEAM SIDE	C. Gun -9	C. Gun -9	C. Gun -9	C. Gun -9	C. Gun -9.5	C. Gun -9	C. Gun 39.5	C. Gun -9	C. Gun -9	C. Gun -9	C. Gun -9
Steam flow rate; lb/h	12,063	11,923	11,907	11,540	12,017	11,890	11,446	11,928	12,104	12,102	12,268
Water temperature into boiler; °F	210	209	208	208	208	209	209	209	209	209	210
Drum pressure; psig	197	194	193	192	195	193	195	193	193	193	193
Calorimeter temperature; °F	301	301	300	300	300	301	301	301	301	300	301
Steam temperature; °F	374	374	373	373	300	301	374	373	373	373	373
Steam quality; %	99.4	99.4	99.4	99.4	99.3	99.4	99.4	99.4	99.4	99.4	99.4
Blowdown rate; lb/h	3,079	3,050	3,046	3,036	3,055	3,041	3,061	3,047	3,044	3,047	3,041
AIR,FUEL, FLUE GAS SIDE											
Coal flow rate; lb/h, MMBtu/h	1,140;15.7	1,140;15.7	1,140;15.8	1,140;15.8	1,140;15.8	1,140;15.8	1,140;16.0	1,140;16.0	1,140;16.0	1,140;16.0	1,140;16.0
Boiler outlet temperature; °F	561	558	564	563	572	568	565	577	584	581	575
Gas temperature leaving air heater; °F	386	386	387	388	388	392	379	386	391	391	388
Air temperature entering air heater; °F	167	168	167	175	160	172	152	143	147	148	145
Air temperature leaving air heater; °F	399	396	398	403	398	403	394	397	403	399	395
Air temperature into boiler; °F	375	375	374	380	375	383	369	375	381	379	376
Ash content of particulate; %	50.17	55.53	56.43	41.08	53.50	50.12	55.60	47.12	56.97	57.94	65.09
Coal combustion efficiency; %	95.1±0.8	96.1±0.5	96.6±0.5	93.8±1.1	95.5±0.4	94.9±0.4	96.2±0.7	94.6±0.9	96.5±0.4	96.7±0.2	97.6±0.5
Combustion air flow; lb/h	14,818	14,896	15,045	14,819	14,735	14,927	14,882	14,766	14,552	14,998	14,862
Boiler draft; in H2O	-0.02	-0.03	0.00	-0.01	0.00	-0.02	-0.01	-0.01	-0.01	-0.01	0.00
Boiler efficiency; %	84.27	84.79	85.26	83.17	84.6	84.03	85.08	83.59	84.91	85.01	85.72
Mill air flow rate; acfm,lb/h	392; 1,759	391; 1,740	363; 1,623	352; 1,557	356; 1,593	378; 1,664	379; 1,703	376; 1,702	382; 1,708	382; 1,696	380; 1,697
Mill outlet temperature; °F	221	235	226	239	235	232	217	218	219	223	225
EMISSIONS											
O2; %	3.7	3.8	3.7	3.4	3.5	3.7	3.6	3.5	3.3	3.8	3.6
CO; ppm;lb/MMBtu@3%O2	137; 0.13	129; 0.12	112;0.10	301; 0.27	124; 0.11	148; 0.14	128; 0.11	200; 0.18	131; 0.11	140; 0.13	118; 0.11
CO2; %	16.0	15.8	16.1	15.7	16.0	15.7	15.6	15.2	15.1	14.6	14.9
SO2; ppm;lb/MMBtu@3%O2	537; 1.12	532; 1.12	546; 1.15	532; 1.09	542; 1.10	519; 1.08	520; 1.07	516; 1.00	532; 1.04	507; 1.06	499; 0.92
NOx; ppm;lb/MMBtu@3%O2	380; 0.57	387; 0.59	301; 0.45	309;0.45	482; 0.71	390; 0.59	441; 0.65	430; 0.62	559; 0.79	459; 0.69	543; 0.80
MISCELLANEOUS DATA											
Maximum load											
(based on 14,700 lb steam/h); %	82.1	81.1	81.0	78.5	81.7	80.9	77.9	81.1	82.3	82.3	83.5

TEST/DESCRIPTION:	10/17/95	10/17/95	10/17/95	10/17/95	10/17/95	10/18/95	10/18/95	10/18/95	10/18/95	10/18/95	10/19/95
	Test #10	Test #11A	Test #11B	Test #13	Test #14	Test # 15	Test # 16	Test # 17	Test #18	Test #19	Test #21
	Prim. 0%	Prim. 0%	Prim. 0%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%
	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 50%	Sec. 50%	Sec. 50%	Sec. 0%
	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%
	Radial 100%	Radial 75%	Radial 25%	Radial 0%	Radial 100%	Radial 25%	Radial 50%	Radial 0%	Radial 25%	Radial 50%	Radial 0%
	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5
WATER/STEAM SIDE	C. Gun -9.5	C. Gun -9.5	C. Gun -9.5	C. Gun -9.5	C. Gun -9.5	C. Gun 38.75	C. Gun 38.75	C. Gun 38.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5
Steam flow rate; lb/h	12,042	12,003	12,066	12,056	11,849	12,061	11,735	12,045	12,132	12,183	12,355
Water temperature into boiler; °F	210	209	209	209	209	208	209	209	209	209	209
Drum pressure; psig	192	191	191	190	191	192	190	188	189	188	184
Calorimeter temperature; °F	301	300	299	299	299	Not Measured	300	300	300	299	299
Steam temperature; °F	373	372	372	372	372	NM	372	372	372	371	369
Steam quality; %	99.4	99.4	99.3	99.3	99.3	Not Determin.	99.4	99.4	99.4	99.3	99.4
Blowdown rate; lb/h	3,035	3,029	3,030	3,022	3,025	NM	3,017	3,004	3,012	3,000	2,970
AIR,FUEL, FLUE GAS SIDE											
Coal flow rate; lb/h, MMBtu/h	1,140;15.9	1,140;15.9	1,140;16.0	1,140;16.0	1,140;16.0	1,140;16.0	1,140;16.0	1,140;16.0	1,140;15.9	1,140;15.9	1,140;16.1
Boiler outlet temperature; °F	577	587	580	576	592	572	565	569	581	578	577
Gas temperature leaving air heater; °F	387	389	393	394	395	381	379	388	397	392	391
Air temperature entering air heater; °F	144	141	155	159	155	152	137	159	163	156	145
Air temperature leaving air heater; °F	396	399	401	401	406	NM	388	396	403	400	395
Air temperature into boiler; °F	377	379	382	383	385	385	369	377	383	381	376
Ash content of particulate; %	52.37	48.57	50.15	60.19	55.56	47.80	42.38	58.12	65.85	56.67	70.84
Coal combustion efficiency; %	96.1±0.5	95.7±0.4	96.2±0.3	97.5±0.2	96.9	95.8±0.2	94.8±0.3	97.3±0.4	97.9±0.2	96.8±0.2	98.2±0.3
Combustion air flow; lb/h	14,823	14,863	14,663	14,966	14,723	14,749	14,840	14,549	14,843	14,749	14,864
Boiler draft; in H2O	-0.01	-0.01	-0.01	0.00	-0.02	-0.15	-0.01	-0.01	-0.01	-0.01	-0.01
Boiler efficiency; %	84.7	84.47	84.62	85.31	84.99	85.50	83.85	85.76	86.04	85.45	86.3
Mill air flow rate; acfm,lb/h	378; 1,712	381; 1,715	389; 1,734	394; 1,763	384; 1,716	376;1,708	383; 1,750	371; 1,664	377; 1,671	377; 1,671	385; 1,731
Mill outlet temperature; °F	219	219	221	214	213	220	215	220	226	226	220
EMISSIONS											
O2; %	3.7	3.7	3.4	3.8	3.5	3.7	3.6	3.4	3.8	3.6	3.5
CO; ppm;lb/MMBtu@3%O2	275; 0.25	282; 0.26	178; 0.16	154; 0.14	238; 0.21	173;0.16	269; 0.24	149; 0.13	149; 0.14	149; 0.13	135; 0.12
CO2; %	15.5	15.5	14.9	14.5	14.8	14.5	15.5	15.5	15.3	15.5	15.5
SO2; ppm;lb/MMBtu@3%O2	498; 1.03	511; 1.06	502; 1.00	497; 1.03	536; 1.08	507;1.04	492; 1.00	513; 1.02	516; 1.07	490; 1.00	499; 1.01
NOx; ppm;lb/MMBtu@3%O2	389; 0.58	443; 0.66	454; 0.65	484; 0.72	458; 0.66	383;0.57	369; 0.54	479; 0.68	463; 0.69	390; 0.57	534; 0.78
MISCELLANEOUS DATA											
Maximum load											
(based on 14,700 lb steam/h); %	81.9	81.7	82.1	82.0	80.6	82.0	79.8	81.9	82.5	82.9	84.0

TEST/DESCRIPTION:	10/19/95	10/19/95	10/19/95	10/20/95	10/20/95	10/20/95	10/24/95	10/24/95	10/25/95	10/25/95	10/30/95
											Continuous/
							385 cfm mill	345 cfm mill	305 cfm mill	395 cfm mill	Deposition
	Test #22	Test #25	Test #29	Test #30	Test #33	Test #34	0900-1200	1230-1955	0830-1400	1430-1959	0600-0800
	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%
	Sec. 0%	Sec. 0%	Sec. 0%	Sec. 0%	Sec. 0%	Sec. 0%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 0%
	Tert. 50%	Tert. 100%	Tert. 75%	Tert. 75%	Tert. 25%	Tert. 25%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 25%
	Radial 25%	Radial 0%	Radial 0%	Radial 25%	Radial 0%	Radial 25%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%
	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9.5	Gas Gun -9
WATER/STEAM SIDE	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.75	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5
Steam flow rate; lb/h	12,298	12,283	12,131	12,065	12,251	12,285	11,882	12,056	12,117	12,369	11,719
Water temperature into boiler; °F	209	209	210	211	211	211	209	209	207	209	210
Drum pressure; psig	185	183	184	185	184	183	166	167	166	168	159
Calorimeter temperature; °F	298	298	300	300	300	299	296	296	295	293	292
Steam temperature; °F	369	369	371	372	371	371	363	363	362	362	359
Steam quality; %	99.3	99.3	99.4	99.4	99.4	99.4	99.4	99.4	99.3	99.2	99.2
Blowdown rate; lb/h	2,980	2,963	2,970	2,981	2,968	2,962	2,825	2,832	2,822	2,839	2,765
AIR,FUEL, FLUE GAS SIDE											
Coal flow rate; lb/h, MMBtu/h	1,140;16.1	1,140;15.9	1,140;15.9	1,140;15.9	1,140;15.9	1,140;15.9	1,140;16.0	1,140;16.0	1,140;16.0	1,140;16.0	1,140;15.9
Boiler outlet temperature; °F	575	573	573	577	575	583	569	571	572	580	559
Gas temperature leaving air heater; °F	391	396	393	395	394	396	386	390	384	392	375
Air temperature entering air heater; °F	157	167	165	160	158	157	158	160	140	145	149
Air temperature leaving air heater; °F	396	399	400	401	399	400	394	392	382	391	384
Air temperature into boiler; °F	376	381	381	383	380	380	368	370	361	370	358
Ash content of particulate; %	61.36	65.59	67.28	62.07	72.75	72.75	54.51	63.14	64.00	73.30	41.90
Coal combustion efficiency; %	97.2±0.3	97.6±0.3	97.8±0.3	97.5±0.2	98.5±0.2	98.6±0.1	97.2±0.6	97.8±0.3	97.7±0.4	98.5±0.2	94.5±0.9
Combustion air flow; lb/h	14,879	14,647	14,774	14,808	14,726	14,621	14832	14,982	14,983	14,811	14,765
Boiler draft; in H2O	-0.02	-0.02	-0.02	-0.01	0.00	-0.01	0.00	-0.01	-0.01	-0.01	-0.02
Boiler efficiency; %	85.67	86.08	86.32	85.92	86.65	86.87	85.66	86.08	86.07	86.69	84.23
Mill air flow rate; acfm,lb/h	372; 1,655	375; 1,645	386; 1,687	379; 1,673	379; 1,675	383; 1,673	385; 1,731	344; 1,530	306; 1,366	395; 1,760	377; 1,684
Mill outlet temperature; °F	228	238	231	225	227	229	191	224	231	214	NM
EMISSIONS											
O2; %	3.5	3.5	3.6	3.7	3.6	3.4	3.5	3.7	3.7	3.5	3.7
CO; ppm;lb/MMBtu@3%O2	141; 0.13	143; 0.13	115; 0.10	148; 0.13	113; 0.10	122; 0.11	131; 0.12	122; 0.11	154; 0.14	93; 0.08	161; 0.14
CO2; %	15.6	15.5	15.4	15.4	15.5	15.6	15.6	15.4	15.3	15.8	15.5
SO2; ppm;lb/MMBtu@3%O2	508; 1.03	502; 1.01	487; 0.99	495; 1.02	473; 0.96	494; 0.99	496; 1.01	500; 1.04	483; 1.00	501; 1.02	513; 1.05
NOx; ppm;lb/MMBtu@3%O2	436; 0.64	456; 0.66	468; 0.69	442; 0.65	582; 0.85	543; 0.79	426; 0.62	522; 0.78	534; 0.80	538; 0.78	356; 0.53
MISCELLANEOUS DATA											
Maximum load											
(based on 14,700 lb steam/h); %	83.7	83.6	82.5	82.1	83.3	83.6	80.8	82.0	82.4	84.1	79.7

TEST/DESCRIPTION:	10/30/95	10/31/95	10/30 1830	10/31/95	10/31/95	10/31/95	11/1/95	10/31 0830	11/1/95	11/2/95	11/1 2200h
	Continuous/	Continuous/	to 10/31	Continuous/	Continuous/	Continuous/	Continuous/	to 11/1	Continuous/	Continuous/	to 11/2
	Deposition	Deposition	0800 hr	Deposition	Deposition	Deposition	Deposition	0800 hr	Deposition	Deposition	0930 hr
	1830-2330	0003-0800		0830-1400	1430-1930	2000-2330	0010-0800		2200-2330	0001-0930	
	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%
	Sec. 0%	Sec. 0%	Sec. 0%	Sec. 0%	Sec. 0%	Sec. 0%	Sec. 0%	Sec. 0%	Sec. 100%	Sec. 100%	Sec. 100%
	Tert. 25%	Tert. 25%	Tert. 25%	Tert. 25%	Tert. 25%	Tert. 25%	Tert. 25%	Tert. 25%	Tert. 50%	Tert. 50%	Tert. 50%
	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 50%	Radial 50%	Radial 50%
	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9
	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun -9	C. Gun -9	C. Gun -9
WATER/STEAM SIDE											
Steam flow rate; lb/h	12,059	12,232	12,165	12,166	12,217	12,294	12,275	12,238	11,815	11,892	11,882
Water temperature into boiler; °F	209	209	209	209	208	209	210	209	210	209	209
Drum pressure; psig	181	203	195	200	201	203	203	202	204	203	203
Calorimeter temperature; °F	298	302	300	302	301	301	302	302	302	301	301
Steam temperature; °F	368	377	374	377	376	377	378	377	378	377	377
Steam quality; %	99.4	99.4	99.4	99.4	99.3	99.3	99.4	99.4	99.4	99.3	99.3
Blowdown rate; lb/h	2,946	3,123	3,055	3,102	3,110	3,122	3,125	3,115	3,131	3,126	3,126
AIR,FUEL, FLUE GAS SIDE											
Coal flow rate; lb/h, MMBtu/h	1,140;15.7	1,140;15.7	1,140;15.7	1,140;15.8	1,140;15.8	1,140;16.0	1,140;15.9	1,140;15.9	1,140;15.9	1,140;15.6	1,140;15.6
Boiler outlet temperature; °F	566	575	572	572	572	571	572	572	566	570	568
Gas temperature leaving air heater; °F	383	388	386	390	392	390	392	391	382	388	387
Air temperature entering air heater; °F	150	144	146	143	151	152	148	148	155	157	157
Air temperature leaving air heater; °F	389	389	389	388	390	390	390	390	387	394	393
Air temperature into boiler; °F	366	368	367	369	371	370	371	370	366	373	372
Ash content of particulate; %	55.00	70.70	62.27	74.60	76.00	78.30	76.70	76.38	53.80	55.00	54.83
Coal combustion efficiency; %	96.0±0.6	98.2±0.3	97.0±1.4	98.5±0.1	98.7	98.8±0.0	98.5±0.1	98.6±0.1	96.6	96.7±0.6	96.7±0.5
Combustion air flow; lb/h	14,361	14,634	14,529	14,672	14,498	14,772	14,632	14,634	14,831	14,683	14,703
Boiler draft; in H2O	-0.02	-0.01	-0.01	0.02	-0.04	-0.05	0.01	-0.01	-0.04	-0.06	-0.06
Boiler efficiency; %	84.72	86.05	85.54	86.69	86.91	86.91	86.51	86.71	84.59	85.55	85.42
Mill air flow rate; acfm,lb/h	295; 1,329	306; 1,360	302; 1,360	372; 1,658	367; 1,634	364; 1,619	363; 1,633	366; 1,637	323; 1,431	326;1,445	326;1,443
Mill outlet temperature; °F	269	270	270	250	250	250	244	248	247	245	245
Burner metal temperature;°F	Not Measured (NM)	NM	NM	NM	NM	NM	NM	NM	NM	547	547
EMISSIONS											
O2; %	3.3	3.6	3.5	3.6	3.5	3.6	3.5	3.5	3.7	3.5	3.5
CO; ppm;lb/MMBtu@3%O2	161; 0.14	124; 0.11	138; 0.12	81; 0.07	91; 0.08	86; 0.08	107; 0.09	94; 0.08	129; 0.12	150;0.13	147;0.13
CO2; %	15.9	15.7	15.8	15.6	15.8	15.8	15.7	15.7	15.7	15.7	15.7
SO2; ppm;lb/MMBtu@3%O2	514; 1.02	491; 1.01	500; 1.01	379; 0.78	409; 0.82	472; 0.96	497; 1.00	444; 0.90	508; 1.05	506;1.02	506;1.03
NOx; ppm;lb/MMBtu@3%O2	483; 0.69	573; 0.85	538; 0.79	510; 0.75	529; 0.76	560; 0.82	573; 0.83	545; 0.79	410; 0.61	430;0.63	427;0.62
MISCELLANEOUS DATA											
Maximum load (based on 14,700 lb steam/h); %	82.0	83.2	82.8	82.8	83.1	83.6	83.5	83.2	80.4	80.9	80.8

TEST/DESCRIPTION:	11/2/95 Continuous/ Deposition 1030-1300 Prim. 100% Sec. 100% Tert. 50% Radial 50% Gas Gun -9 C. Gun -9	11/2/95 Continuous/ Deposition 1330-2300 Prim. 100% Sec. 100% Tert. 50% Radial 50% Gas Gun -9 C. Gun -9	11/3/95 Continuous/ Deposition 0000-1200 Prim. 100% Sec. 100% Tert. 50% Radial 50% Gas Gun -9 C. Gun -9	11/2 1030h to 11/3 1200 hr Prim. 100% Sec. 100% Tert. 50% Radial 50% Gas Gun -9 C. Gun -9	11/3/95 Continuous/ Deposition 1230-1800 Prim. 100% Sec. 100% Tert. 50% Radial 0% Gas Gun -9 C. Gun -9	11/3/95 Continuous/ Deposition 1830-2330 Prim. 100% Sec. 100% Tert. 50% Radial 0% Gas Gun -9 C. Gun -9	11/4/95 Continuous/ Deposition 0000-1000 Prim. 100% Sec. 100% Tert. 50% Radial 0% Gas Gun -9 C. Gun -9	11/4/95 Continuous/ Deposition 1030-2330 Prim. 100% Sec. 100% Tert. 50% Radial 0% Gas Gun -9 C. Gun -9	11/5/95 Continuous/ Deposition 0000-0430 Prim. 100% Sec. 100% Tert. 50% Radial 0% Gas Gun -9 C. Gun -9	11/5/95 Continuous/ Deposition 0500-1300 Prim. 100% Sec. 100% Tert. 50% Radial 0% Gas Gun -9 C. Gun -9	11/5/95 Continuous/ Deposition 1330-2330 Prim. 100% Sec. 100% Tert. 50% Radial 0% Gas Gun -9 C. Gun -9
WATER/STEAM SIDE											
Steam flow rate; lb/h	11,773	11,723	11,729	11,731	12,022	11,934	11,771	11,813	11,733	11,847	11,792
Water temperature into boiler; °F	207	205	209	207	208	210	211	209	209	210	209
Drum pressure; psig	202	201	200	201	201	200	202	201	202	202	200
Calorimeter temperature; °F	300	299	300	300	302	302	302	301	300	300	299
Steam temperature; °F	376	375	376	376	377	378	379	377	377	377	377
Steam quality; %	99.3	99.2	99.3	99.3	99.4	99.4	99.4	99.3	99.3	99.3	99.2
Blowdown rate; lb/h	3,112	3,103	3,099	3,102	3,110	3,102	3,113	3,107	3,114	3,111	3,098
AIR,FUEL, FLUE GAS SIDE											
Coal flow rate; lb/h, MMBtu/h	1,140;15.6	1,140;15.6	1,140;15.9	1,140; 15.7	1,140;15.9	1,140;15.9	1,140;15.6	1,140;15.6	1,140;15.6	1,140;15.6	1,140;15.6
Boiler outlet temperature; °F	564	565	572	568	573	577	579	576	578	578	577
Gas temperature leaving air heater; °F	387	386	386	386	386	385	384	382	383	383	385
Air temperature entering air heater; °F	162	162	158	160	148	139	136	135	133	133	140
Air temperature leaving air heater; °F	396	397	401	399	396	392	395	394	394	395	396
Air temperature into boiler; °F	377	378	382	380	377	374	376	375	375	376	378
Ash content of particulate; %	50.80	50.80	51.20	50.99	67.00	70.00	62.90	62.50	61.50	61.00	56.90
Coal combustion efficiency; %	96.4	96.4±0.4	96.1±0.8	96.3±0.6	98.2±0.3	98.4±0.3	97.7±0.3	97.2±0.2	97.3±0.2	97.2±0.2	96.6±0.2
Combustion air flow; lb/h	14,483	14,628	14,706	14,651	14,745	14,837	14,851	14,575	14,593	14,591	14,552
Boiler draft; in H2O	-0.01	-0.02	-0.02	-0.02	0.00	0.00	0.00	-0.02	-0.02	-0.02	-0.02
Boiler efficiency; %	85.22	85.37	85.11	85.23	86.68	86.84	86.13	85.78	85.67	85.56	85.10
Mill air flow rate; acfm,lb/h	405;1,798	392;1,738	390;1,730	392;1,740	393;1,737	363;1,601	370;1,668	367;1,673	362;1,666	370;1,707	374;1,722
Mill outlet temperature; °F	220	233	235	233	236	247	236	225	225	220	214
Burner metal temperature;°F	559	607	639	618	650	639	652	655	668	670	672
EMISSIONS											
O2; %	3.7	3.6	3.6	3.6	3.6	3.7	3.7	3.5	3.6	3.5	3.5
CO; ppm;lb/MMBtu@3%O2	160;0.14	172; 0.15	174;0.15	172;0.15	122;0.11	132;0.12	101;0.09	119;0.11	135;0.12	210;0.11	130;0.12
CO2; %	15.4	15.6	15.6	15.6	15.6	15.5	15.6	15.8	15.7	15.7	15.6
SO2; ppm;lb/MMBtu@3%O2	492;1.02	483;0.97	479;0.97	482;0.98	479;0.98	486;1.01	468; 0.97	4640.94	4410.89	4560.92	485;0.98
NOx; ppm;lb/MMBtu@3%O2	398;0.59	413;0.60	406;0.59	408;0.59	519;0.76	549;0.82	562;0.84	523;0.76	492;0.72	503;0.73	481;0.70
MISCELLANEOUS DATA											
Maximum load (based on 14,700 lb steam/h); %	80.1	79.7	79.8	79.8	81.8	81.2	80.1	80.4	79.8	80.6	80.2

TEST/DESCRIPTION:	11/6/95	11/6/95	11/3 1830h	11/13/95	11/14/95	11/14/95	11/13 1330	11/16/95	11/16/95	11/17/95	11/16 0310
	Continuous/	Continuous/	to 11/6	Continuous	Continuous	Continuous	to 11/14	Continuous	Continuous	Continuous	to 11/17
	Deposition	Deposition	1235 hr	operation	operation	operation	2230 hr	operation	operation	operation	1416 hr
	0004-0600	0600-1235		1635-2230	0304-1508	1513-2319		0310-1203	1209-2350	2355-1416	
	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%
	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%
	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%
	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%
	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9
	C. Gun -9	C. Gun -9	C. Gun -9	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5
WATER/STEAM SIDE											
Steam flow rate; lb/h	11,737	11,876	11,810	12,038	12,101	12,110	12,089	11,934	11,705	11,740	11,778
Water temperature into boiler; °F	209	206	209	208	207	208	208	208	209	209	209
Drum pressure; psig	200	200	201	206	206	205	206	206	205	204	205
Calorimeter temperature; °F	299	300	300	301	301	302	301	303	302	302	302
Steam temperature; °F	376	376	377	377	377	378	377	379	378	378	378
Steam quality; %	99.2	99.3	99.3	99.3	99.3	99.4	99.3	99.4	99.4	99.4	99.4
Blowdown rate; lb/h	3,098	3,100	3,106	3,141	3,141	3,140	3,141	3,144	3,261	3,128	3,177
AIR,FUEL, FLUE GAS SIDE											
Coal flow rate; lb/h, MMBtu/h	1,140;15.6	1,140;15.6	1,140;15.6	1,140;16.0	1,140;16.1	1,140;16.1	1,140;16.1	1,140;16.0	1,140;16.0	1,140;15.8	1140; 15.9
Boiler outlet temperature; °F	577	578	577	557	558	570	561	553	563	566	562
Gas temperature leaving air heater; °F	384	383	384	375	376	382	378	373	381	383	380
Air temperature entering air heater; °F	136	137	136	142	140	137	140	142	145	141	143
Air temperature leaving air heater; °F	394	394	394	387	387	391	388	383	396	395	392
Air temperature into boiler; °F	376	375	376	365	366	372	368	359	374	375	371
Ash content of particulate; %	54.40	54.60	60.42	54.06	58.18	60.34	57.89	53.66	53.91	58.34	55.65
Coal combustion efficiency; %	96.3±0.3	96.4±0.5	97.2±0.7	96.1±0.7	97.3±0.3	97.3±0.3	97.0±0.6	96.9±0.6	96.9±0.4	97.2±0.6	97.0±0.5
Combustion air flow; lb/h	14,692	14,684	14,662	15,002	15,122	15,080	15,081	15,141	15,050	14,842	14,989
Boiler draft; in H2O	-0.02	-0.02	-0.02	-0.03	-0.03	-0.04	-0.03	-0.02	-0.03	-0.03	-0.03
Boiler efficiency; %	84.81	84.93	85.60	84.85	85.91	85.57	85.56	85.69	85.34	85.65	85.56
Mill air flow rate; acfm,lb/h	379;1,752	367;1,683	369;1,687	388;1,762	386; 1,727	379;1,738	384;1,737	386; 1,737	400; 1,824	388; 1,759	392; 1,776
Mill-outlet temperature; °F	211	222	224	219	227	219	223	228	219	220	222
Burner metal temperature;°F	663	668	661	566	571	607	581	575	590	571	578
EMISSIONS											
O2; %	3.6	3.5	3.6	3.6	3.7	3.6	3.6	3.7	3.7	3.6	3.7
CO; ppm;lb/MMBtu@3%O2	134;0.12	150;0.13	136;0.11	114; 0.10	143; 0.13	112; 0.10	127; 0.11	106; 0.10	139; 0.13	128; 0.12	126; 0.11
CO2; %	15.6	15.5	15.6	15.5	15.6	15.8	15.6	15.6	15.6	15.6	15.6
SO2; ppm;lb/MMBtu@3%O2	510;1.03	480;0.97	473;0.96	493; 1.02	449; 0.93	170; 0.35	463; 0.96	478; 1.00	467 0.97	506 1.05	486; 1.01
NOx; ppm;lb/MMBtu@3%O2	489;0.71	500;0.73	514;0.75	389; 0.58	408; 0.61	328; 0.49	379; 0.56	375; 0.56	430; 0.64	454 0.67	426; 0.63
MISCELLANEOUS DATA											
Maximum load											
(based on 14,700 lb steam/h); %	79.8	80.8	80.3	81.9	82.3	82.4	82.2	81.2	79.6	79.9	80.1

TEST/DESCRIPTION:	11/22/95	11/28/95	11/29/95	11/30/95	12/13/95	12/14/95	12/14/95	12/15/95	12/16/95	12/16/95	12/16/95
					Continuous/	Continuous/	Continuous/	Continuous/	Continuous/	Continuous/	Continuous/
	400 acfm	400 acfm	320 acfm	320 acfm	Deposition	Deposition	Deposition	Deposition	Deposition	Deposition	Deposition
	1630-2230	1045-1500	1145-1535	1006-1645	1620-0016	0022-1245	1251-0036	0041-1603	1607-0013	0019-1210	1216-0009
	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%
	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%
	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%
	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%
	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9
	C. Gun 39.5	C. Gun 39.5	C. Gun 36.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5
WATER/STEAM SIDE											
Steam flow rate; lb/h	12,716	12,397	12,434	12,431	12,657	12,721	12,690	12,891	12,272	12,693	12,733
Water temperature into boiler; °F	208	208	209	208	210	208	209	213	219	219	219
Drum pressure; psig	205	203	204	202	205	205	205	202	203	198	196
Calorimeter temperature; °F	NM	303	303	303	302	301	302	305	310	310	310
Steam temperature; °F	NM	378	379	378	379	378	378	381	387	386	385
Steam quality; %	ND	99.4	99.4	99.5	99.4	99.3	99.4	99.6	99.8	99.9	99.9
Blowdown rate; lb/h	3,136	3,120	3,128	3,118	3,141	3,136	3,135	3,113	3,119	3,086	3,066
AIR,FUEL, FLUE GAS SIDE											
Coal flow rate; lb/h, MMBtu/h	1,140; 15.9	1,140;16.0	1,140; 15.9	1,140; 16.1	1,140; 15.5	1,140; 15.5	1,140; 15.6	1,140; 15.6	1,140; 15.6	1,140; 15.4	1,140; 15.6
Boiler outlet temperature; °F	575	561	567	565	563	566	563	571	567	573	580
Gas temperature leaving air heater; °F	376	373	371	373	370	376	375	385	388	390	391
Air temperature entering air heater; °F	140	141	137	141	124	134	140	151	159	157	152
Air temperature leaving air heater; °F	387	388	390	395	381	388	390	398	403	405	407
Air temperature into boiler; °F	371	362	364	371	357	367	370	317	385	386	388
Ash content of particulate; %	50.95	42.78	40.50	45.22	59.35	66.36	63.56	66.32	59.82	64.88	69.30
Coal combustion efficiency; %	95.1±0.3	94.6±0.4	94.6±0.5	95.0±0.5	96.9±0.5	97.5±0.4	97.6±0.2	98.0±0.2	97.0±0.3	98.3±0.4	98.5±0.4
Combustion air flow; lb/h	15,248	15,365	15,032	15,393	14,863	14,514	14,239	14,482	14,629	14,625	14,616
Boiler draft; in H2O	-0.05	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03	-0.02	-0.03	-0.03
Boiler efficiency; %	84.37	83.11	83.90	84.00	85.90	86.18	86.50	86.52	85.80	86.53	86.63
Mill air flow rate; acfm,lb/h	388; 1,720	389;1,747	312;1,389	331;1,484	372;1,640	376;1,673	370;1,631	374;1,630	383;1,661	377;1,665	378;1,664
Mill outlet temperature; °F	228	213	228	237	236	225	228	234	220	213	213
Burner metal temperature;°F	547	515	478	544	534	571	576	589	628	630	642
EMISSIONS											
O2; %	4.1	4.0	3.7	4.0	4.1	3.6	3.2	3.5	3.7	3.5	3.7
CO; ppm;lb/MMBtu@3%O2	136; 0.13	228; 0.22	329; 0.30	523; 0.49	71; 0.07	82; 0.07	99; 0.09	108; 0.10	201; 0.18	199; 0.18	202; 0.18
CO2; %	15.2	15.2	15.4	15.2	15.3	15.7	16.0	16.0	15.5	15.6	15.6
SO2; ppm;lb/MMBtu@3%O2	486; 1.05	510; 1.10	501; 1.05	465; 1.00	513; 1.11	525; 1.08	529; 1.04	513; 1.04	542; 1.13	551; 1.12	539; 1.12
NOx; ppm;lb/MMBtu@3%O2	424; 0.66	381; 0.59	385; 0.58	350; 0.54	397; 0.62	471; 0.70	481;0.68	520; 0.76	444; 0.66	476; 0.69	497; 0.74
MISCELLANEOUS DATA											
Maximum load											
(based on 14,700 lb steam/h); %	86.5	84.3	84.6	84.6	86.1	86.5	86.3	87.7	83.5	86.3	86.6

TEST/DESCRIPTION:	12/17/95 Continuous/ Deposition 0015-1226	12/17/95 Continuous/ Deposition 1233-0013	12/18/95 Continuous/ Deposition 0019-1240	12/18/95 Continuous/ Deposition 1244-0021	12/19/95 Continuous/ Deposition 0027-0820	12/13 1620 to 12/19 0820 hr	1/9/96 Continuous/ Deposition 0714-1730	1/9/96 Continuous/ Deposition 1800-0100	1/10/96 Continuous/ Deposition 2030-1238	1/11/96 Continuous/ Deposition 1244-0020	1/12/96 Continuous Deposition 0025-1205
	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%
	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%
	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%
	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%
	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9
	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5
WATER/STEAM SIDE											
Steam flow rate; lb/h	12,674	12,430	12,676	12,586	12,144	12,626	13,368	14,555	17,249	16,366	12,461
Water temperature into boiler; °F	220	219	219	219	218	216	218	219	219	219	218
Drum pressure; psig	197	196	194	198	198	200	194	196	160	155	200
Calorimeter temperature; °F	310	310	309	310	310	307	309	311	300	300	310
Steam temperature; °F	385	385	384	385	385	383	384	385	364	366	386
Steam quality; %	99.9	99.9	99.9	99.9	99.9	99.7	99.9	100.0	99.7	99.7	99.9
Blowdown rate; lb/h	3,072	3,070	3,052	3,080	3,085	3,095	3,054	3,065	2,682	2,724	3,095
AIR,FUEL, FLUE GAS SIDE											
Coal flow rate; lb/h, MMBtu/h	1,140; 15.4	1,140; 15.3	1,140; 15.4	1,140; 15.4	1,140; 15.3	1,140; 15.5	1,116; 14.9	1,188; 16.8	1,188; 16.1	1,140; 15.4	1,140; 15.4
Boiler outlet temperature; °F	578	578	581	580	576	573	574	582	570	581	584
Gas temperature leaving air heater; °F	389	391	389	388	387	385	381	391	382	382	384
Air temperature entering air heater; °F	148	154	146	149	147	147	139	138	121	128	133
Air temperature leaving air heater; °F	405	409	406	406	403	401	401	402	397	395	404
Air temperature into boiler; °F	386	391	387	387	384	374	380	382	276	375	384
Ash content of particulate; %	65.67	56.73	51.44	64.45	66.85	63.07	56.32	51.82	61.72	71.61	65.87
Coal combustion efficiency; %	98.5±0.5	97.2±0.3	97.2±0.4	98.4±0.2	98.2±0.2	97.8±0.6	97.7±0.3	97.2±0.6	98.3±0.6	98.9±0.1	98.2±0.5
Combustion air flow; lb/h	14,417	14,382	14,394	14,278	14,145	14,459	13,866	14,746	15,265	14,703	14,582
Boiler draft; in H2O	-0.02	-0.03	-0.03	-0.01	-0.03	-0.03	-0.03	-0.02	-0.06	-0.05	-0.05
Boiler efficiency; %	86.59	85.53	85.84	86.60	86.72	86.30	86.16	85.68	86.42	87.05	86.66
Mill air flow rate; acfm,lb/h	382;1,696	382;1,706	379;1,671	376;1,679	374;1,642	377;1,668	385; 1,173	380; 1,681	380; 1,691	381; 1,664	381; 1,655
Mill outlet temperature; °F	212	210	215	205	211	219	238	240	237	245	243
Burner metal temperature;°F	642	652	655	631	631	616	607	586	598	610	633
EMISSIONS											
O2; %	3.7	3.7	3.7	3.5	3.5	3.6	3.4	3.1	3.7	3.9	3.8
CO; ppm;lb/MMBtu@3%O2	301; 0.27	336; 0.30	453; 0.41	176; 0.16	167; 0.15	203; 0.18	143; 0.13	231; 0.19	128; 0.12	90; 0.08	134; 0.12
CO2; %	15.6	15.5	15.6	15.9	15.8	15.7	15.6	15.9	15.4	15.2	15.5
SO2; ppm;lb/MMBtu@3%O2	536; 1.11	539; 1.09	495; 1.03	563; 1.15	557; 1.13	533; 1.09	559; 1.13	566; 1.06	553;1.16	571; 1.20	561; 1.18
NOx; ppm;lb/MMBtu@3%O2	469; 0.70	426;0.62	420; 0.63	451; 0.66	447; 0.65	463; 0.68	423; 0.62	488; 0.66	467; 0.70	499; 0.77	470; 0.71
MISCELLANEOUS DATA											
Maximum load											
(based on 14,700 lb steam/h); %	86.2	84.6	86.2	85.6	82.6	85.9	90.9	99.0	117.3	111.5	84.8

TEST/DESCRIPTION:	1/12/96 Continuous/ Deposition 1209-0001	1/13/96 Continuous/ Deposition 0006-1233	1/13/96 Continuous/ Deposition 1256-0006	1/14/96 Continuous/ Deposition 0010-1203	1/14/96 Continuous/ Deposition 1207-0010	1/15/96 Continuous/ Deposition 0015-1205	1/16/96 Continuous/ Deposition 1210-0014	1/18/96 Continuous/ Deposition 0018-1206	1/16/96 Continuous/ Deposition 1210-1733	1/9 0714 to 1/16 1733 hr*	2/12/96 Continuous/ Deposition 0530-1149
	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%
	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%
	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%
	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%
	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9
	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5
WATER/STEAM SIDE											
Steam flow rate; lb/h	12,697	12,612	12,295	12,300	12,317	12,790	12,723	12,581	12,364	12,535	12,560
Water temperature into boiler; °F	219	218	219	219	217	218	220	220	219	219	218
Drum pressure; psig	196	197	198	201	199	194	191	193	202	197	197
Calorimeter temperature; °F	310	310	310	310	311	310	309	309	310	310	310
Steam temperature; °F	385	386	386	386	386	384	383	384	387	386	385
Steam quality; %	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	100	99.9
Blowdown rate; lb/h	3,065	3,074	3,079	3,104	3,087	3,050	3,024	3,044	3,111	3,074	3,077
AIR,FUEL, FLUE GAS SIDE											
Coal flow rate; lb/h, MMBtu/h	1,140; 15.3	1,140; 15.3	1,140; 15.4	1,140; 15.2	1,140; 15.4	1,140; 15.3	1,140; 15.2	1,140; 15.2	1,140; 15.4	1,141; 15.5	1,140; 15.3
Boiler outlet temperature; °F	580	587	582	586	583	589	578	587	592	583	570
Gas temperature leaving air heater; °F	381	385	387	391	393	392	387	390	394	387	371
Air temperature entering air heater; °F	136	141	146	149	161	150	141	139	147	140	135
Air temperature leaving air heater; °F	402	409	411	413	417	415	409	411	412	407	396
Air temperature into boiler; °F	382	389	391	394	398	396	390	391	393	378	373
Ash content of particulate; %	52.62	51.14	54.86	63.47	52.47	59.53	54.37	53.22	52.83	57.83	44.03
Coal combustion efficiency; %	96.7±0.8	97.5±0.2	98.1±0.3	98.5±0.1	97.5±0.4	98.4±0.2	97.9±0.1	97.9±0.1	97.8±0.0	97.9±0.7	96.8±0.5
Combustion air flow; lb/h	14,502	14,583	14,445	14,308	14,283	14,377	14,322	14,297	14,238	14,528	14,687
Boiler draft; in H2O	-0.05	-0.06	-0.06	-0.06	-0.07	-0.05	-0.06	-0.05	-0.04	-0.05	-0.09
Boiler efficiency; %	85.57	86.22	86.89	86.57	85.87	86.89	86.59	86.59	86.47	86.44	85.57
Mill air flow rate; acfm,lb/h	378; 1,645	383; 1,667	387; 1,669	391; 1,695	386; 1,677	387; 1,657	391; 1,683	393; 1,683	394; 1,684	385; 1,672	388; 1,691
Mill outlet temperature; °F	237	237	260	230	237	241	235	236	235	240	228
Burner metal temperature;°F	629	639	638	626	646	640	647	653	650	630	592
EMISSIONS											
O2; %	3.7	3.8	3.6	3.7	3.4	3.7	3.7	3.7	3.6	3.7	3.7
CO; ppm;lb/MMBtu@3%O2	165; 0.15	179; 0.17	197; 0.18	155; 0.14	230; 0.20	148; 0.13	182; 0.17	185; 0.17	172; 0.15	166; 0.15	165; 0.15
CO2; %	15.4	15.7	16.3	14.9	15.3	15.4	15.4	15.5	15.5	15.5	14.9
SO2; ppm;lb/MMBtu@3%O2	566; 1.18	499; 1.06	408; 0.84	562; 1.17	564; 1.14	557; 1.16	560; 1.17	568; 1.18	569; 1.17	545; 1.13	562; 1.20
NOx; ppm;lb/MMBtu@3%O2	396; 0.60	378; 0.58	491; 0.73	493; 0.74	438; 0.64	472; 0.71	495; 0.74	492; 0.73	483; 0.59	464; 0.69	388; 0.60
MISCELLANEOUS DATA											
Maximum load (based on 14,700 lb steam/h); %	86.4	85.8	83.6	83.7	83.8	87.0	86.6	85.6	84.1	91.2	85.4

** Periods 1/9/96 1800-0100 hrs, 1/10/96 2030-1238 hrs, and 1/11/96 1244-0020 hrs not used in averaging steam flow, drum pressure, calorimeter temperature, steam temperature, steam quality, and blowdown rate due to low steam pressure*

TEST/DESCRIPTION:	2/12/96	2/12/96	2/12 0530	2/13/96	2/13/96	2/13/96	2/13 1700	2/14/96	2/14/96	2/14/96	2/14 1700
	Continuous/	Continuous/	to 2/13	Continuous/	Continuous/	Continuous/	to 2/14	Continuous/	Continuous/	Continuous/	to 2/15
	Deposition	Deposition	0800 hr	Deposition	Deposition	Deposition	0830 hr	Deposition	Deposition	Deposition	0800 hr
	1157-2346	2352-0800		0830-1630	1700-2348	2353-0830		0900-1630	1700-2340	2344-0800	
	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%
	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%
	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%
	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%
	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9
	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5
WATER/STEAM SIDE			15.2 MMBtu/h	12.0 MMBtu/h			15.7 MMBtu/h	12.1 MMBtu/h			15.7 MMBtu/h
Steam flow rate; lb/h	13,071	13,062	12,945	11,041	13,874	12,610	13,165	10,105	12,964	12,492	12,698
Water temperature into boiler; °F	219	219	219	219	218	216	217	218	218	218	218
Drum pressure; psig	192	191	193	182	186	202	195	197	200	204	202
Calorimeter temperature; °F	309	309	309	305	308	311	310	309	311	311	311
Steam temperature; °F	383	383	383	379	381	387	384	385	386	387	387
Steam quality; %	99.9	99.9	99.9	99.7	99.9	99.9	99.9	99.8	99.9	99.9	99.9
Blowdown rate; lb/h	3,035	3,028	3,043	2,953	2,990	3,110	3,057	3,078	3,096	3,126	3,113
AIR,FUEL, FLUE GAS SIDE											
Coal flow rate; lb/h, MMBtu/h	1,140; 15.2	1,140; 15.2	1,140; 15.2	900; 12.0	1,170; 15.8	1,170; 15.7	1,170; 15.7	900; 12.1	1,170; 15.7	1,170; 15.7	1,170; 15.7
Boiler outlet temperature; °F	584	583	580	571	590	579	584	565	583	568	575
Gas temperature leaving air heater; °F	378	381	377	367	387	384	385	370	388	384	386
Air temperature entering air heater; °F	130	130	131	145	134	140	137	159	146	148	147
Air temperature leaving air heater; °F	401	401	400	405	402	402	402	408	406	404	405
Air temperature into boiler; °F	379	380	378	385	382	383	383	388	387	384	385
Ash content of particulate; %	50.50	53.16	49.77	55.50	54.99	54.17	54.53	58.25	54.99	54.17	54.54
Coal combustion efficiency; %	97.2±0.4	97.3±0.3	97.1±0.4	97.6±0.4	98.1±0.1	98.1±0.1	98.1±0.1	98.5±0.2	98.2±0.1	97.1±0.3	97.6±0.6
Combustion air flow; lb/h	14,341	14,451	14,458	11,434	15,150	15,240	15,201	11,955	15,148	15,122	15,134
Boiler draft; in H2O	-0.09	-0.09	-0.09	-0.02	-0.04	-0.06	-0.05	-0.04	-0.04	-0.04	-0.04
Boiler efficiency; %	86.03	86.00	85.91	86.52	86.43	86.43	86.43	86.79	86.53	87.76	87.21
Mill air flow rate; acfm,lb/h	385; 1,699	381; 1,658	377; 1,671	377; 1,626	380; 1,633	375; 1,620	377; 1,626	347; 1,488	379; 1,623	377; 1,629	378; 1,626
Mill outlet temperature; °F	233	233	232	240	240	239	239	250	241	237	239
Burner metal temperature;°F	673	661	649	578	653	652	652	740	659	651	655
EMISSIONS											
O2; %	3.4	3.5	3.5	3.6	3.7	3.9	3.8	4.2	3.8	3.7	3.7
CO; ppm;lb/MMBtu@3%O2	183; 0.17	141; 0.13	166; 0.15	156; 0.14	124; 0.12	152; 0.14	140, 0.13	168; 0.17	200; 0.19	214; 0.20	208; 0.19
CO2; %	252.0	15.6	121.9	15.5	15.2	15.2	15.2	14.6	15.1	15.3	15.2
SO2; ppm;lb/MMBtu@3%O2	581; 1.20	558; 1.16	569; 1.19	576; 1.21	581; 1.23	583; 1.22	571; 1.23	556; 1.25	576; 1.24	558; 1.19	566; 1.21
NOx; ppm;lb/MMBtu@3%O2	429; 0.64	439; 0.66	422; 0.63	392; 0.59	552; 0.84	532; 0.83	541; 0.84	445; 0.72	552; 0.85	545; 0.83	548; 0.84
MISCELLANEOUS DATA											
Maximum load											
(based on 14,700 lb steam/h); %	88.9	88.9	88.1	75.1	94.4	85.8	89.6	68.7	88.1	85.0	86.4

TEST/DESCRIPTION:	2/15/96	2/15/96	2/16/96	2/16/96	2/16/96	2/16/96	2/16 1800	2/17/96	2/17/96	2/17 0900	2/18/96
	Continuous/ Deposition	Continuous/ Deposition	Continuous/ Deposition	Continuous/ Deposition	Continuous/ Deposition	Continuous/ Deposition	to 2/17	Continuous/ Deposition	Continuous/ Deposition	to 2/17	Continuous Operation
	0830-1630	1700-2230	0430-0830	0900-1630	1800-2342	2347-0730	0730 hr	0900-1156	1200-2230	2230 hr	2300-0130
	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%	Prim. 100%
	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%	Sec. 100%
	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 50%	Tert. 28%	Tert. 28%	Tert. 28%	Tert. 28%
	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%	Radial 0%
	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9	Gas Gun -9
	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5	C. Gun 39.5
WATER/STEAM SIDE	12.1 MMBtu/h	15.6 MMBtu/h	15.6 MMBtu/h	12.0 MMBtu/h	16.3 MMBtu/h	16.1 MMBtu/h	16.2 MMBtu/h	11.9 MMBtu/h	12.2 MMBtu/h	12.1 MMBtu/h	16.3 MMBtu/h
Steam flow rate; lb/h	11,303	13,013	12,436	10,124	13,194	12,674	12,895	10,826	10,734	10,754	15,410
Water temperature into boiler; °F	217	219	218	217	218	218	218	218	218	218	217
Drum pressure; psig	199	196	203	197	195	198	197	200	201	201	162
Calorimeter temperature; °F	310	310	311	309	309	310	310	310	310	310	302
Steam temperature; °F	385	385	387	385	384	385	385	386	387	387	371
Steam quality; %	99.9	99.9	99.9	99.8	99.9	99.9	99.9	99.9	99.9	99.9	99.7
Blowdown rate; lb/h	3,087	3,065	3,120	3,074	3,057	3,080	3,070	3,095	3,108	3,105	2,790
AIR,FUEL, FLUE GAS SIDE											
Coal flow rate; lb/h, MMBtu/h	900; 12.1	1,170; 15.6	1,170; 15.6	900; 12.0	1,218; 16.3	1,218; 16.1	1,218; 16.2	900; 11.9	900; 12.2	900; 12.1	1,218; 16.3
Boiler outlet temperature; °F	589	587	565	566	577	555	564	571	569	569	545
Gas temperature leaving air heater; °F	386	388	377	368	382	376	379	376	376	376	361
Air temperature entering air heater; °F	148	144	139	145	132	133	133	145	147	147	133
Air temperature leaving air heater; °F	412	410	396	402	402	396	399	409	403	404	374
Air temperature into boiler; °F	391	389	376	381	381	376	378	388	383	384	351
Ash content of particulate; %	61.14	54.32	50.81	63.80	38.16	34.42	36.01	44.85	55.70	53.35	27.38
Coal combustion efficiency; %	98.4±0.6	97.7±0.3	97.1±0.5	98.8±0.2	96.1±0.7	95.0±0.6	95.0±0.7	96.7±0.8	98.1±1.2	97.8±1.2	93.1±0.1
Combustion air flow; lb/h	12,818	15,100	15,229	12,650	16,626	15,306	15,442	11,767	12,757	12,543	16,807
Boiler draft; in H2O	-0.04	-0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.04	-0.03	-0.03	-0.08
Boiler efficiency; %	85.86	86.25	85.81	86.19	84.32	84.30	84.31	85.19	86.01	85.83	82.61
Mill air flow rate; acfm,lb/h	375; 1,611	383; 1,640	389; 1,702	380; 1,642	381; 1,634	378; 1,642	379; 1,639	369; 1,612	383; 1,661	380; 1,650	376; 1,642
Mill outlet temperature; °F	237	234	223	230	234	231	232	236	231	232	232
Burner metal temperature;°F	678	662	635	705	660	649	654	722	679	688	560
EMISSIONS											
O2; %	5.3	3.8	3.9	5.3	3.7	3.6	3.6	4.2	5.2	5.0	4.9
CO; ppm;lb/MMBtu@3%O2	124; 0.14	192; 0.18	187; 0.18	113; 0.13	622; 0.58	759; 0.69	701; 0.64	400; 0.40	232; 0.26	268; 0.29	190; 0.20
CO2; %	13.7	15.4	15.2	13.0	15.2	15.4	15.3	14.9	14.3	14.4	14.4
SO2; ppm;lb/MMBtu@3%O2	530; 1.37	574; 1.24	563; 1.23	514; 1.10	579; 1.23	549; 1.15	562; 1.18	561; 1.27	530; 1.35	537; 1.33	550; 1.35
NOx; ppm;lb/MMBtu@3%O2	543; 1.01	545; 0.85	445; 0.70	430; 0.79	481; 0.73	493; 0.74	488; 0.74	489; 0.79	592; 1.08	570; 1.02	325; 0.57
MISCELLANEOUS DATA											
Maximum load											
(based on 14,700 lb steam/h); %	76.9	88.5	84.6	68.9	89.8	86.2	87.7	73.6	73.0	73.2	104.8

	2/19/96	2/19/96
TEST/DESCRIPTION:	Continuous	Continuous
	Operation	Operation
	0200-0700	0730-1630
	Prim. 100%	Prim. 100%
	Sec. 100%	Sec. 100%
	Tert. 28%	Tert. 28%
	Radial 0%	Radial 0%
	Gas Gun -9	Gas Gun -9
	C. Gun 39.5	C. Gun 39.5
WATER/STEAM SIDE	15.2 MMBtu/h	12.0 MMBtu/h
Steam flow rate; lb/h	15,481	10,748
Water temperature into boiler; °F	218	219
Drum pressure; psig	156	185
Calorimeter temperature; °F	301	305
Steam temperature; °F	368	379
Steam quality; %	99.7	99.7
Blowdown rate; lb/h	2,742	2,971
AIR,FUEL, FLUE GAS SIDE		
Coal flow rate; lb/h, MMBtu/h	1,140; 15.2	900; 12.0
Boiler outlet temperature; °F	545	557
Gas temperature leaving air heater; °F	358	362
Air temperature entering air heater; °F	137	157
Air temperature leaving air heater; °F	385	402
Air temperature into boiler; °F	363	379
Ash content of particulate; %	30.98	40.45
Coal combustion efficiency; %	94.1±0.6	96.1±0.7
Combustion air flow; lb/h	14,807	12,270
Boiler draft; in H2O	-0.04	-0.04
Boiler efficiency; %	83.75	84.86
Mill air flow rate; acfm,lb/h	391; 1,717	390; 1,694
Mill outlet temperature; °F	227	224
Burner metal temperature;°F	612	708
EMISSIONS		
O2; %	2.8	4.6
CO; ppm;lb/MMBtu@3%O2	216; 0.20	244; 0.26
CO2; %	15.3	14.5
SO2; ppm;lb/MMBtu@3%O2	573; 1.24	540; 1.29
NOx; ppm;lb/MMBtu@3%O2	309; 0.48	298; 0.51
MISCELLANEOUS DATA		
Maximum load		
(based on 14,700 lb steam/h); %	105.3	73.1

Appendix D. Graphs of Coal Combustion Efficiency and Emissions as a Function of Time for Testing Conducted in Task 5

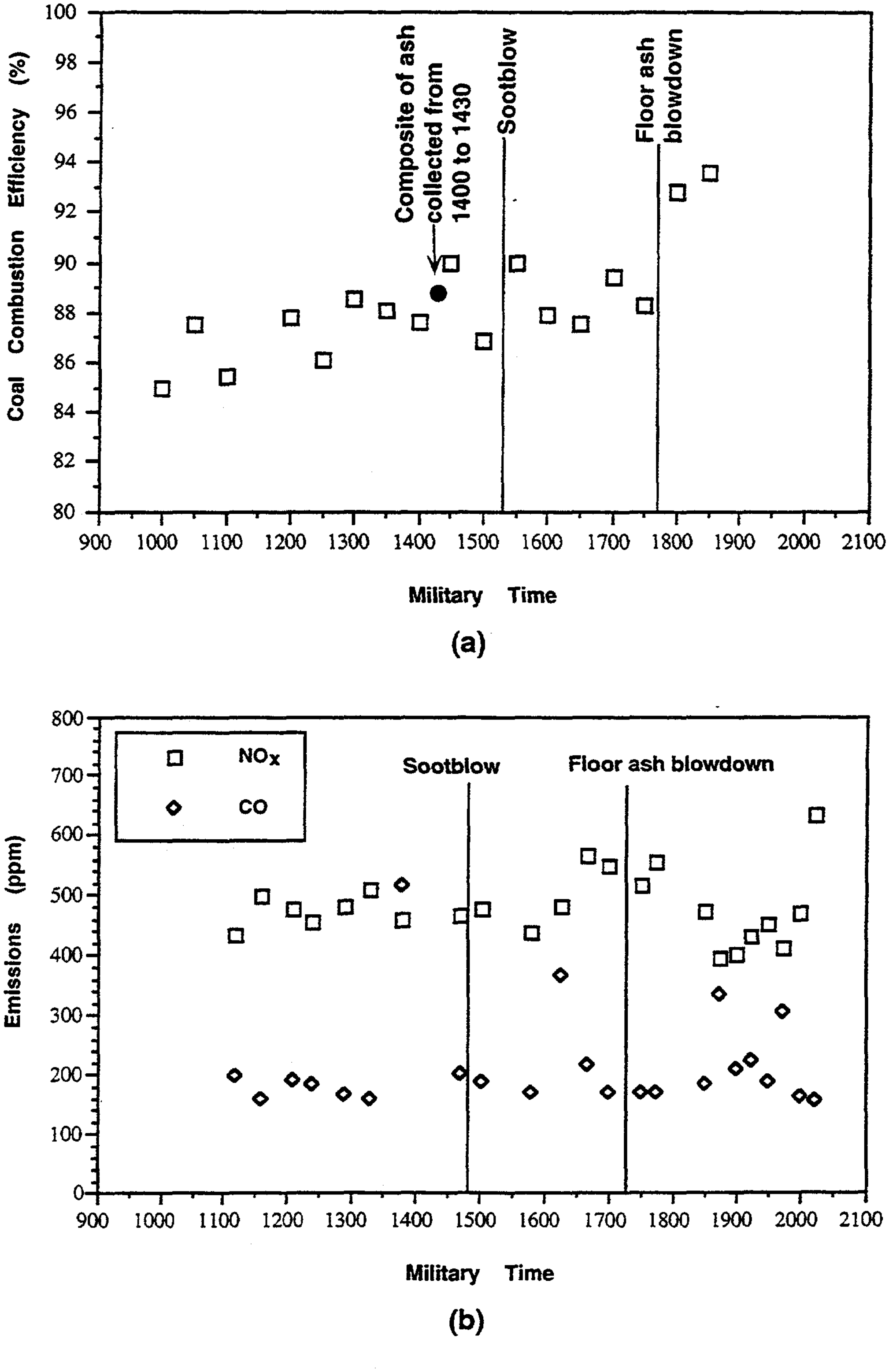
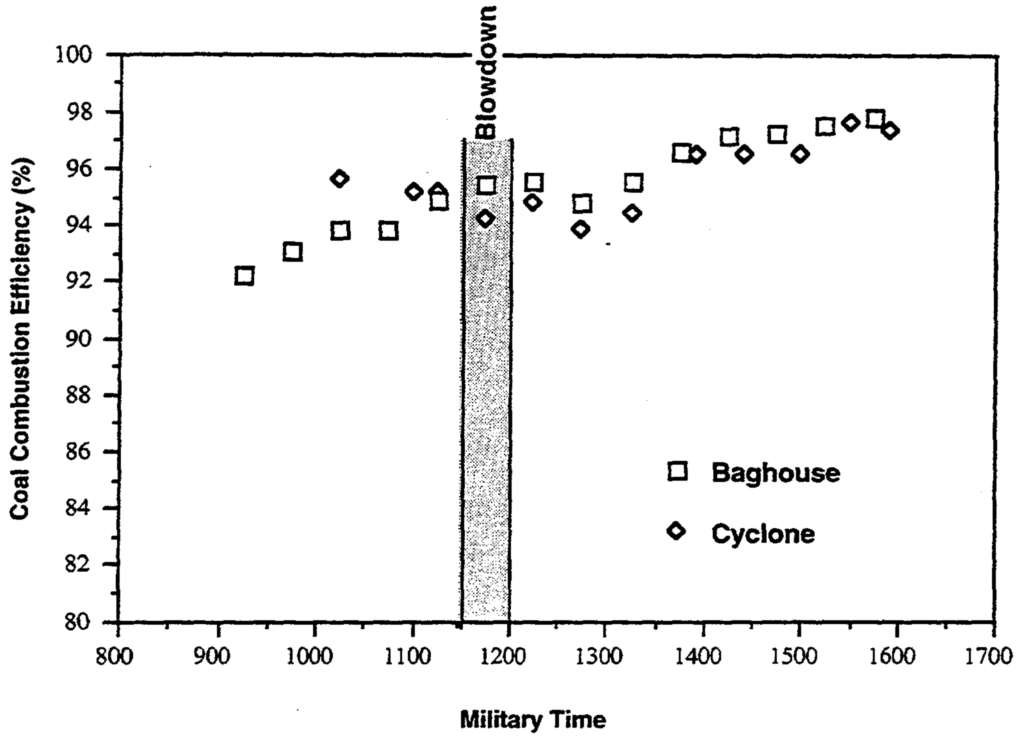
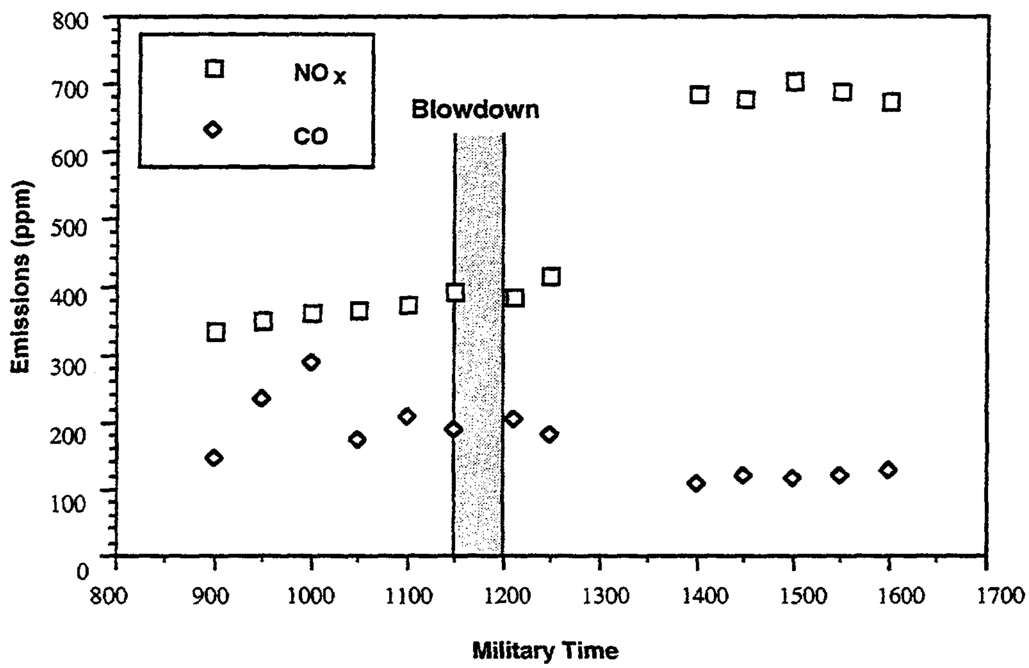


Figure D-1. COAL COMBUSTION EFFICIENCY BASED ON THE BAGHOUSE ASH SAMPLES (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING CONDUCTED ON 08/03/95

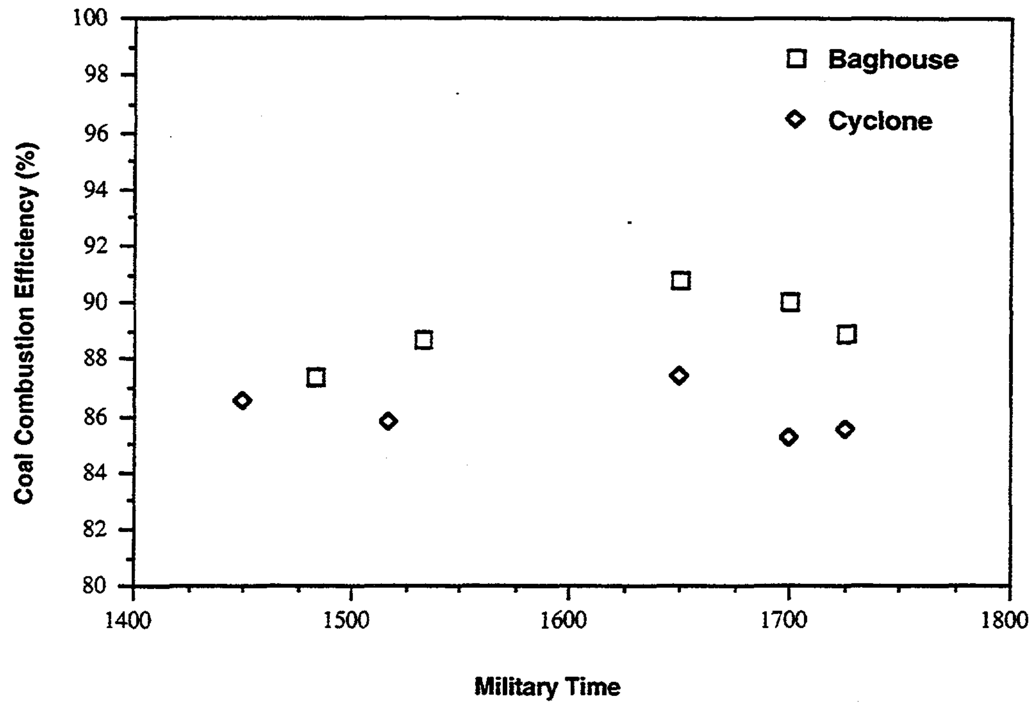


(a)

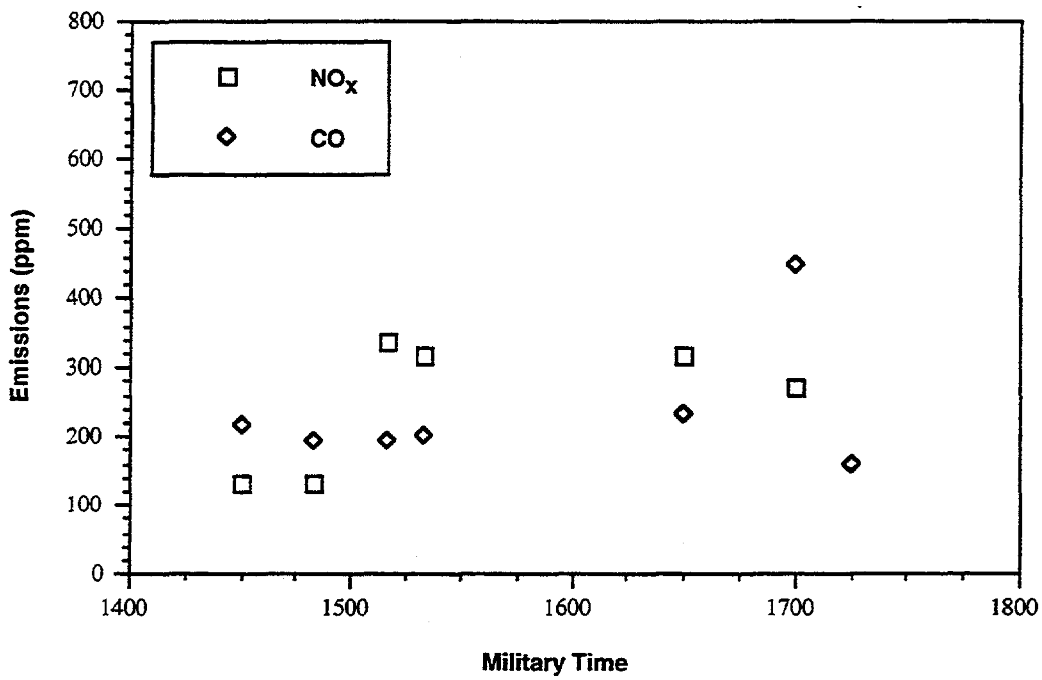


(b)

Figure D-2. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 08/09/95



(a)



(b)

Figure D-3. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 08/23/95

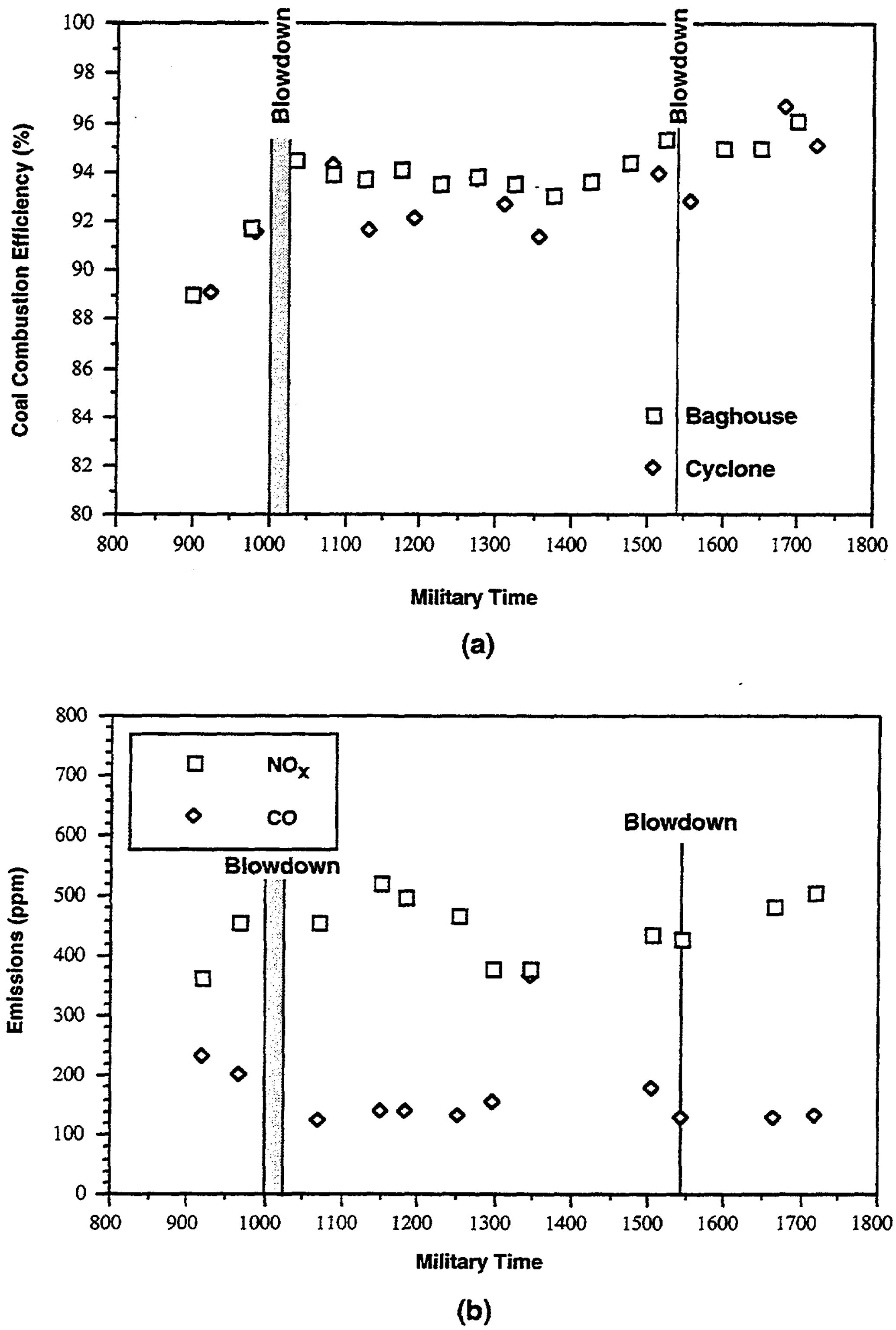


Figure D-4. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 08/24/95

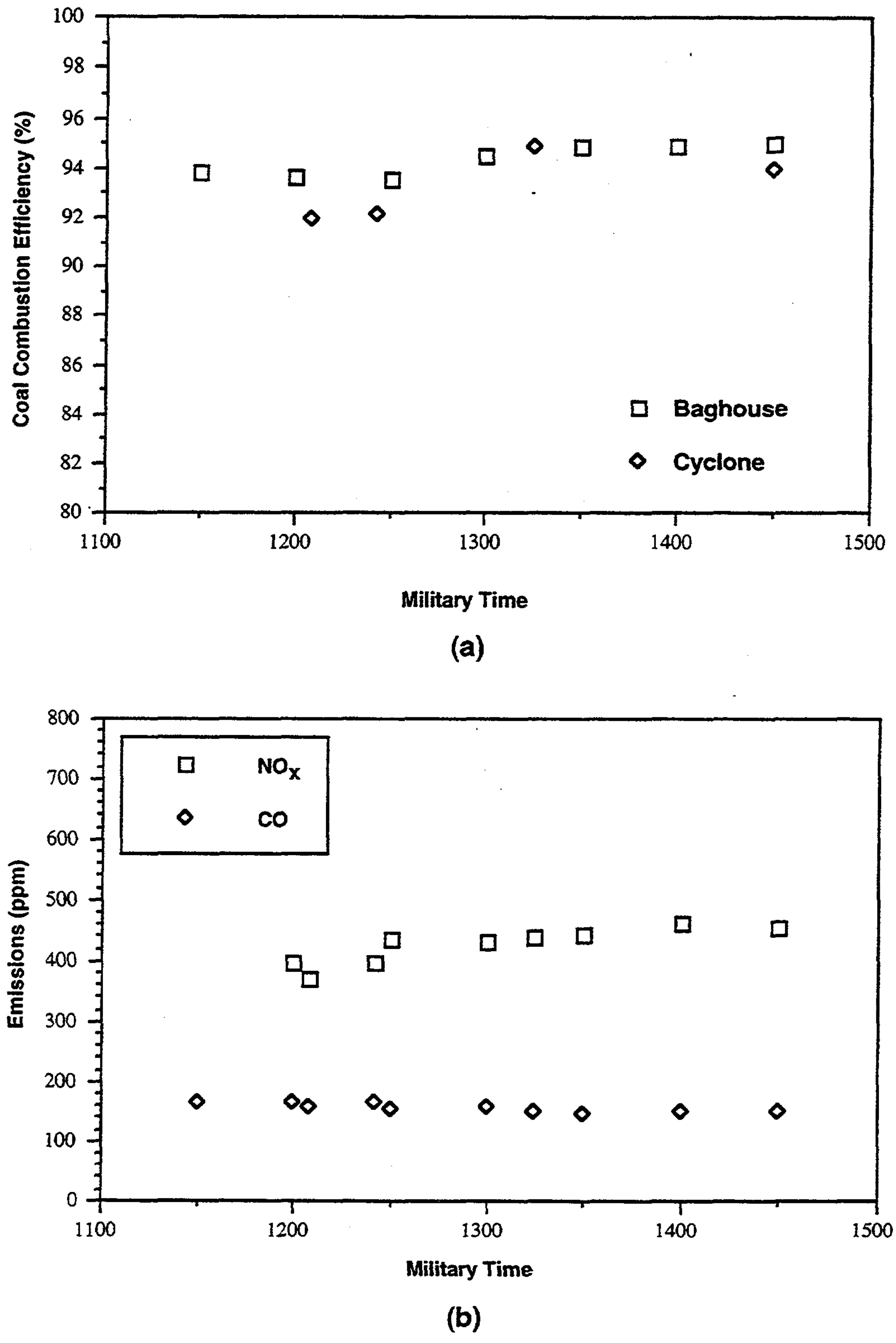
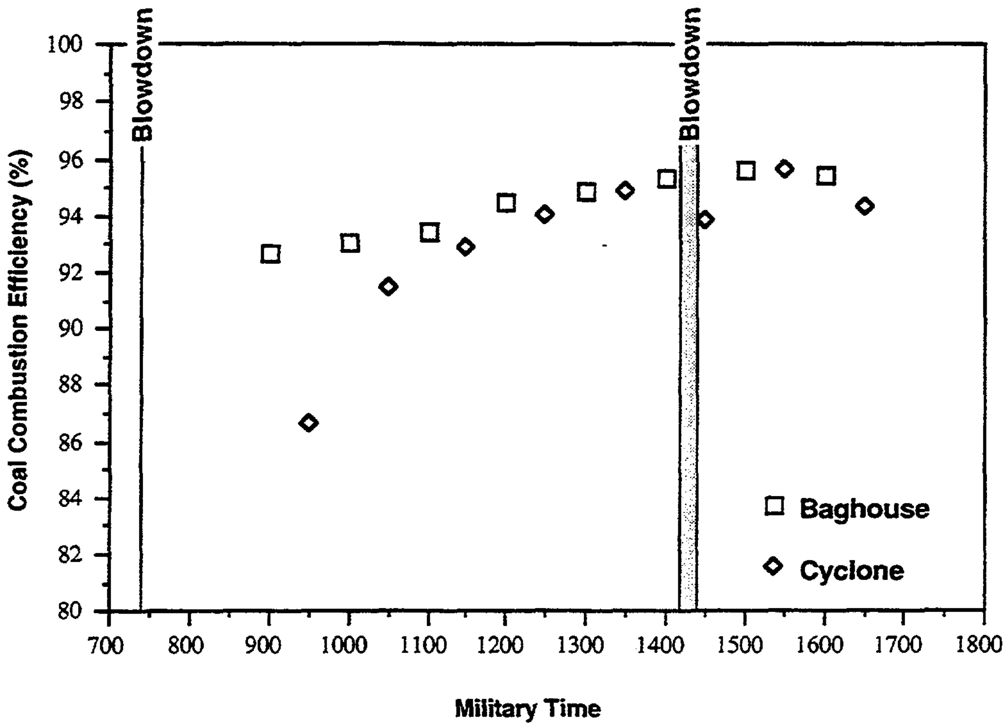
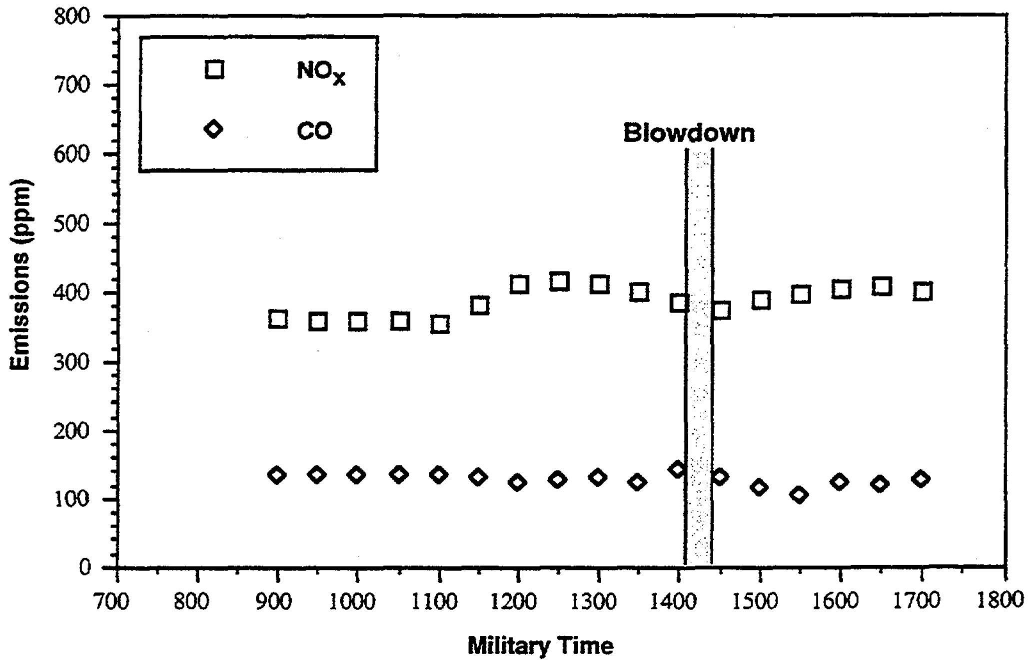


Figure D-5. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 08/25/95

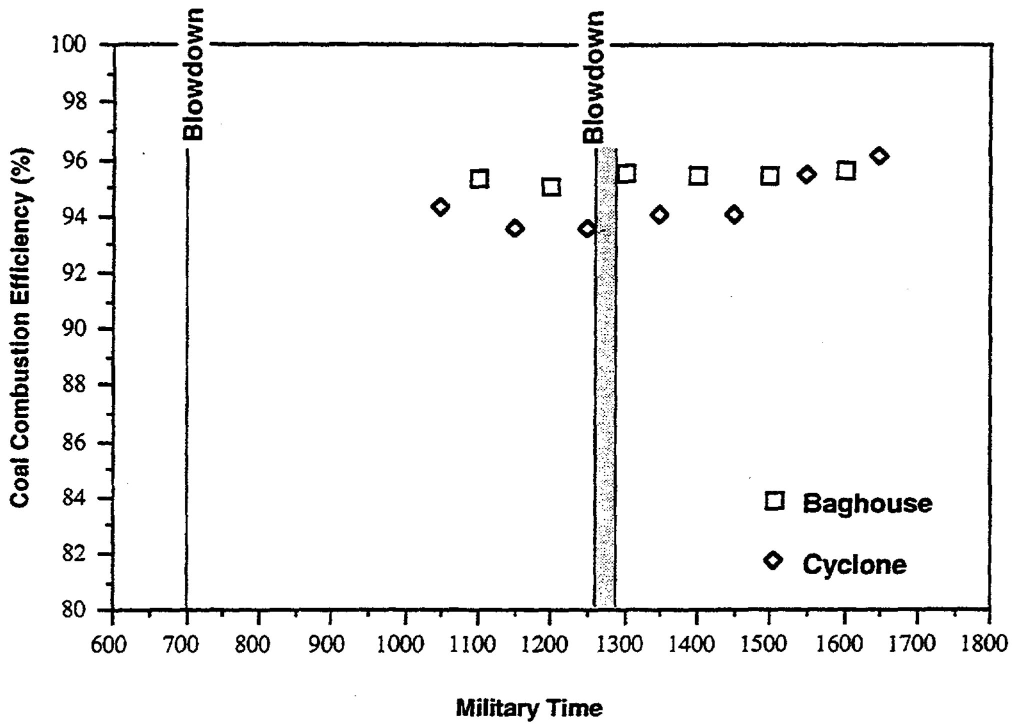


(a)

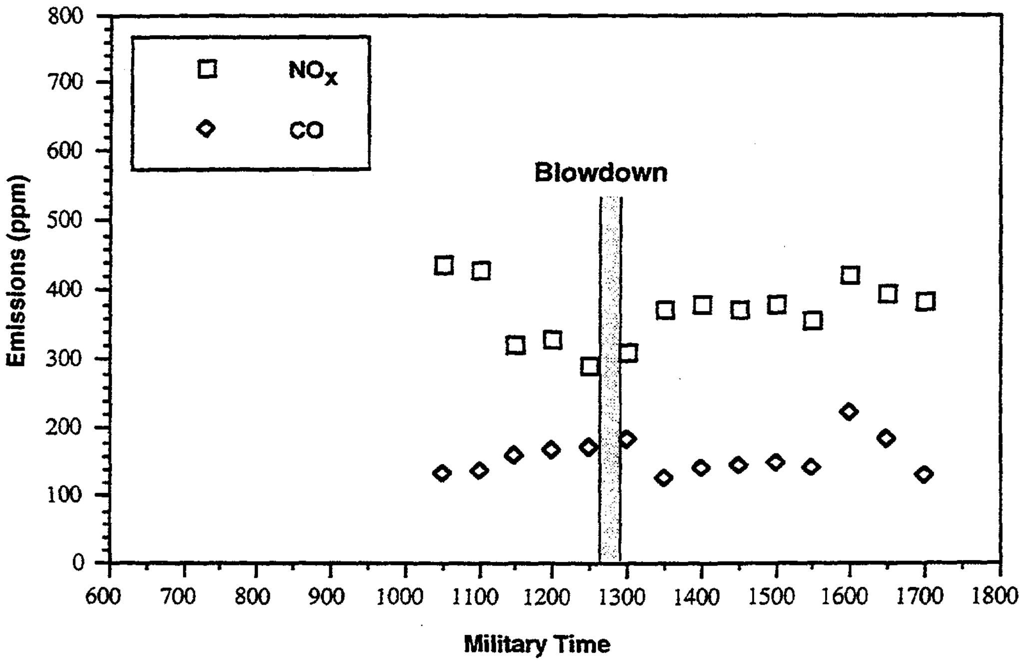


(b)

Figure D-6. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 08/28/95



(a)



(b)

Figure D-7. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 08/29/95

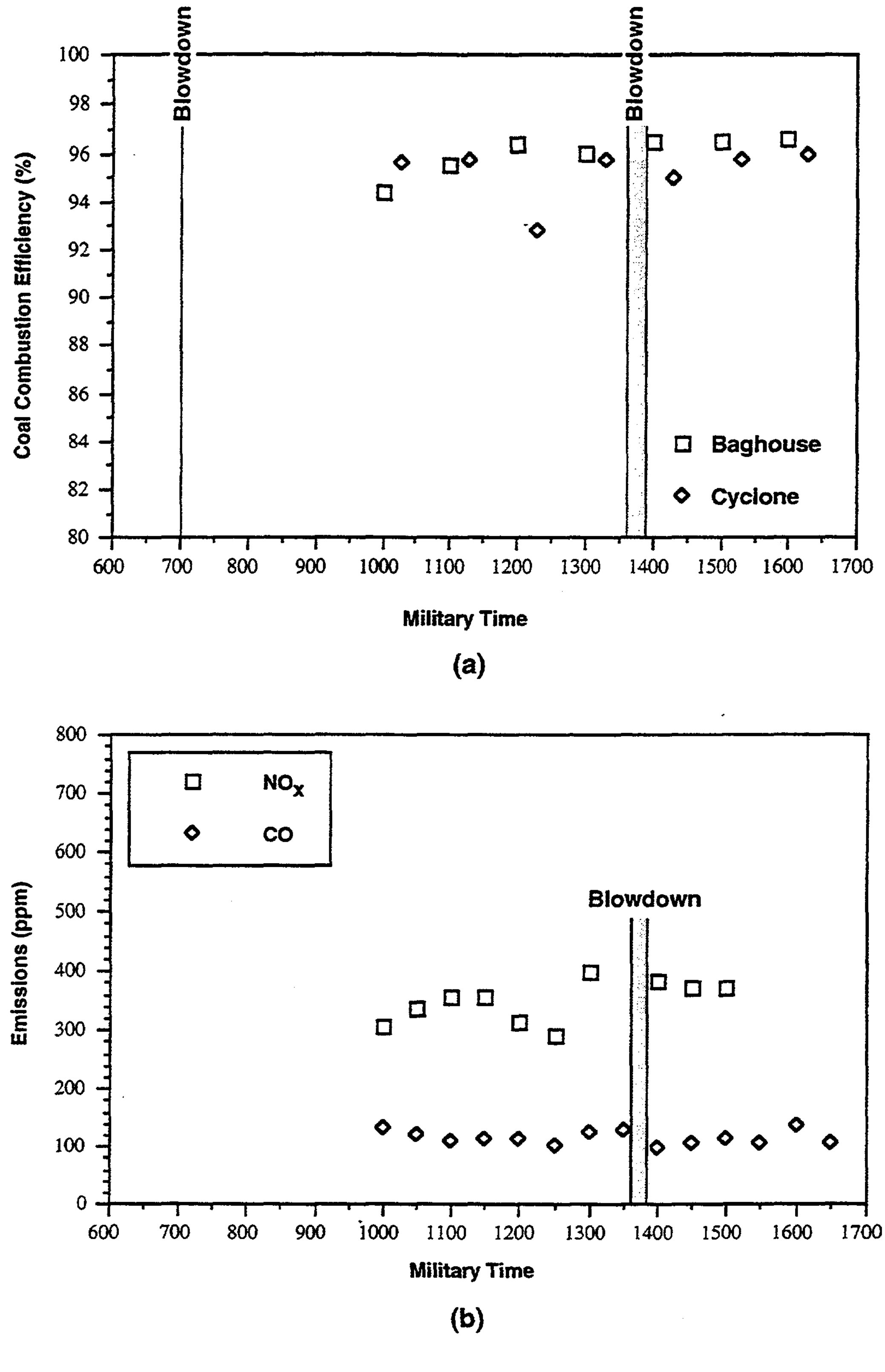


Figure D-8. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 08/30/95

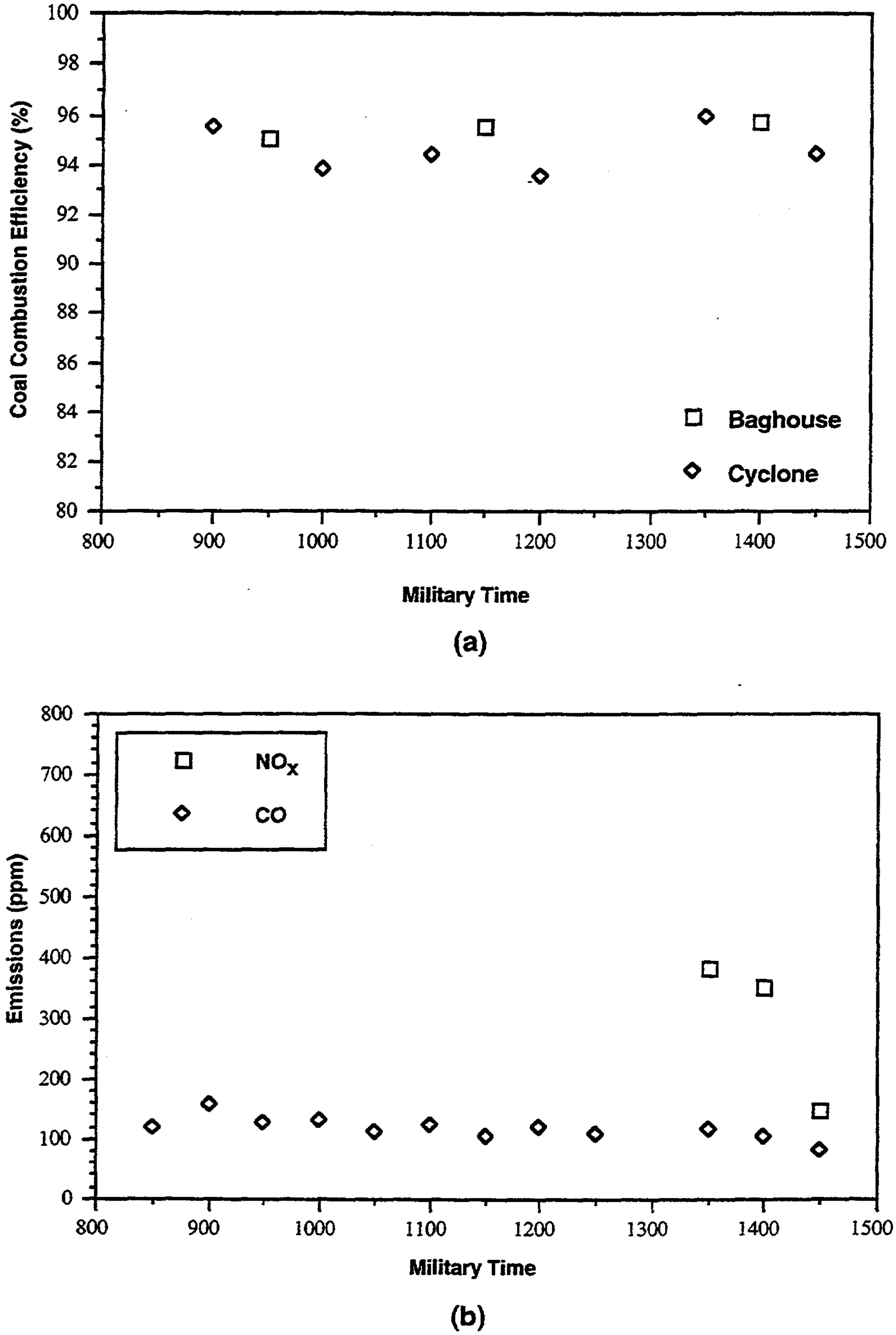
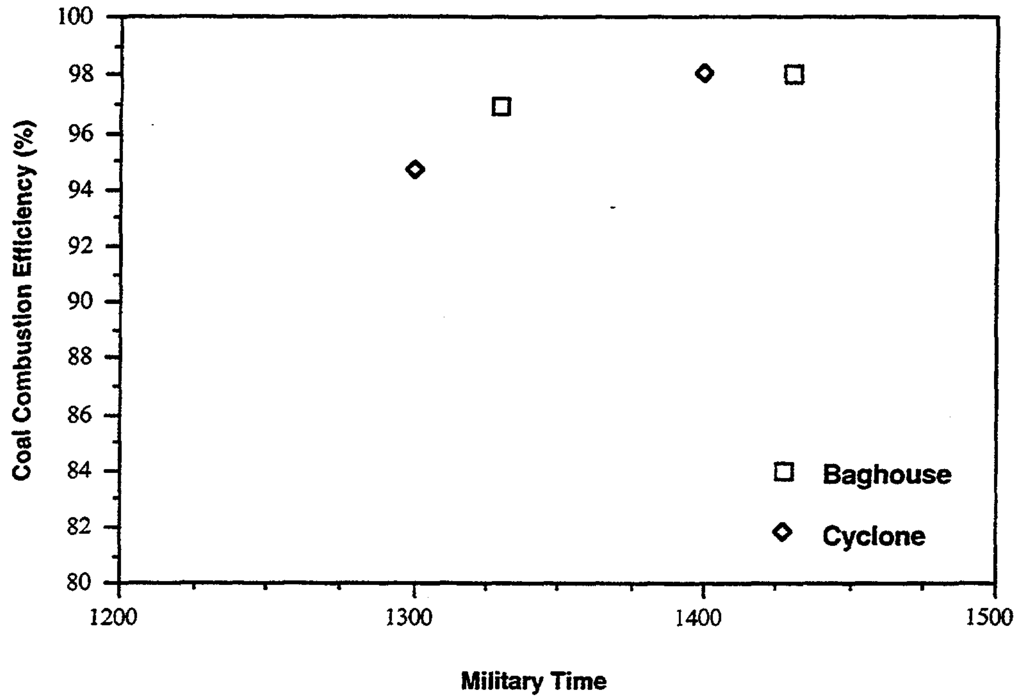
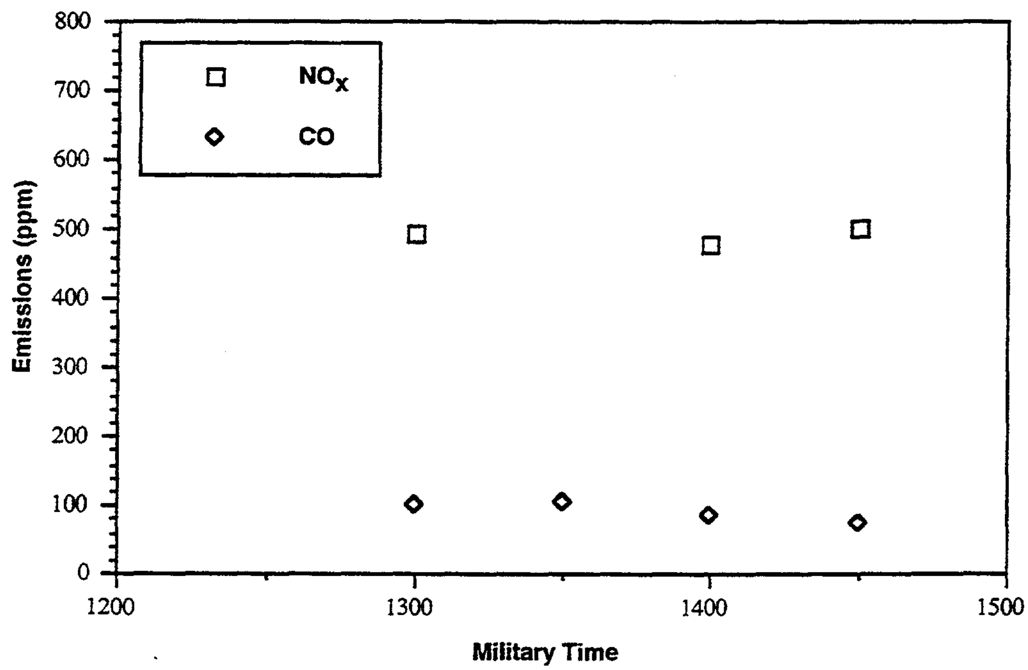


Figure D-9. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 08/31/95



(a)



(b)

Figure D-10. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 09/05/95

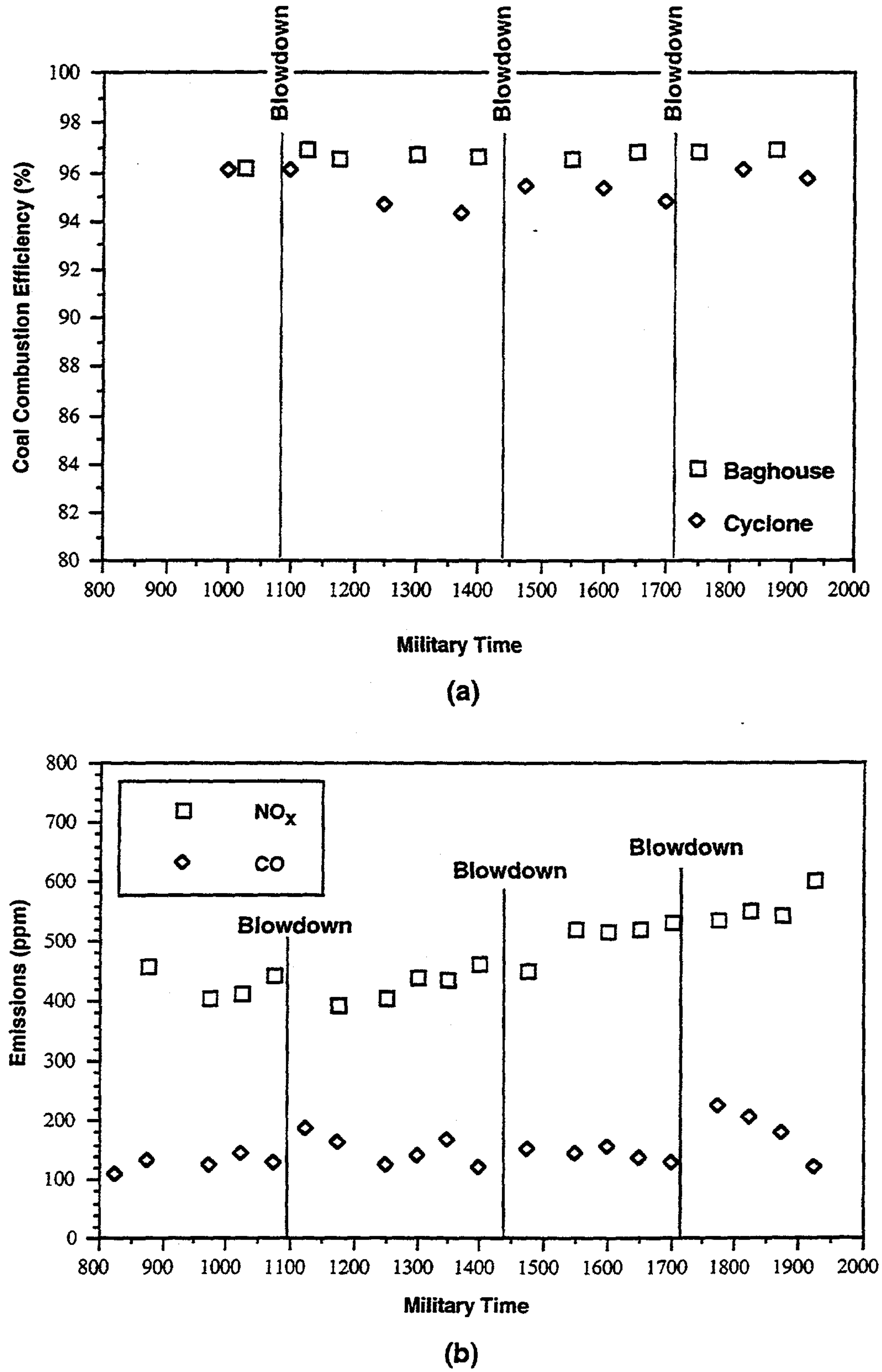


Figure D-11. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 09/06/95

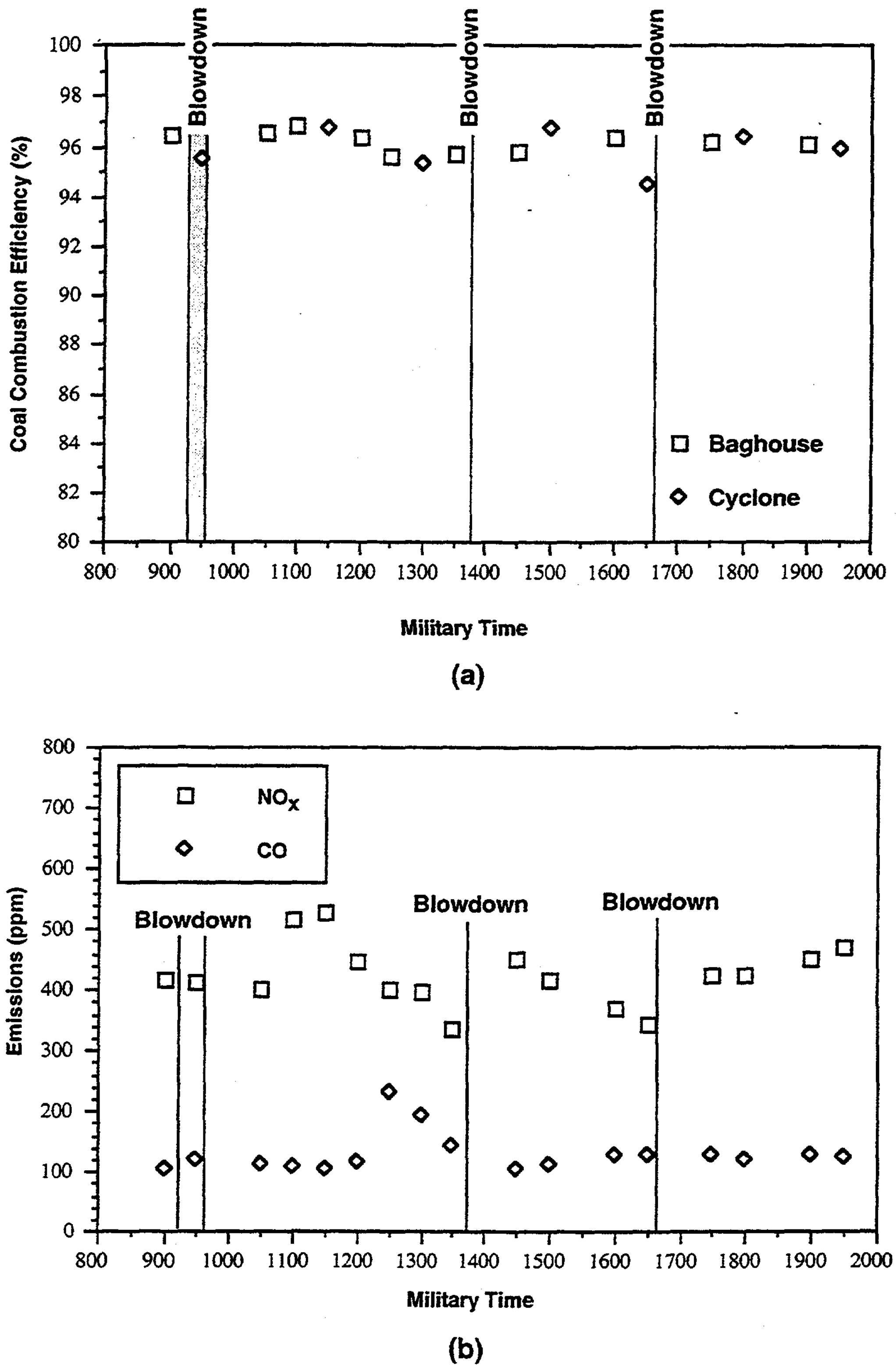
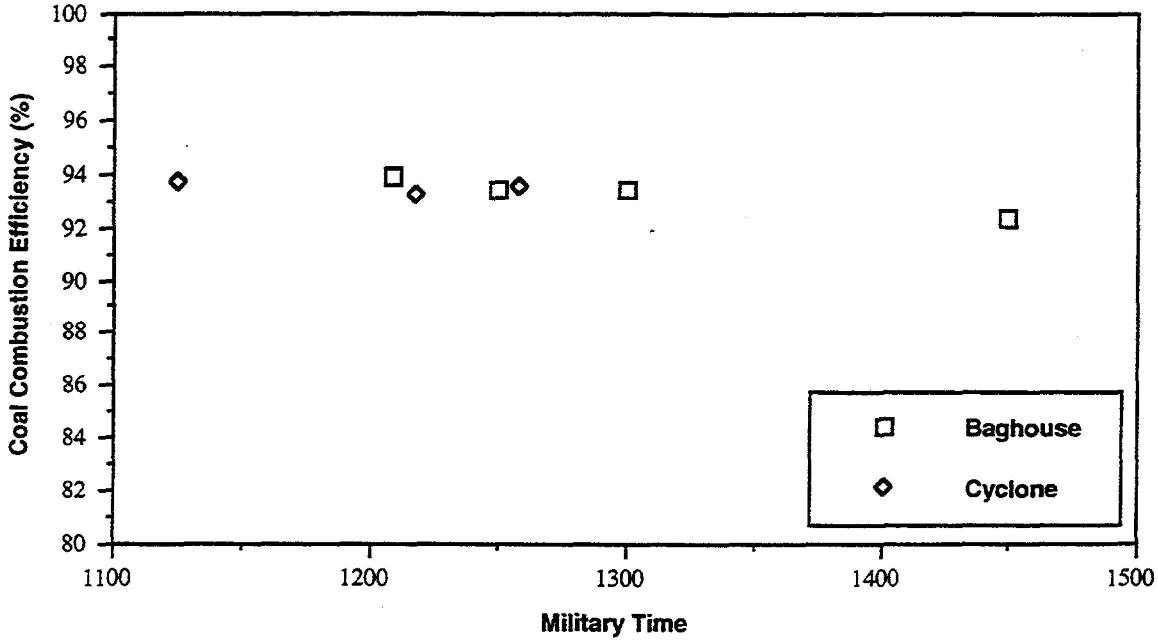
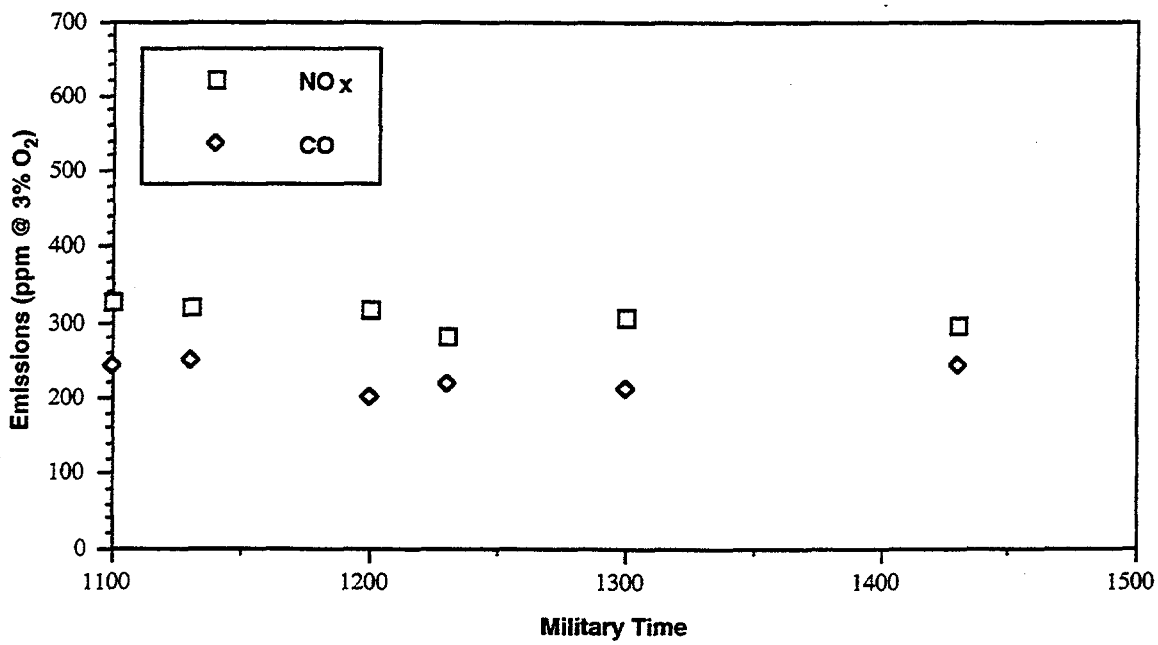


Figure D-12. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 09/07/95

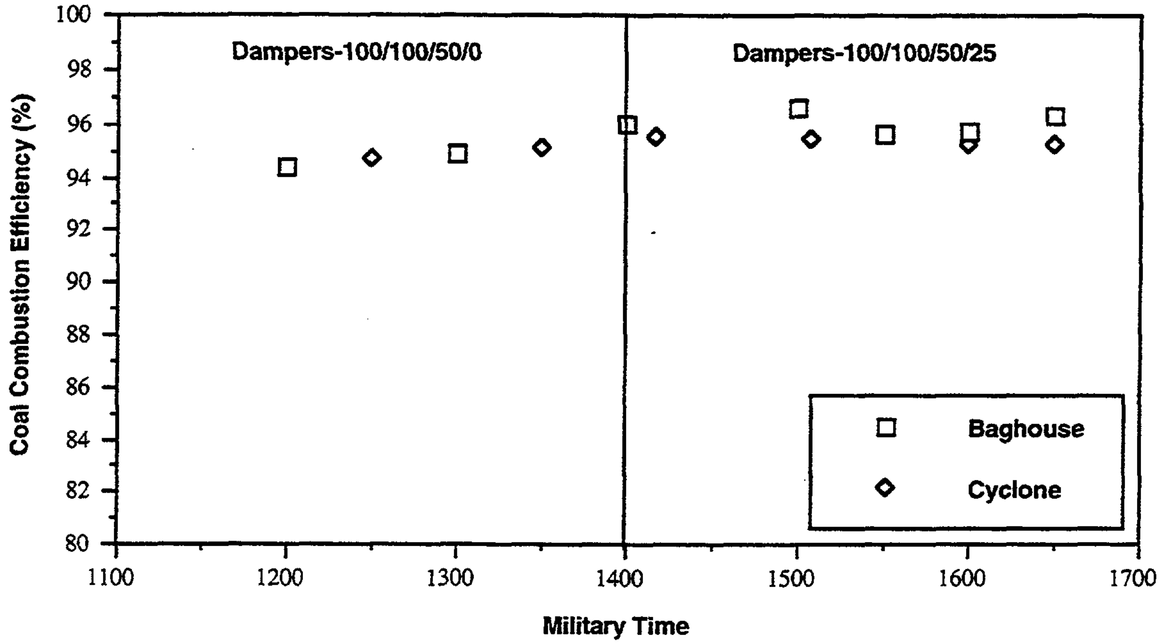


(a)

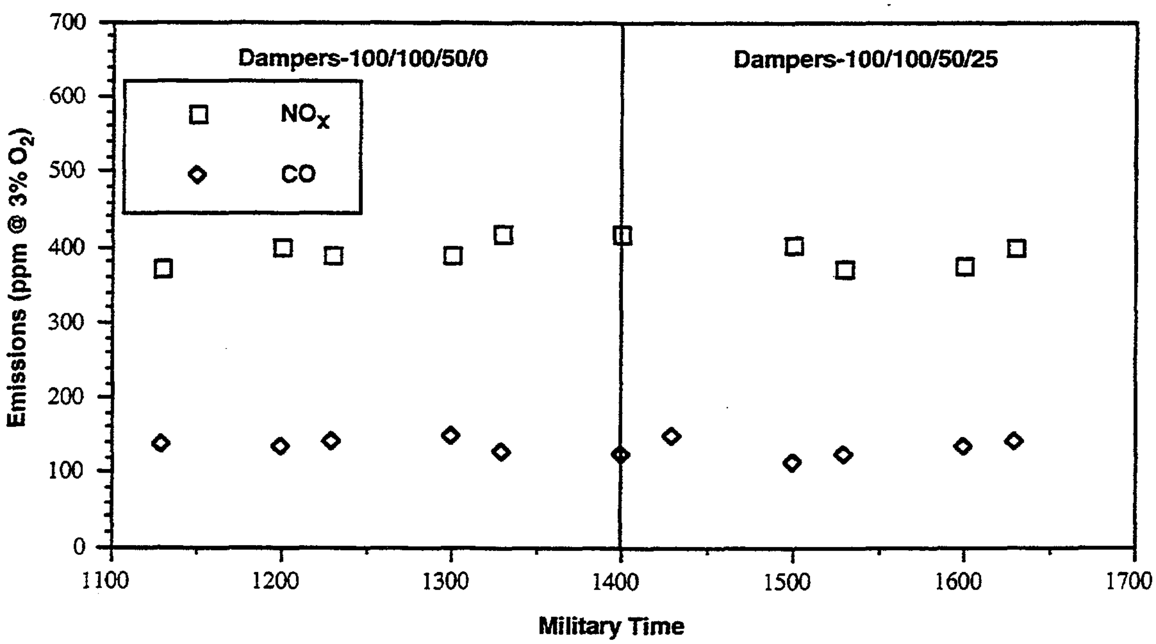


(b)

Figure D-13. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/09/95 WITH DAMPER SETTINGS OF 100/100/50/0

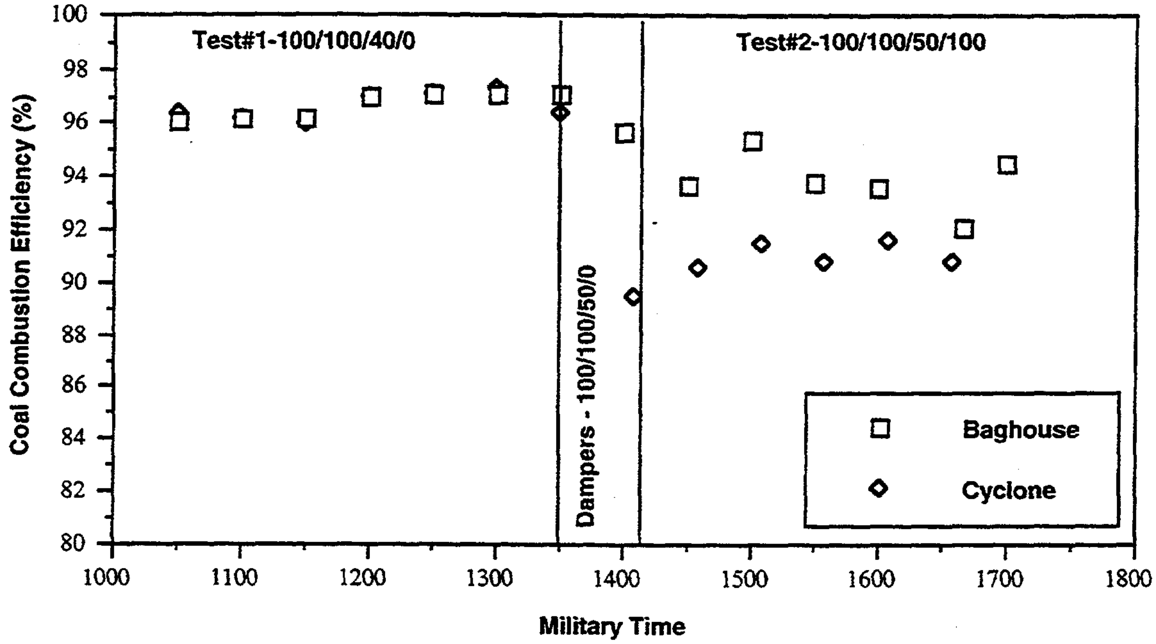


(a)

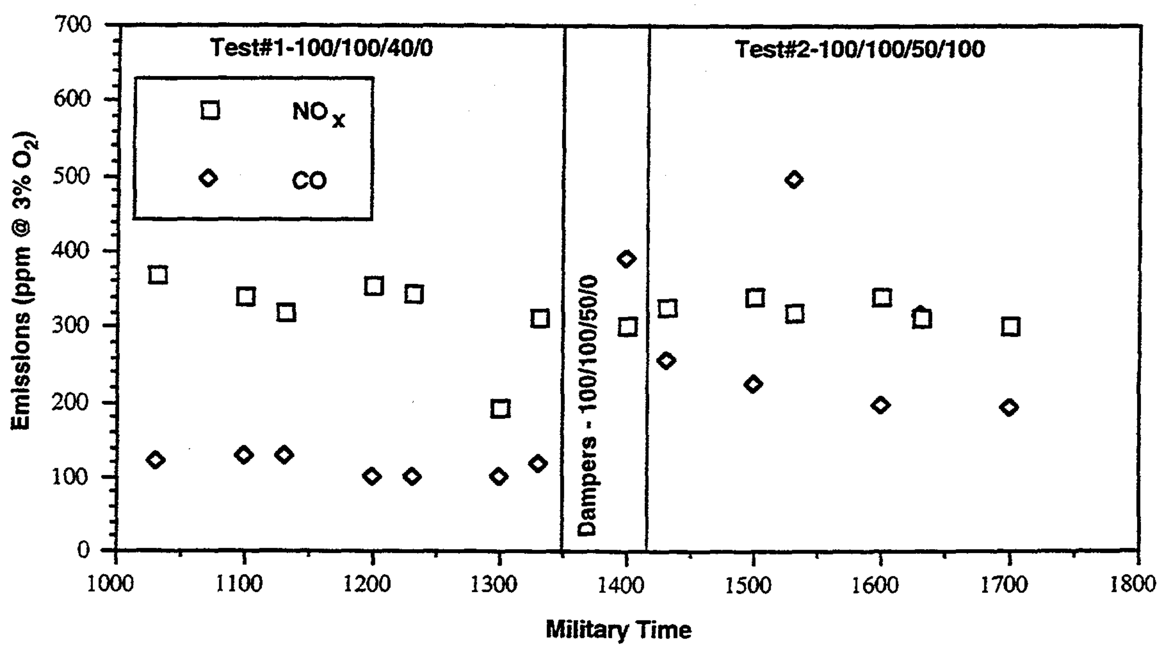


(b)

Figure D-14. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/11/95

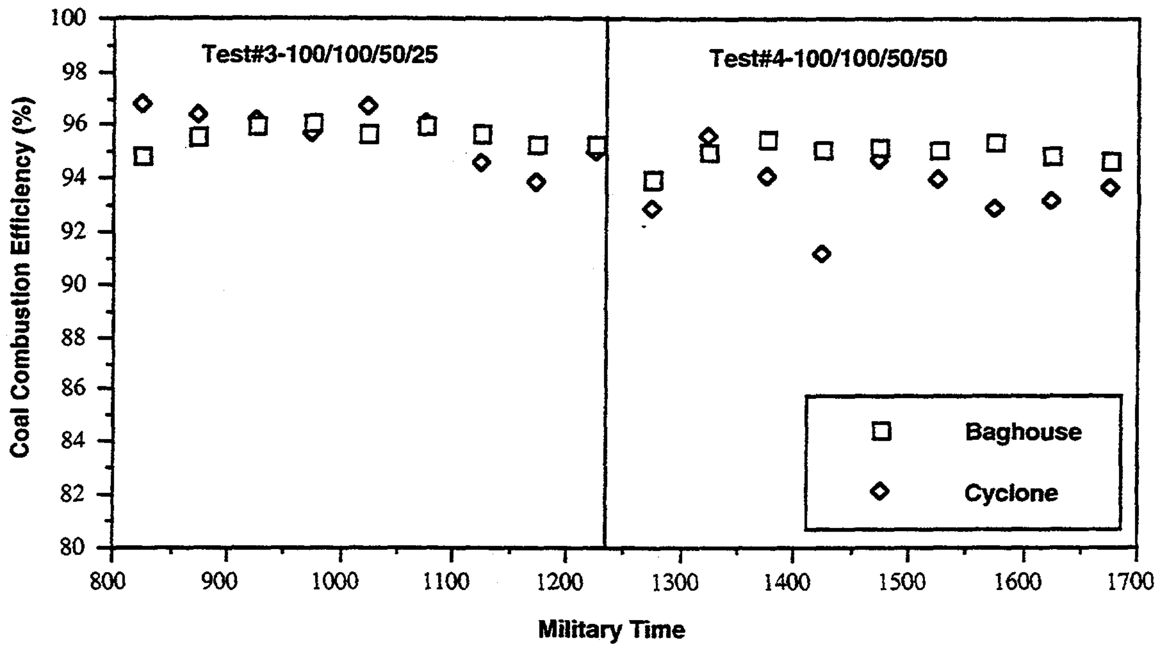


(a)

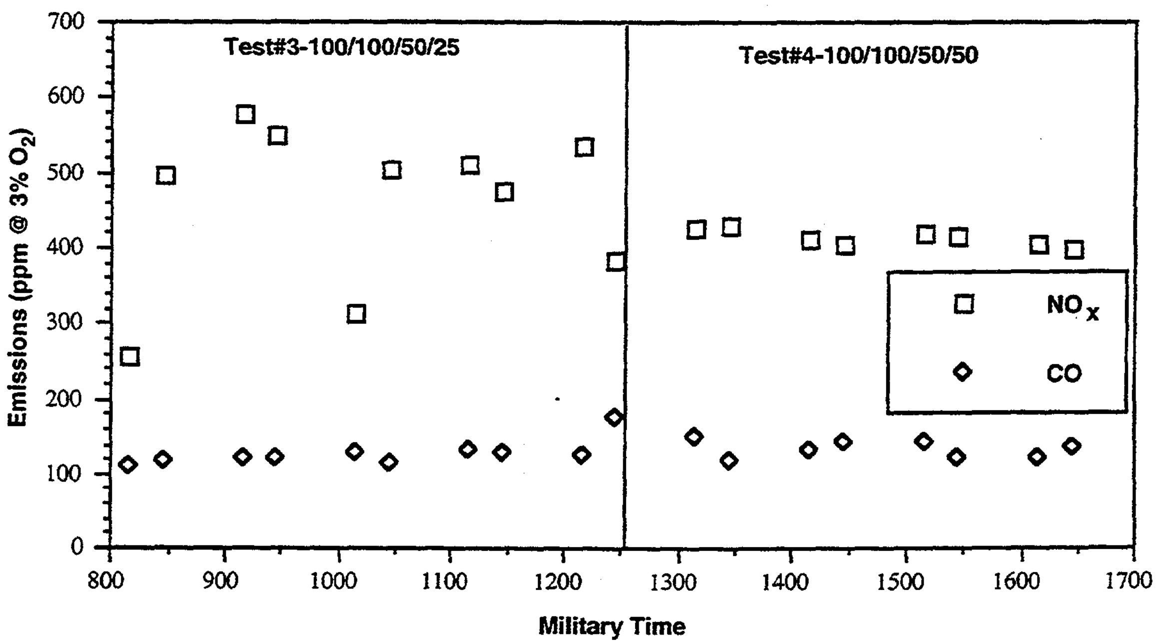


(b)

Figure D-15. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/12/95

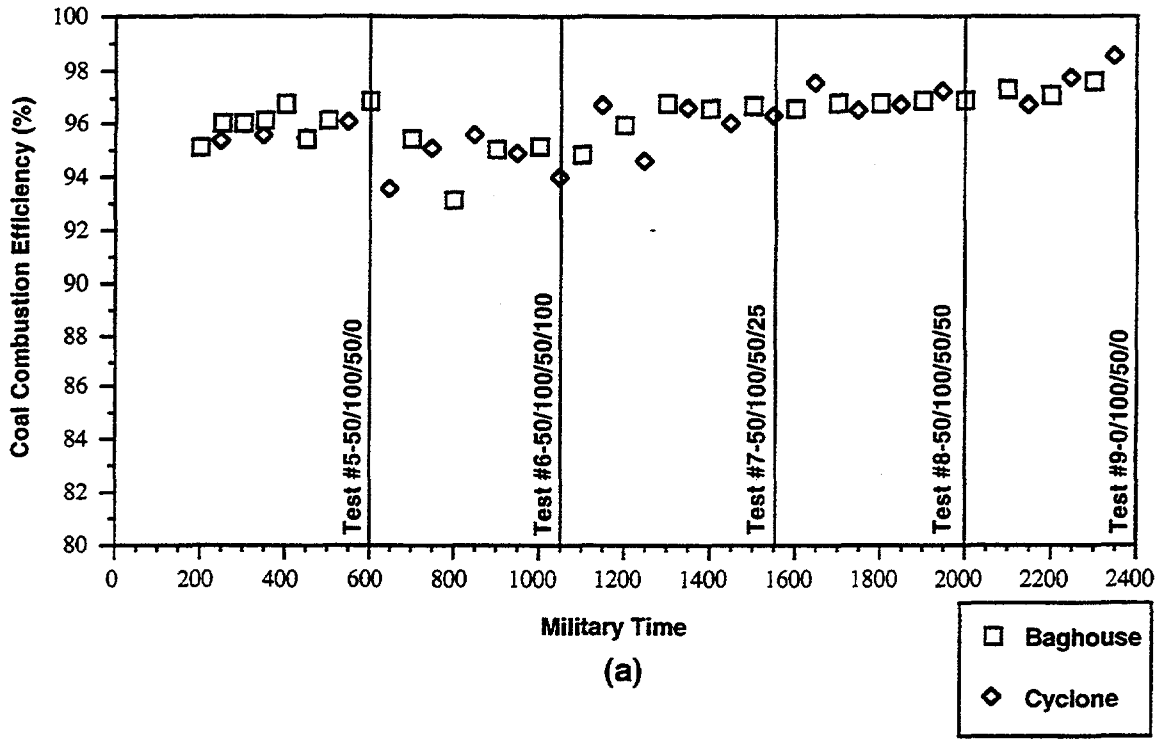


(a)

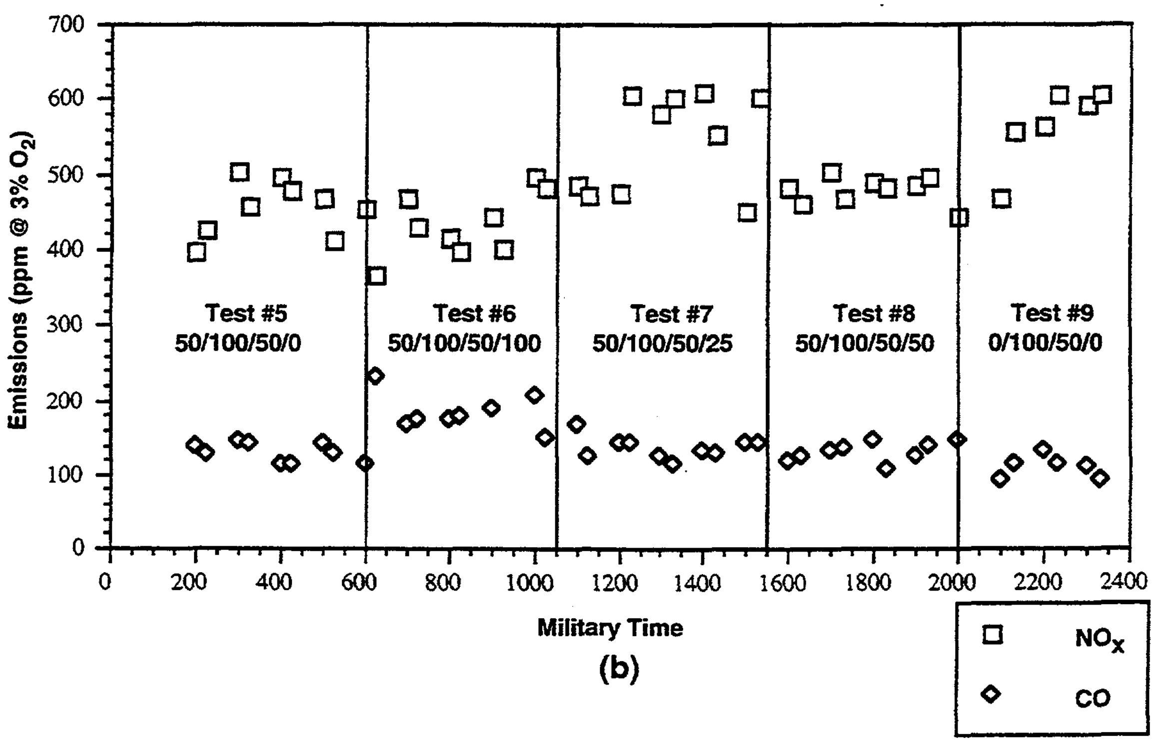


(b)

Figure D-16. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/13/95



(a)



(b)

Figure D-17. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/16/95

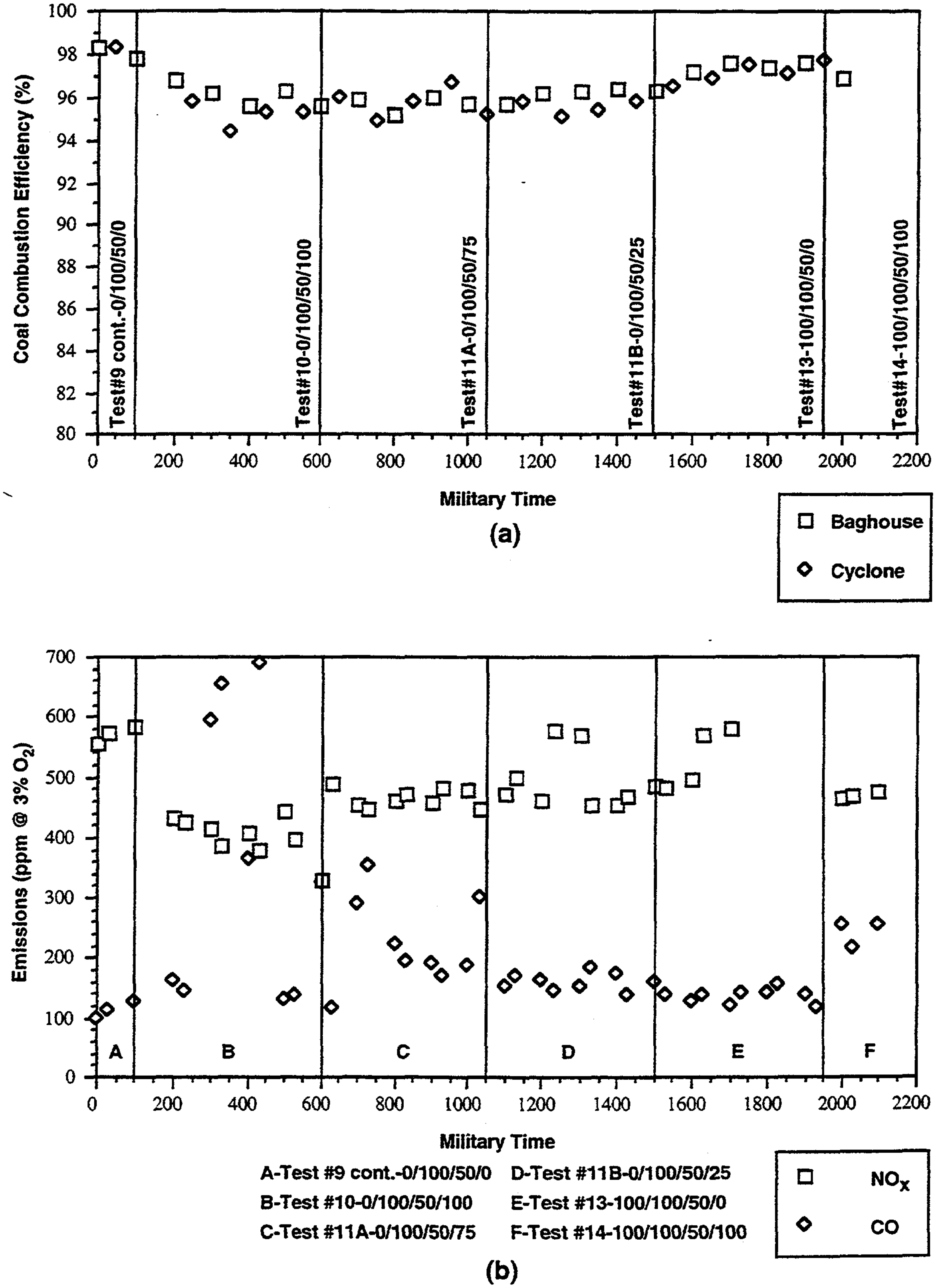


Figure D-18. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/17/95

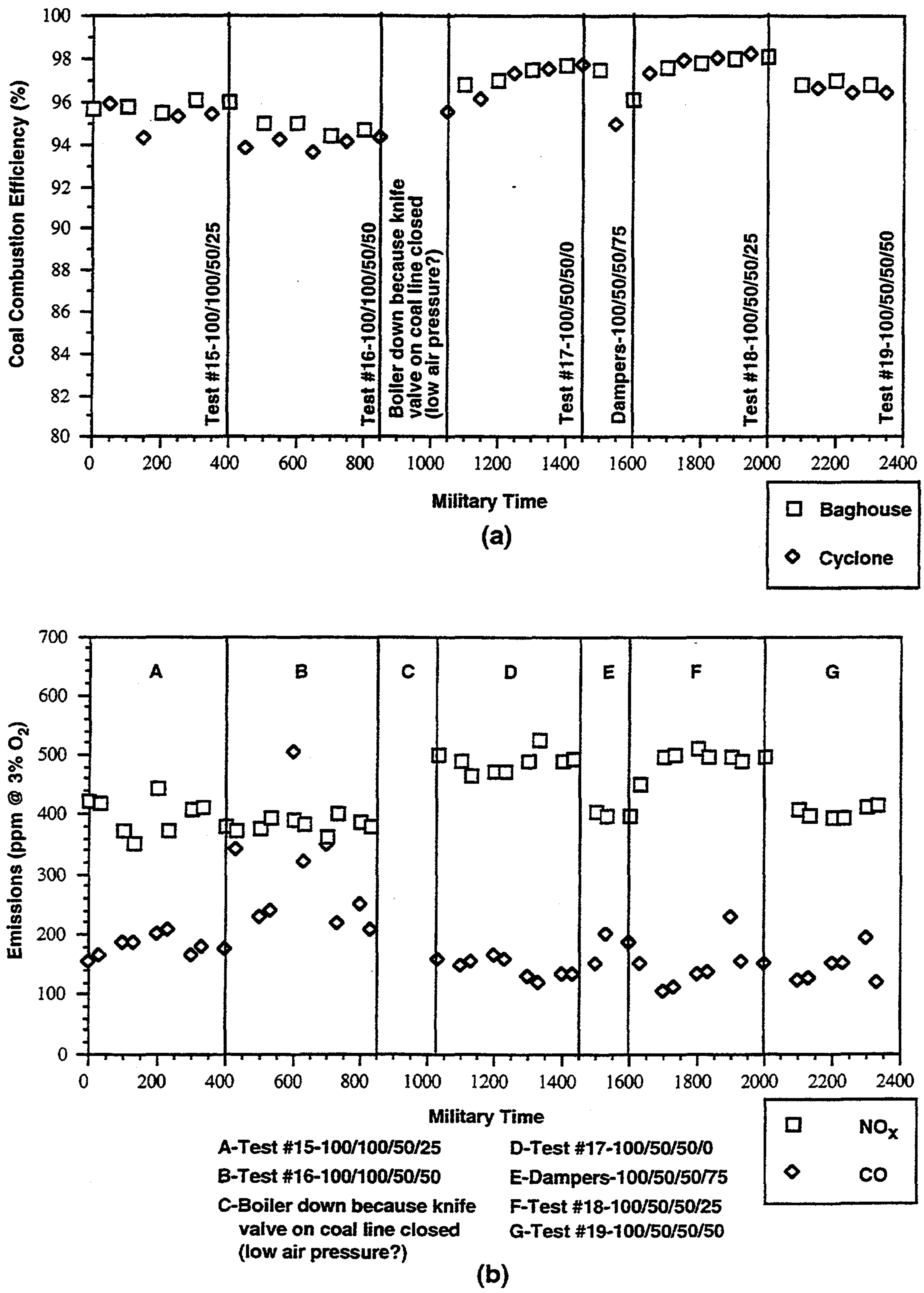


Figure D-19. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/18/95

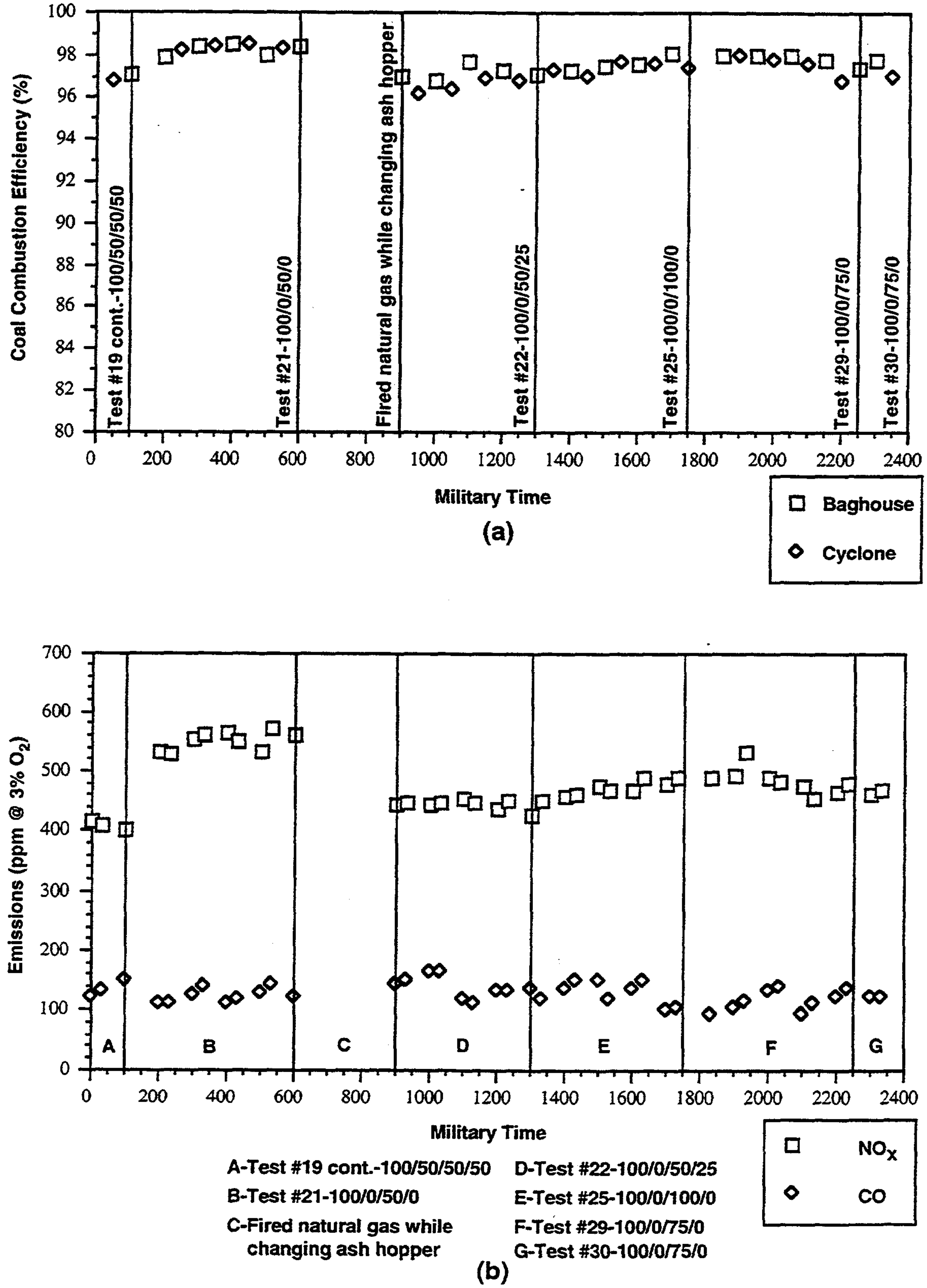


Figure D-20. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/19/95

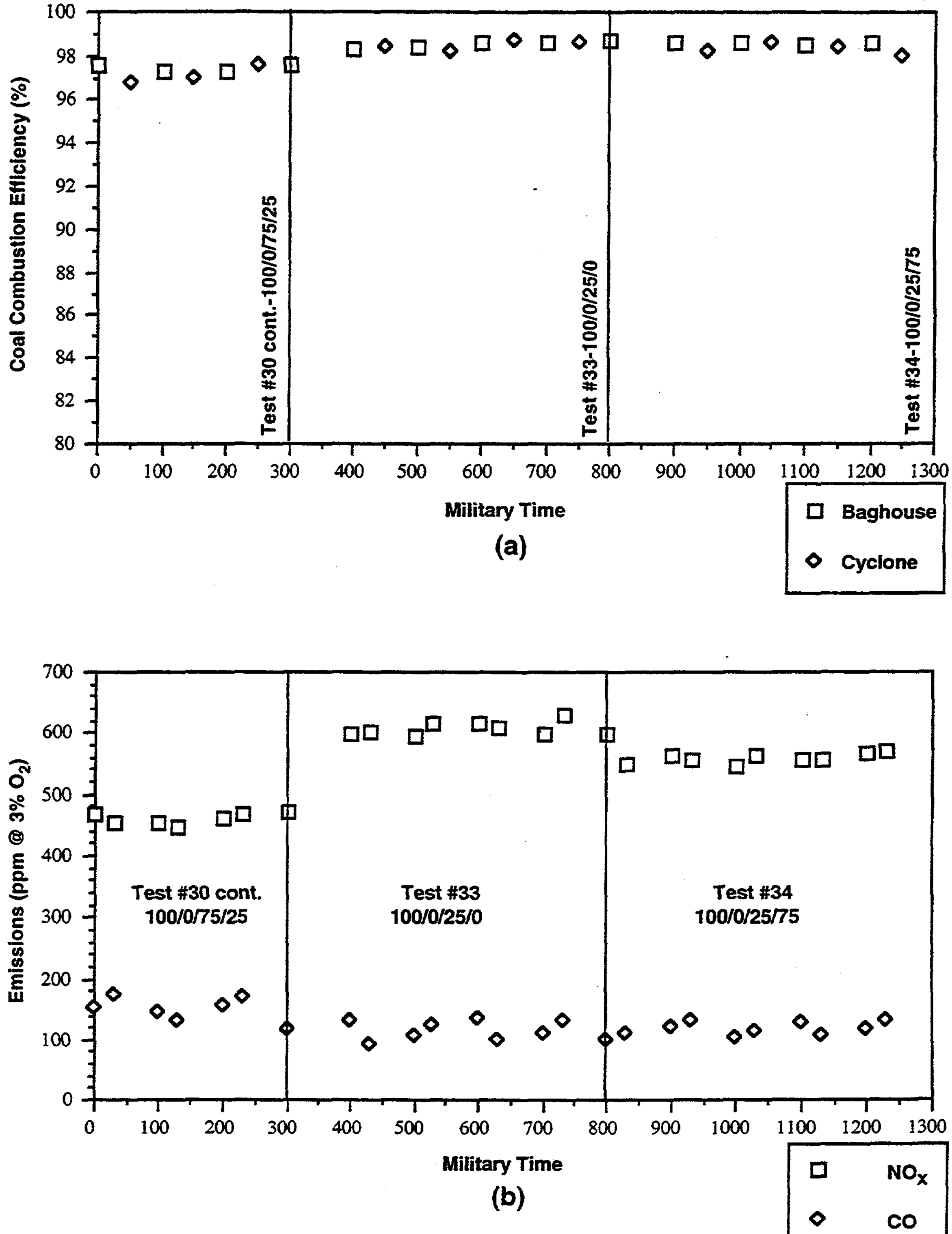


Figure D-21. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/20/95

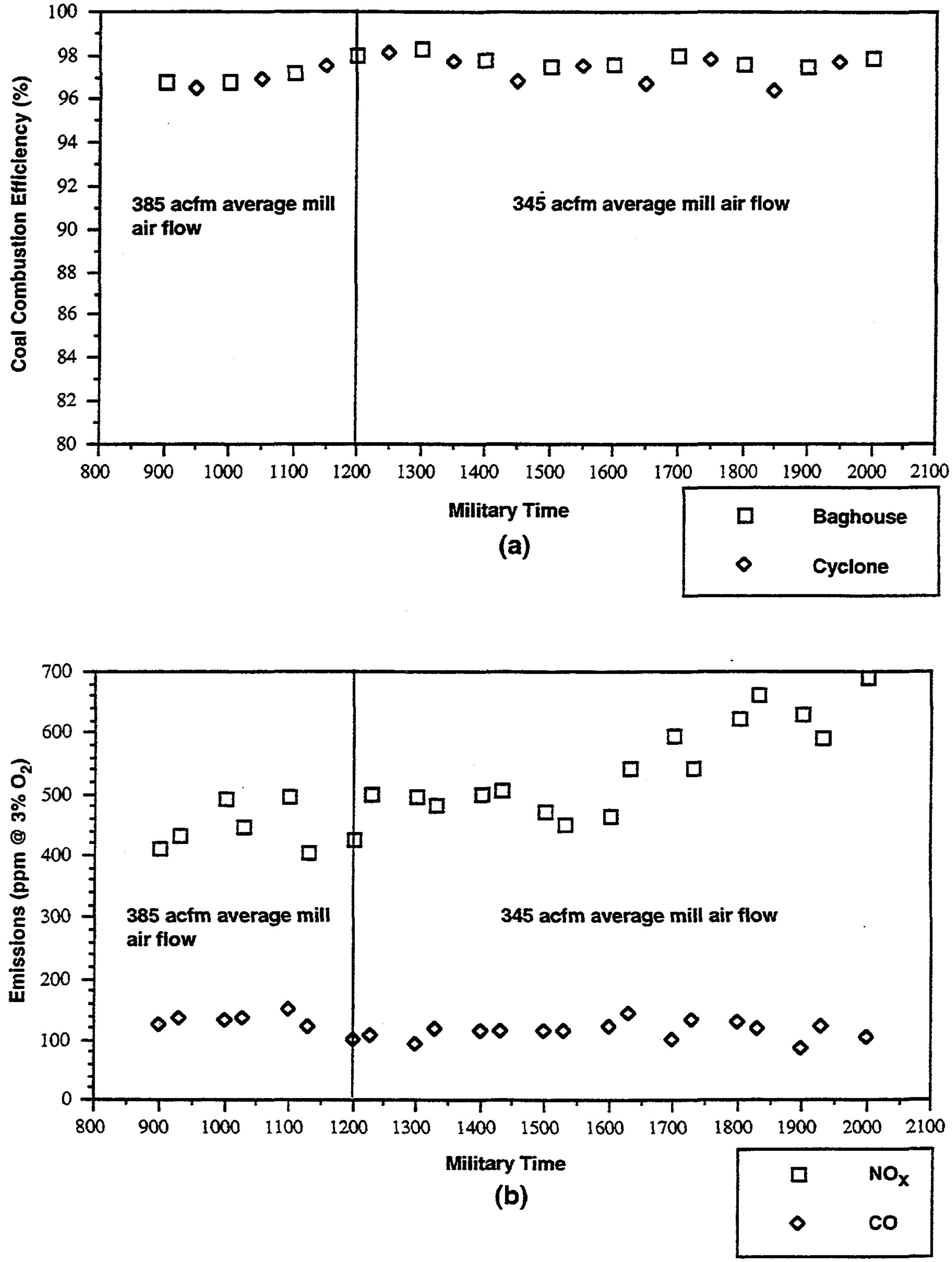


Figure D-22. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/24/95 WITH DAMPER SETTINGS OF 100/100/50/0

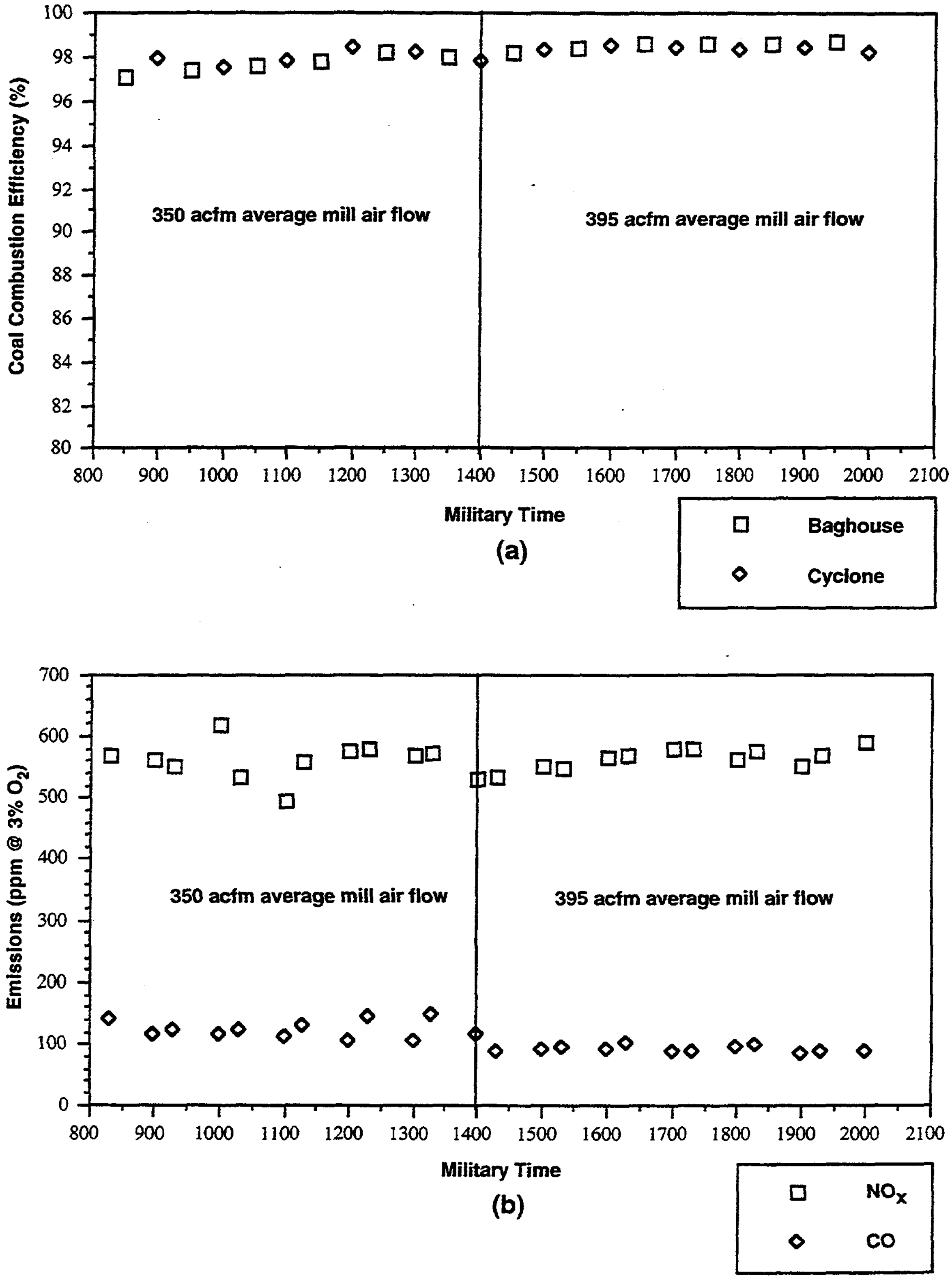


Figure D-23. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/25/95 WITH DAMPER SETTINGS OF 100/100/50/0

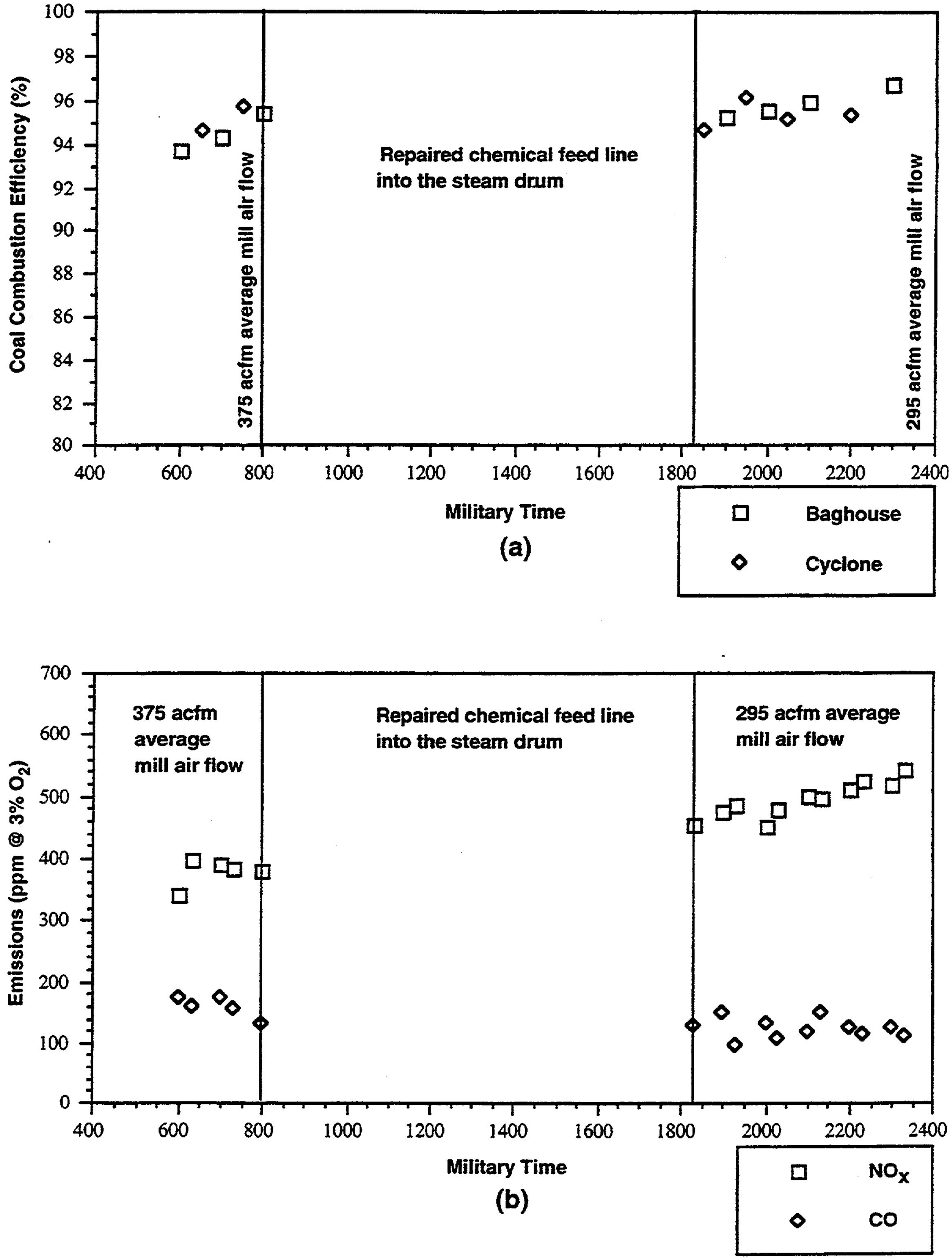
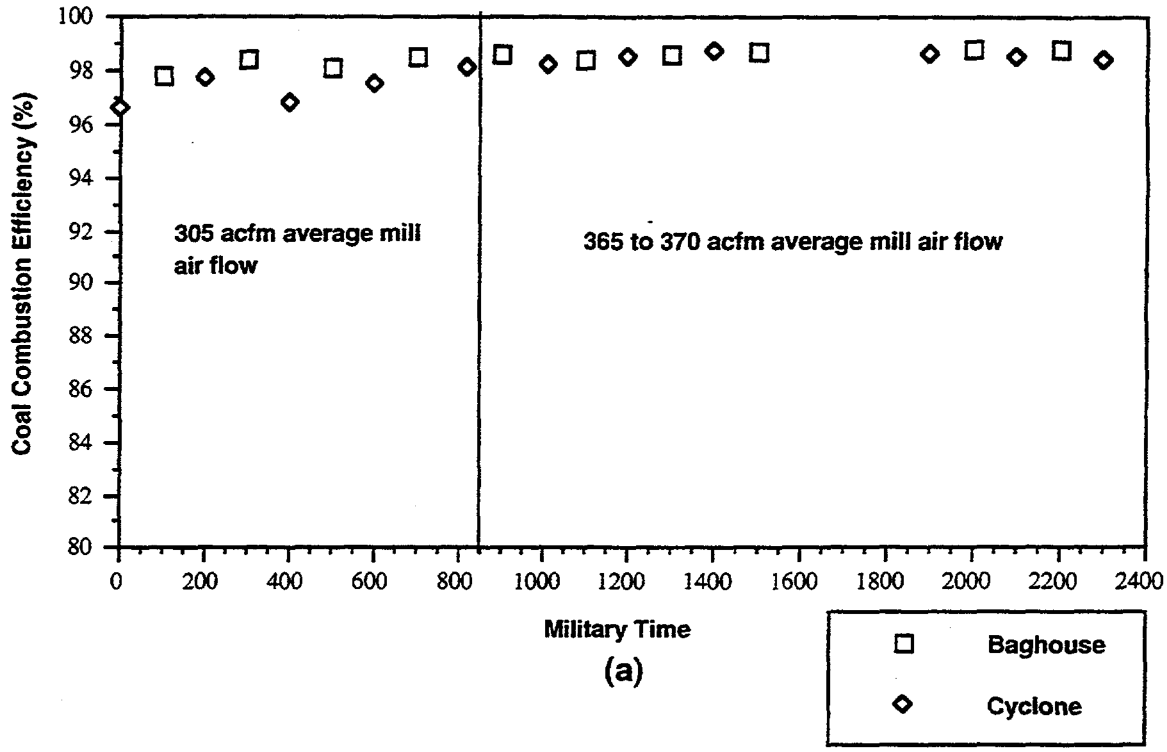


Figure D-24. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/30/95 WITH DAMPER SETTINGS OF 100/0/25/0



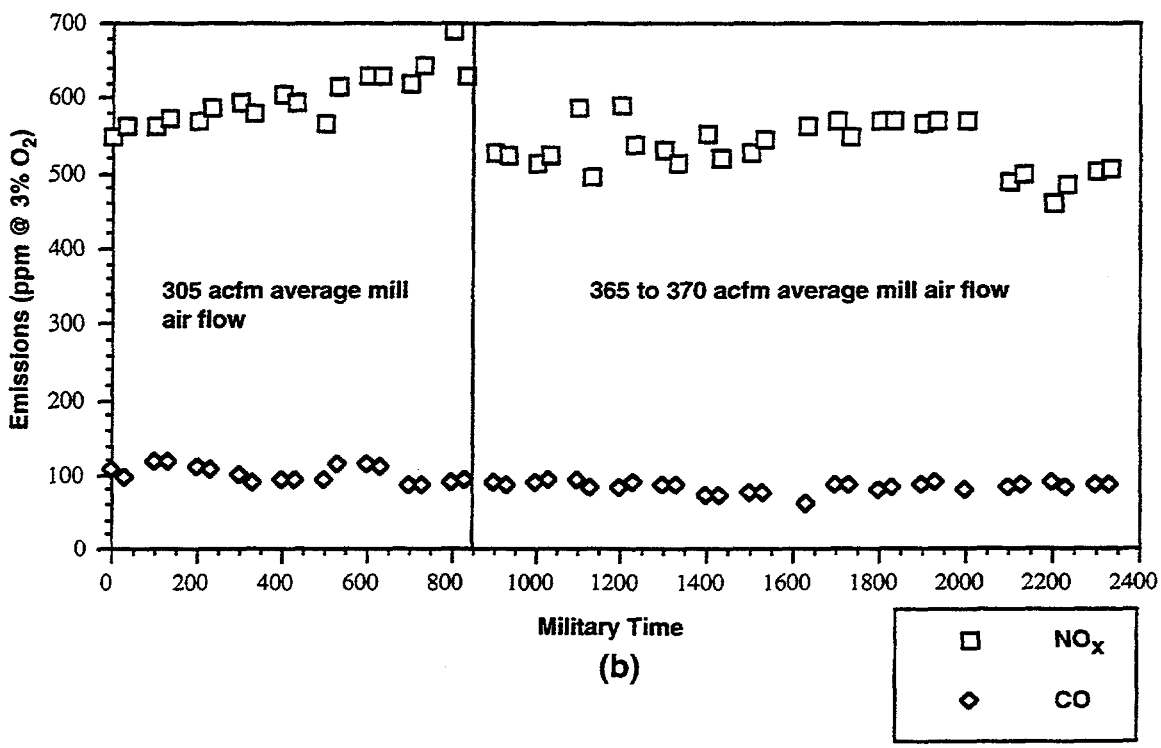


Figure D-25. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 10/31/95 WITH DAMPER SETTINGS OF 100/0/25/0

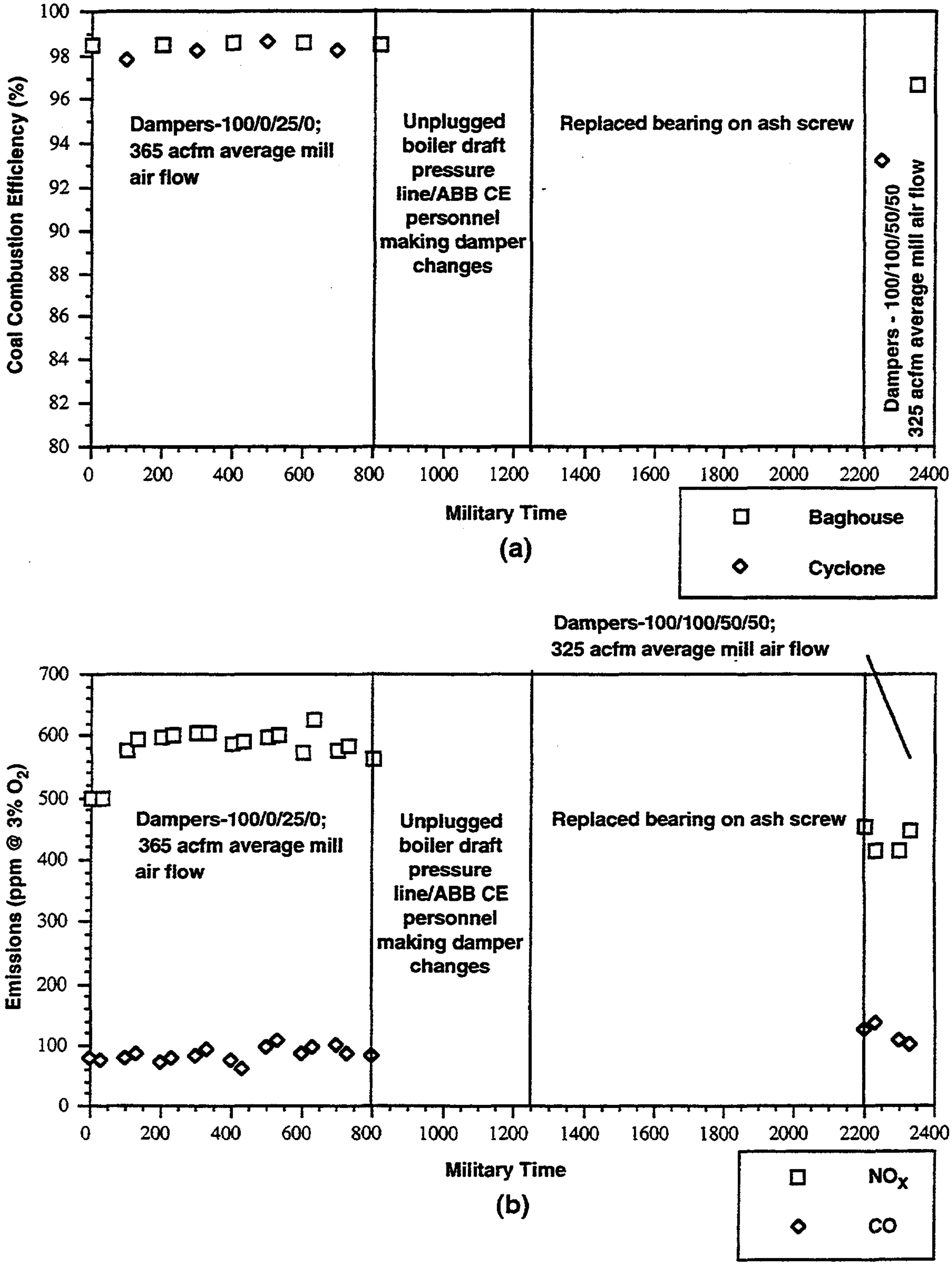
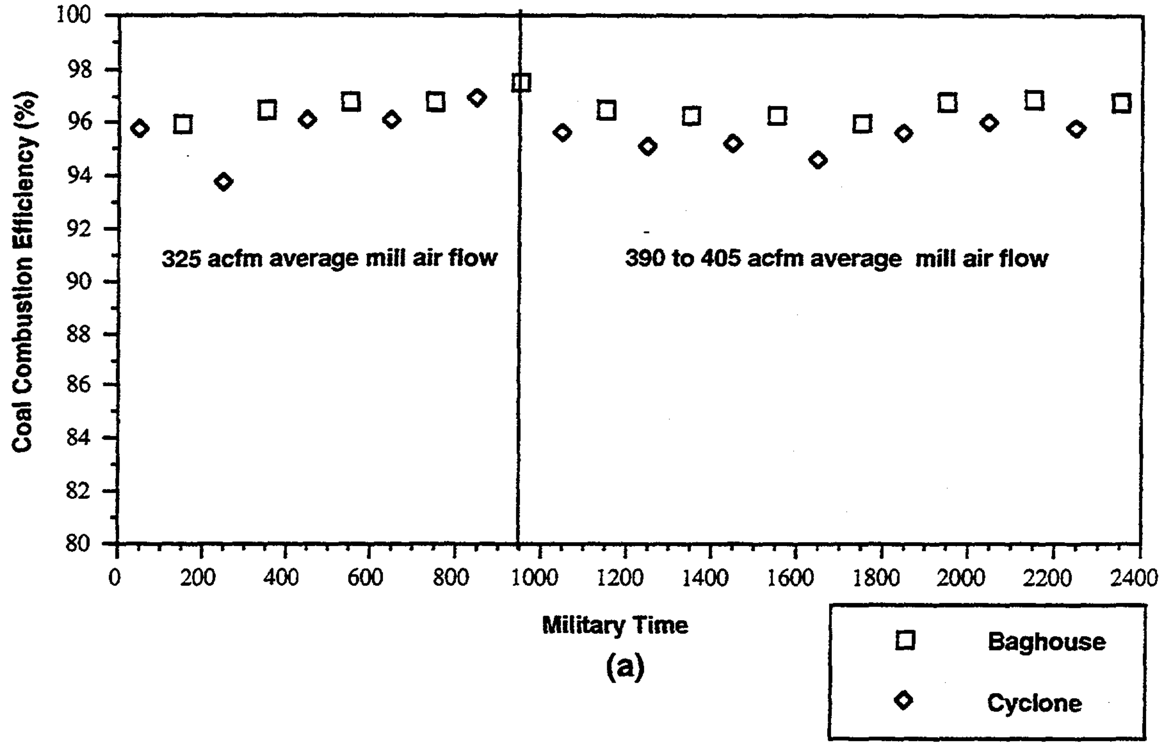
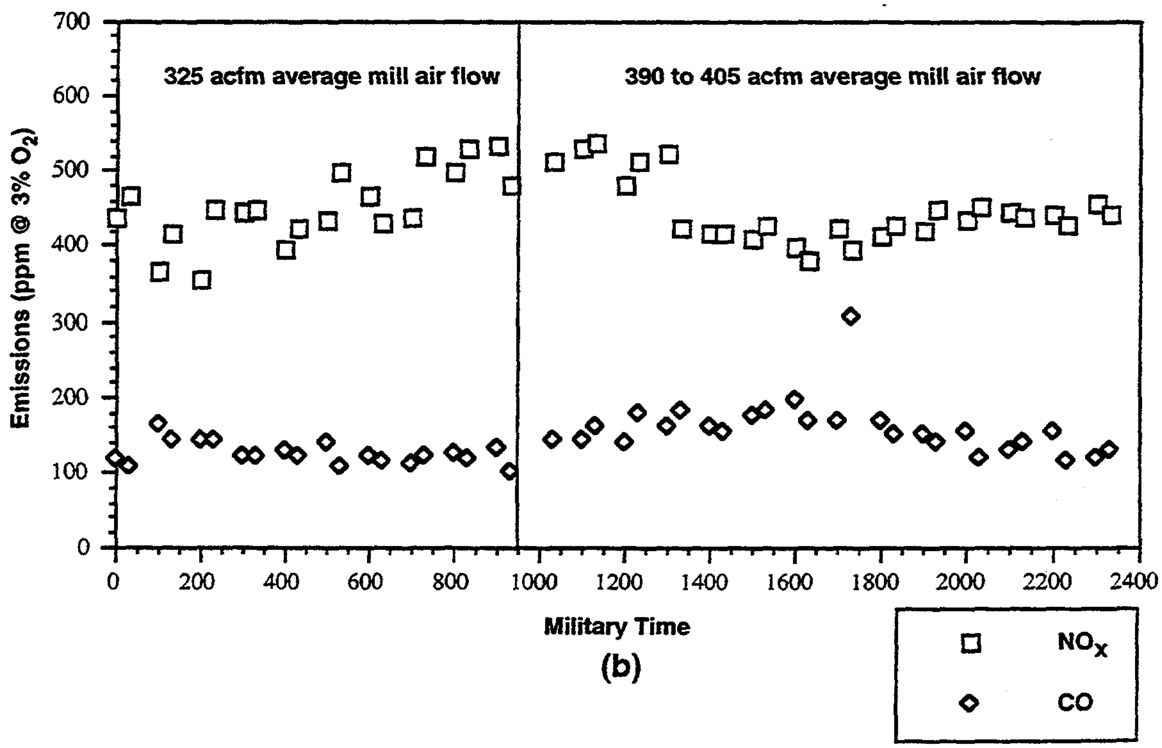


Figure D-26. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/01/95



(a)



(b)

Figure D-27. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/02/95 WITH DAMPER SETTINGS OF 100/100/50/50

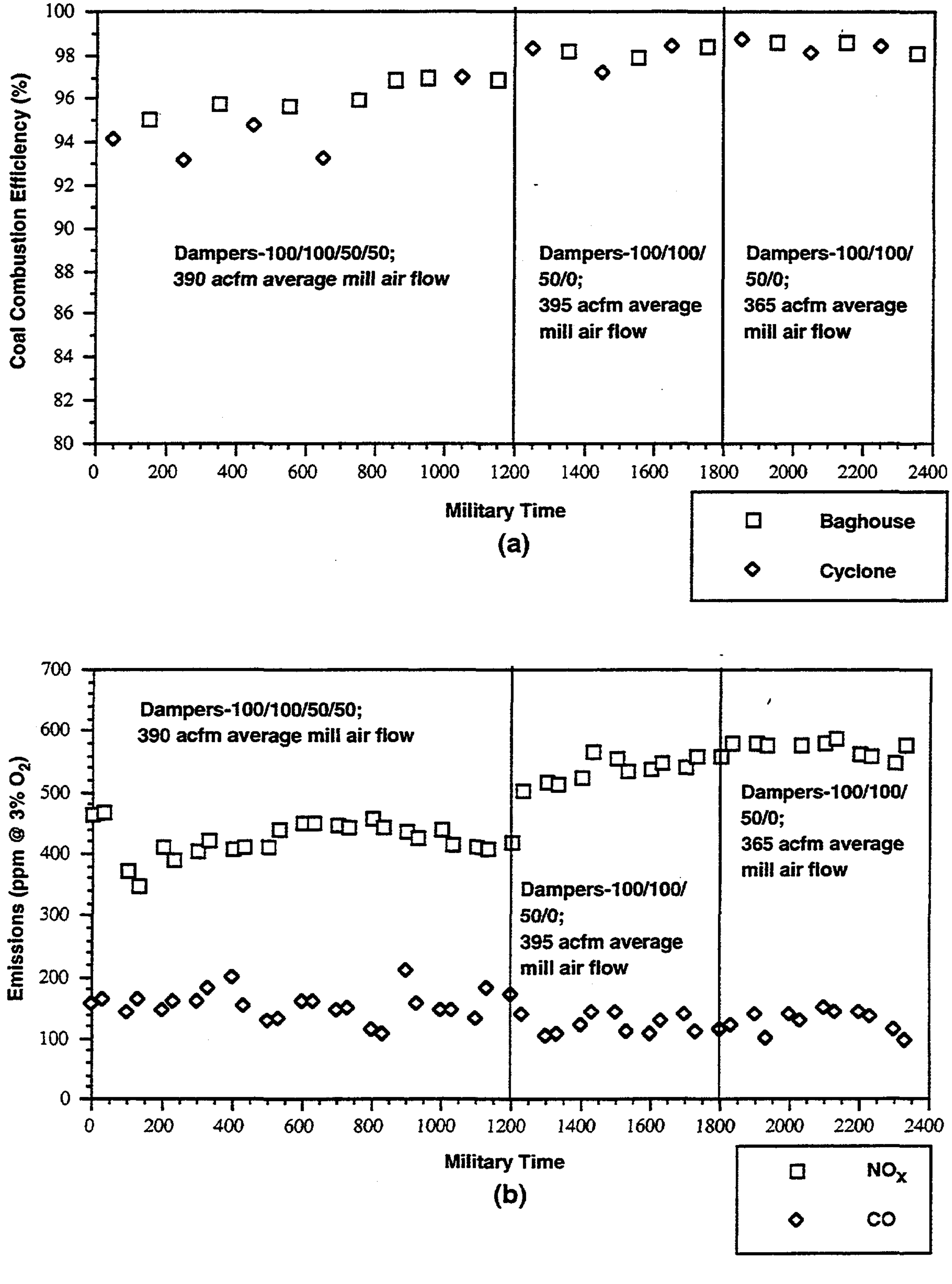
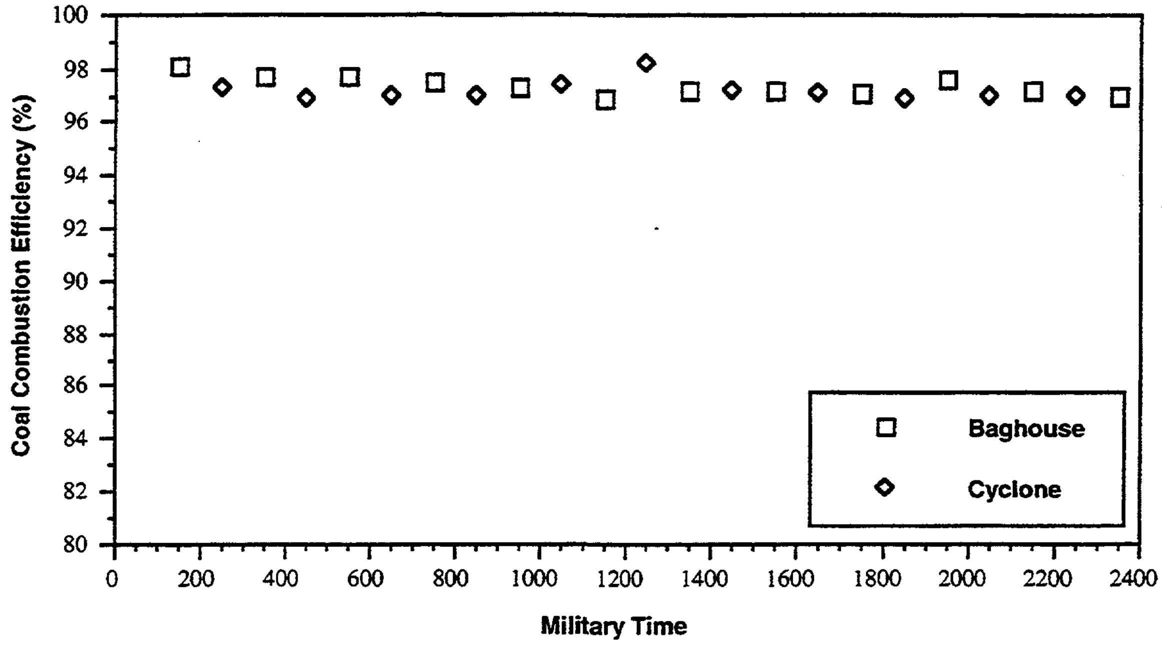
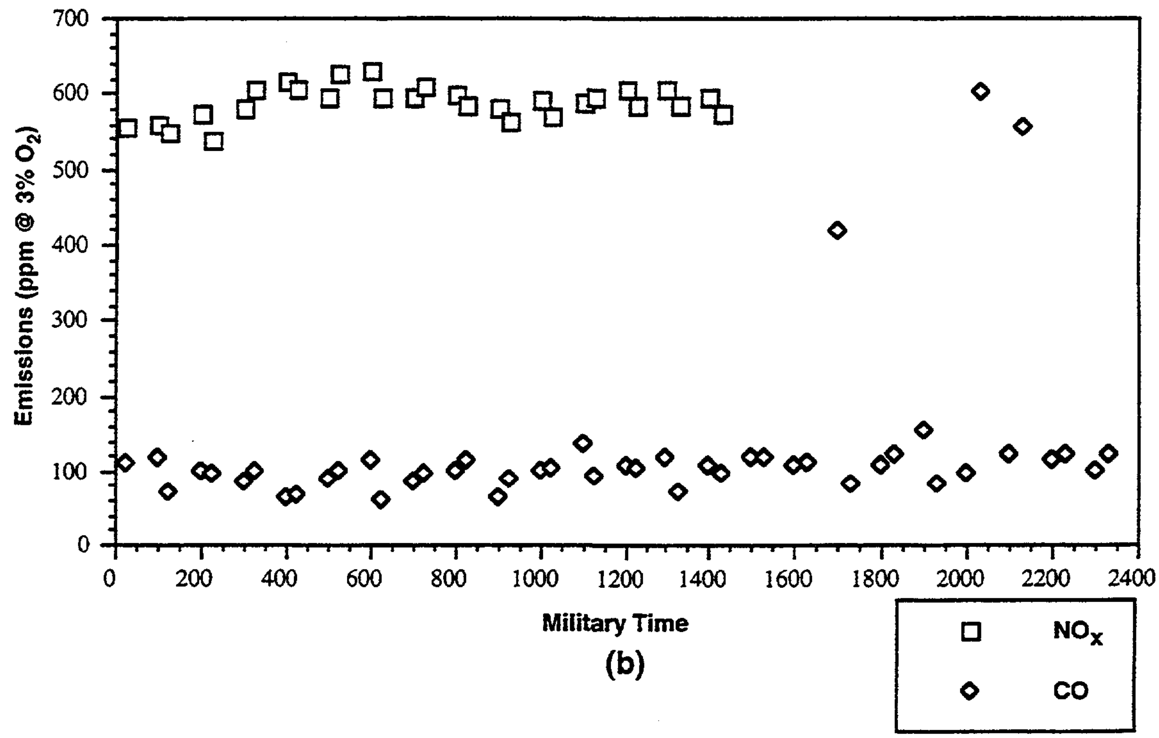


Figure D-28. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/03/95

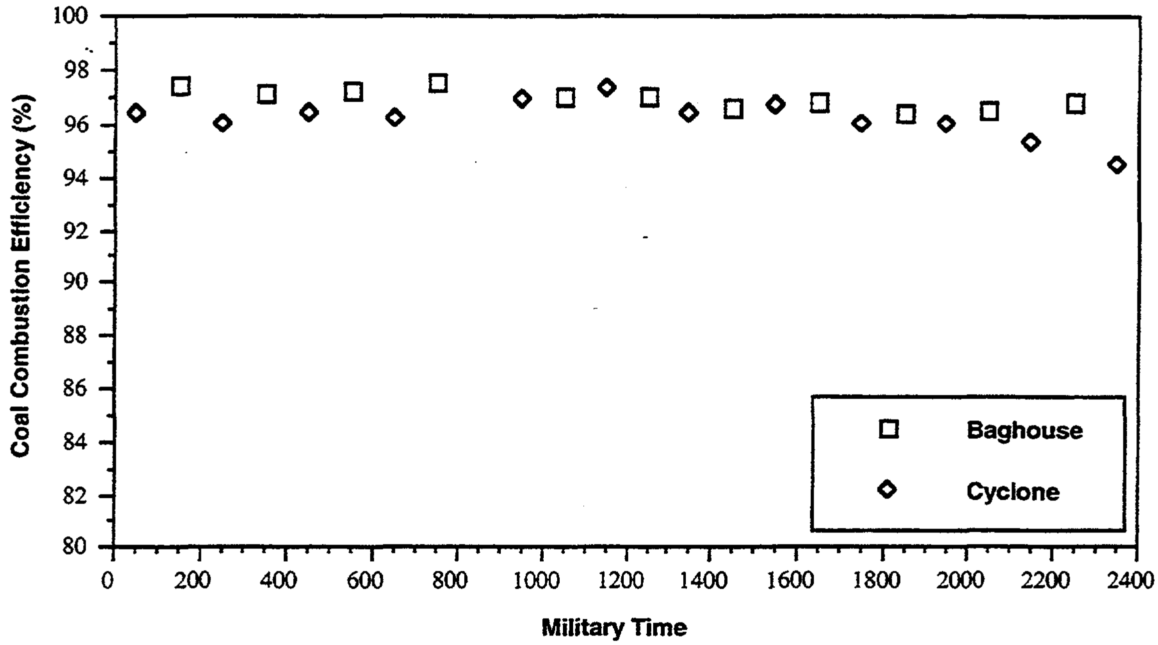


(a)

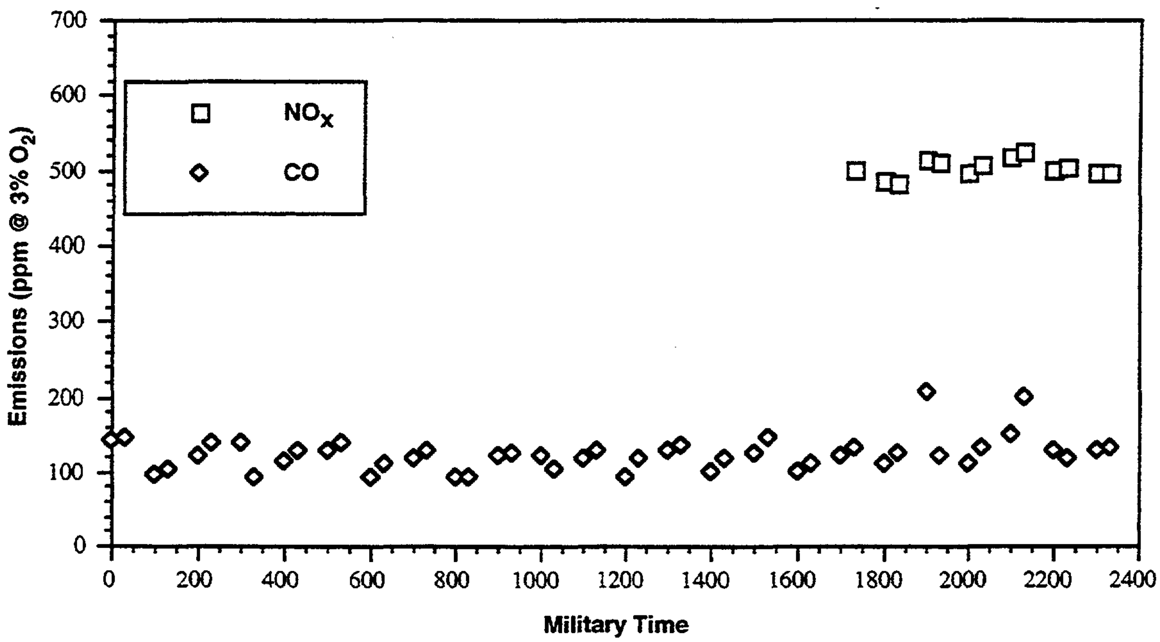


(b)

Figure D-29. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/04/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 365 TO 370 ACFM AVERAGE MILL AIR FLOW



(a)



(b)

Figure D-30. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/05/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 360 TO 375 ACFM AVERAGE MILL FLOW

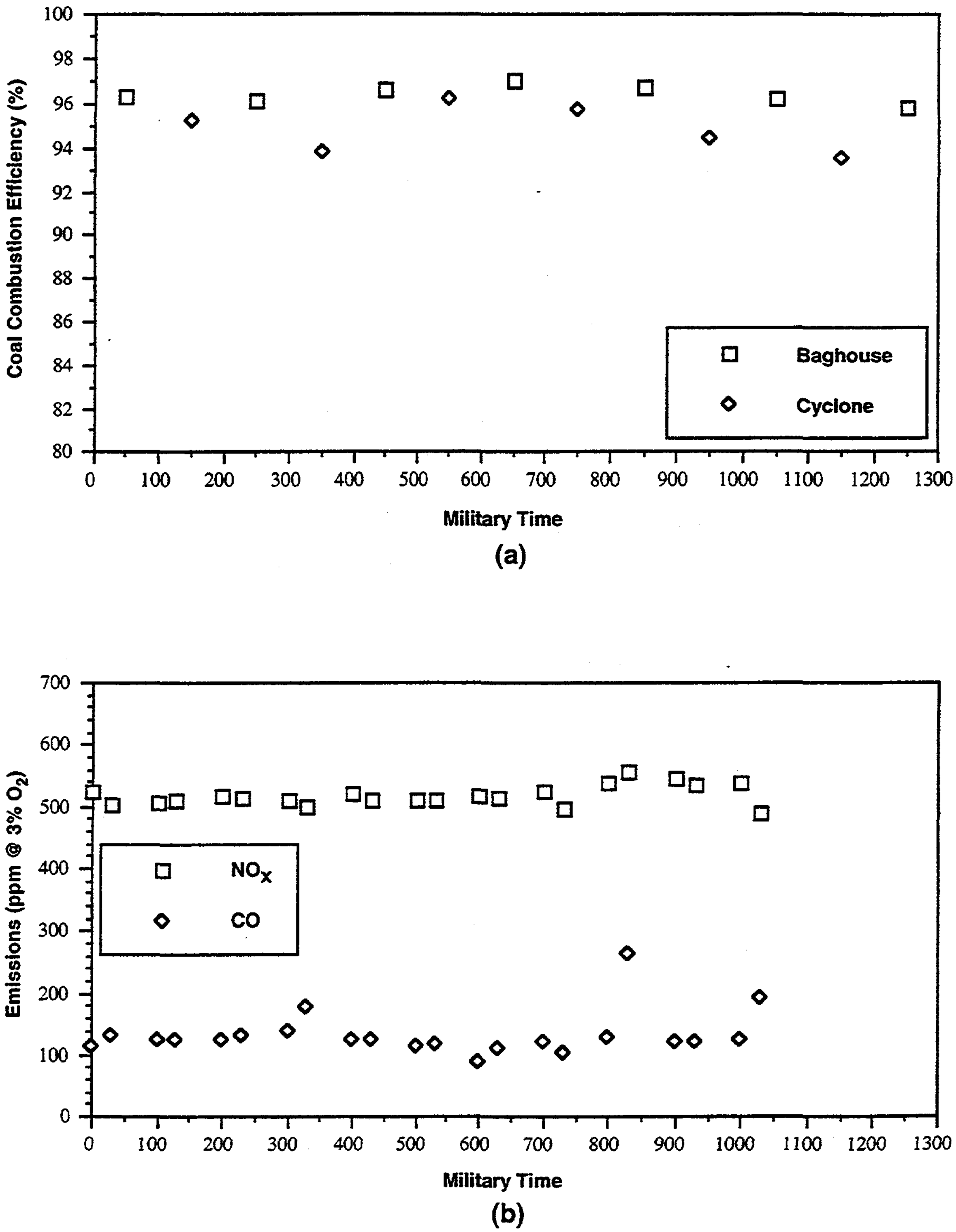
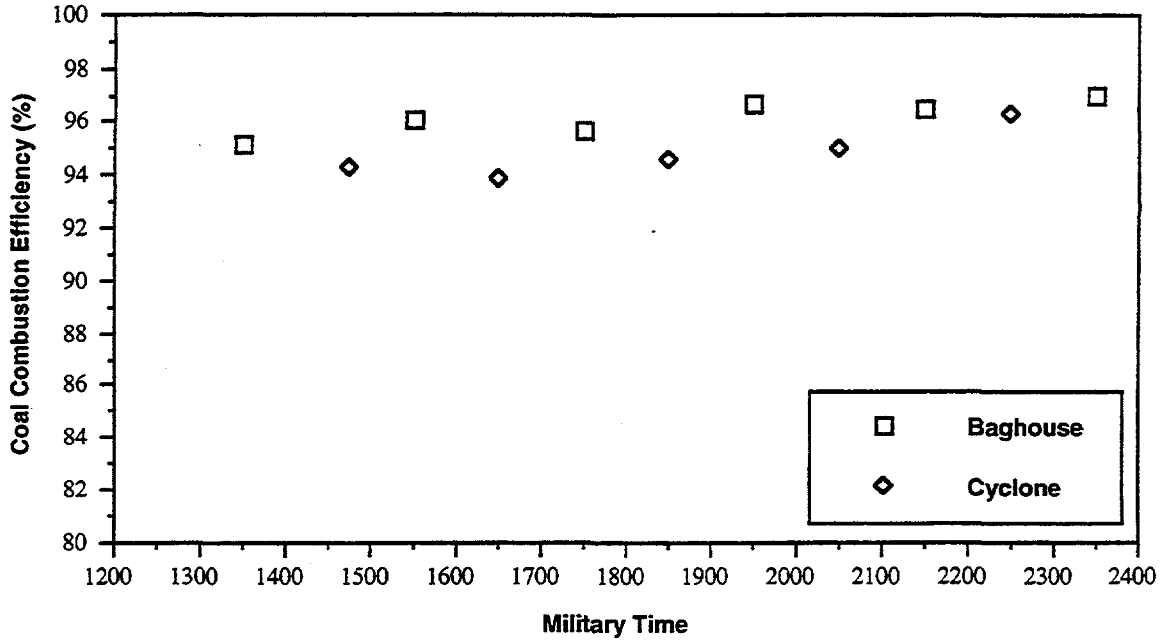
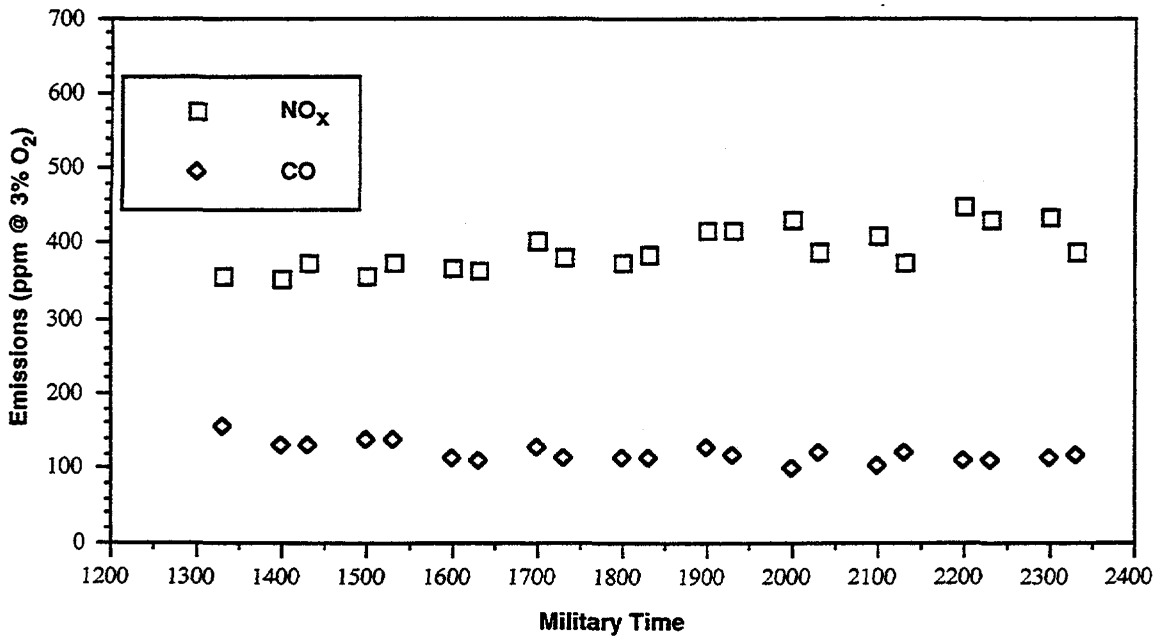


Figure D-31. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/06/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 365 TO 380 ACFM AVERAGE MILL FLOW

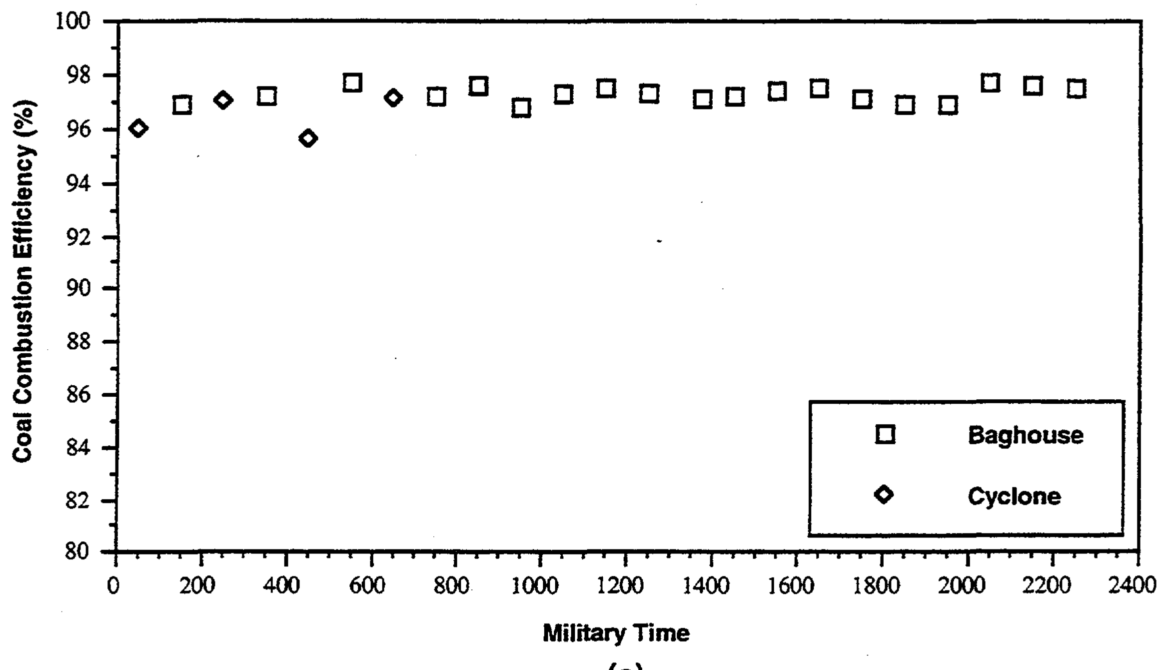


(a)

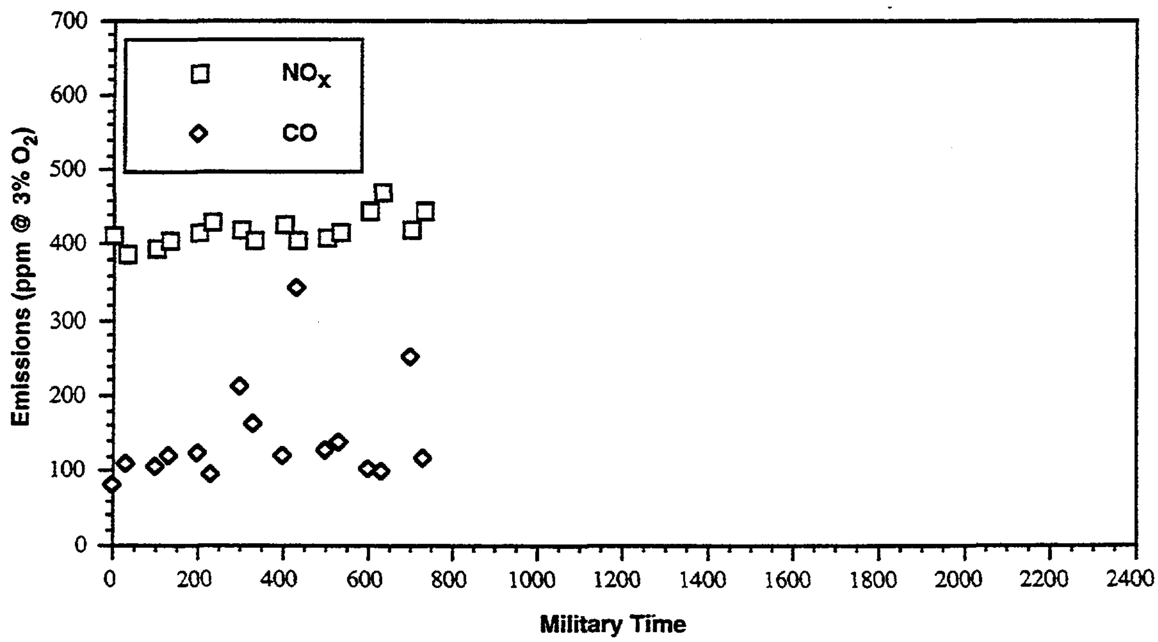


(b)

Figure D-32. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/13/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 375 TO 405 ACFM AVERAGE MILL FLOW

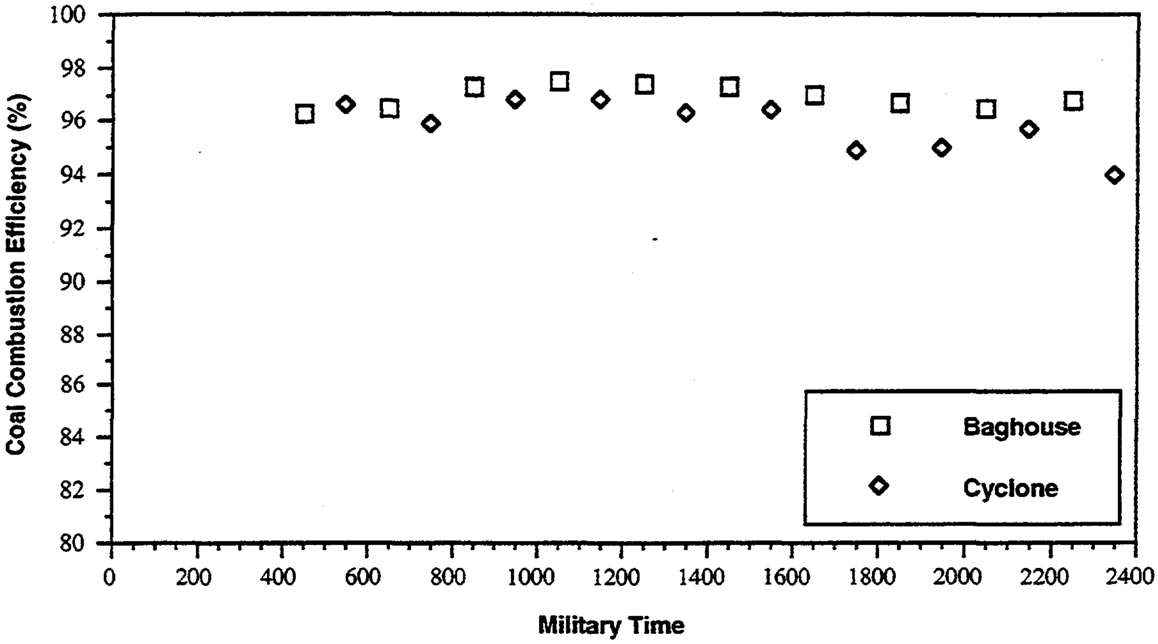


(a)

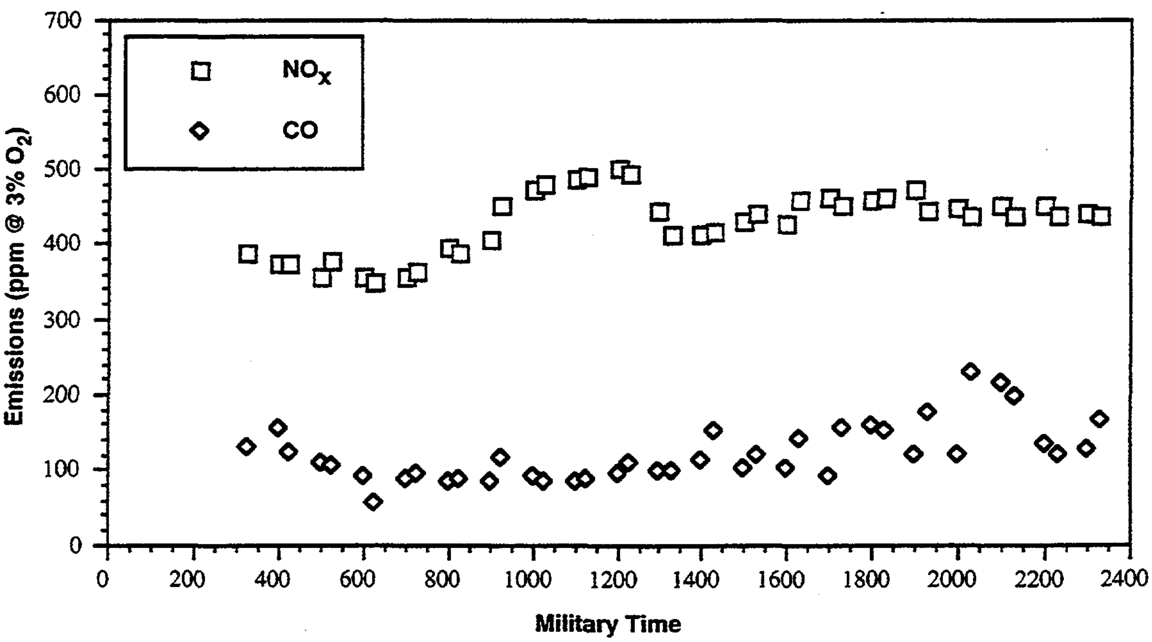


(b)

Figure D-33. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/14/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 365 TO 395 ACFM AVERAGE MILL FLOW



(a)



(b)

Figure D-34. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/16/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 370 TO 410 MILL AIR FLOW

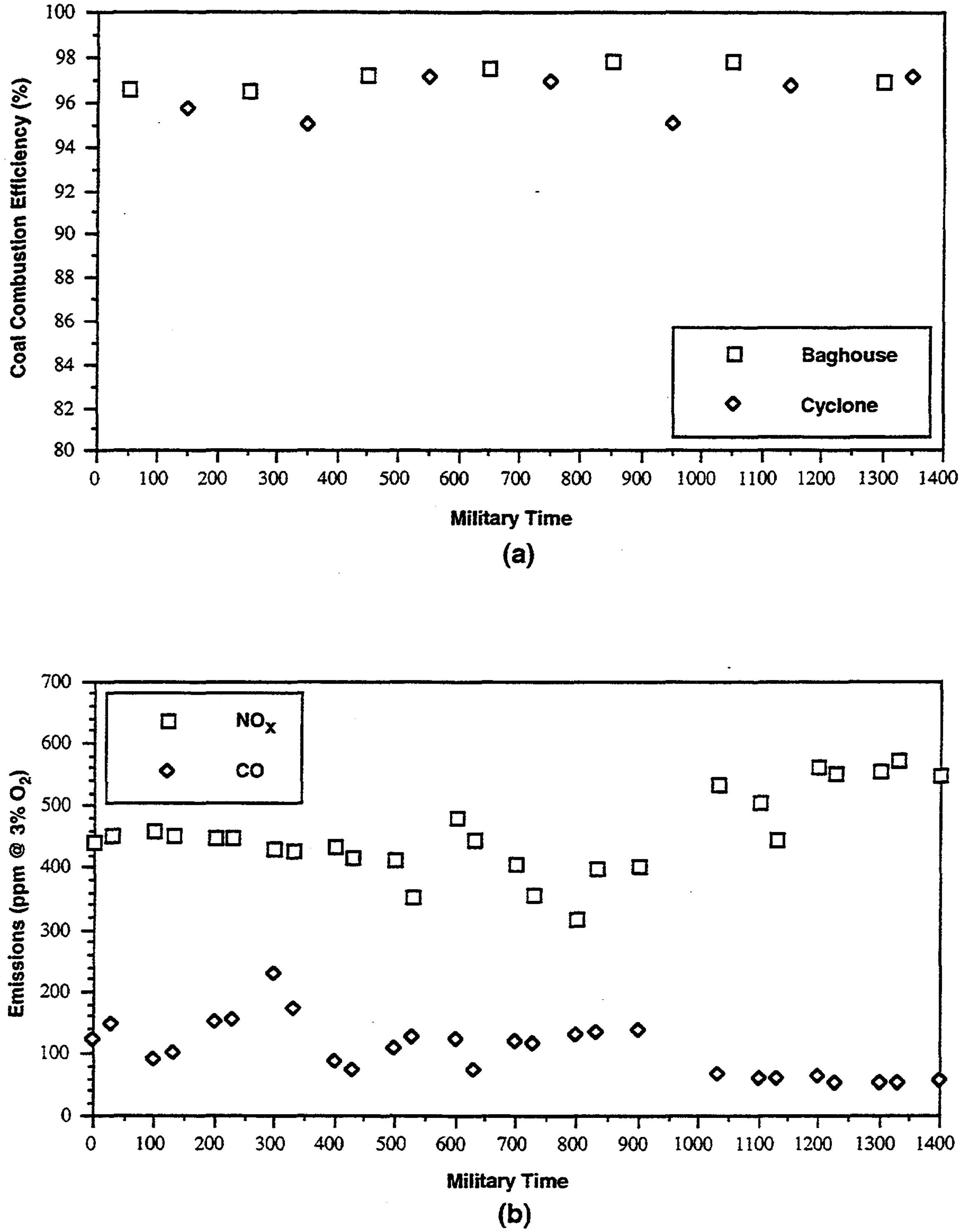
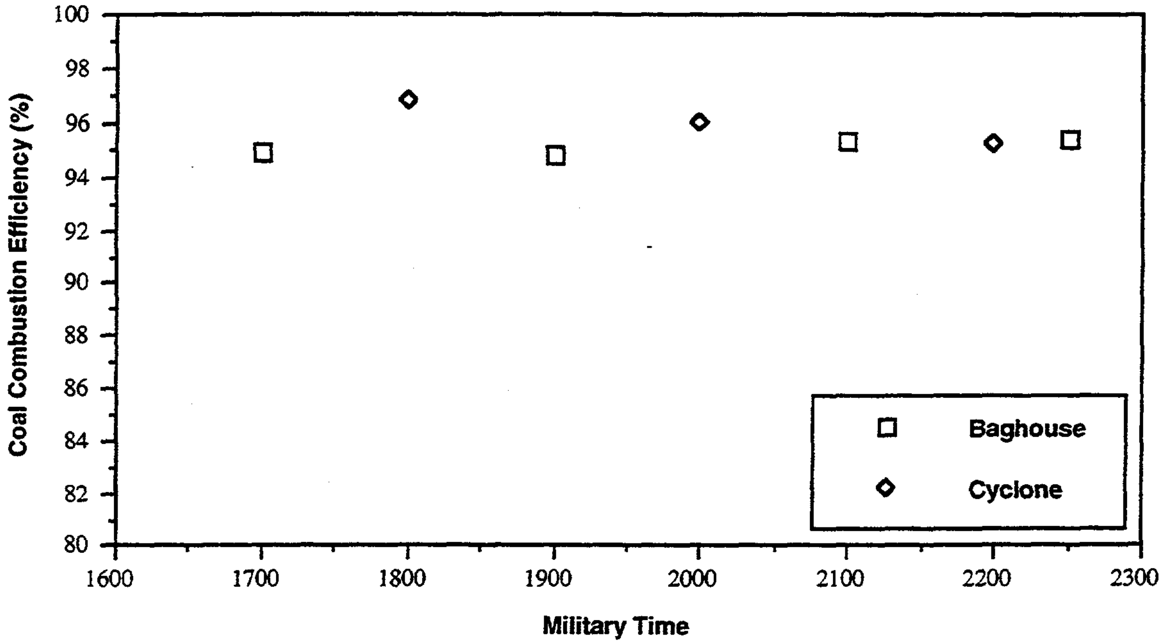
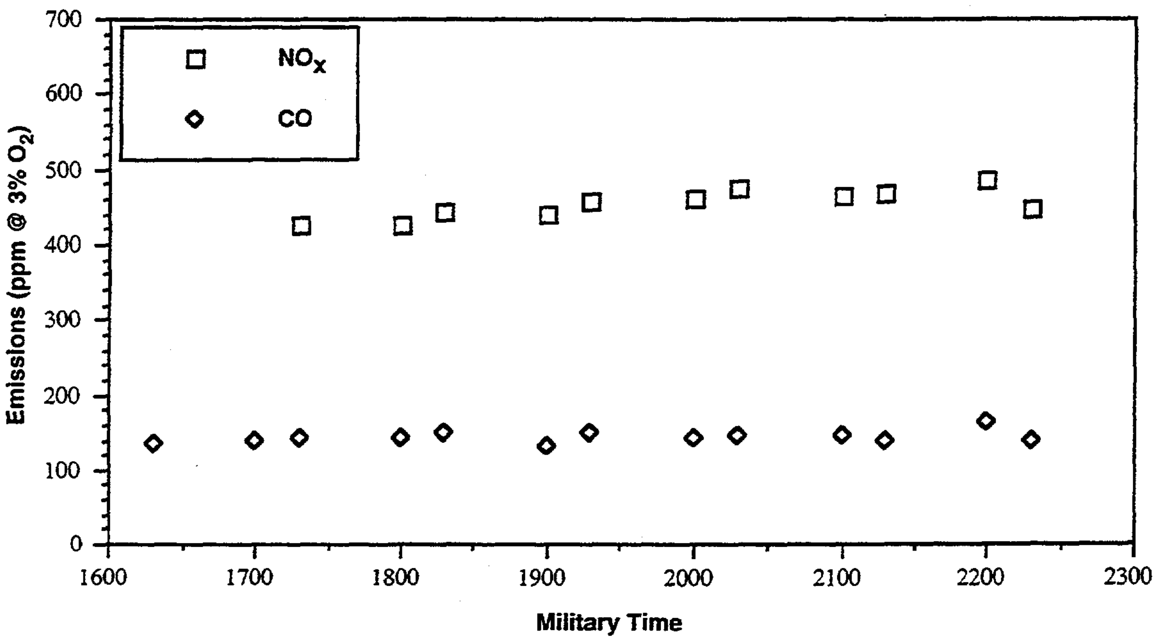


Figure D-35. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/17/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 370 TO 395 MILL AIR FLOW

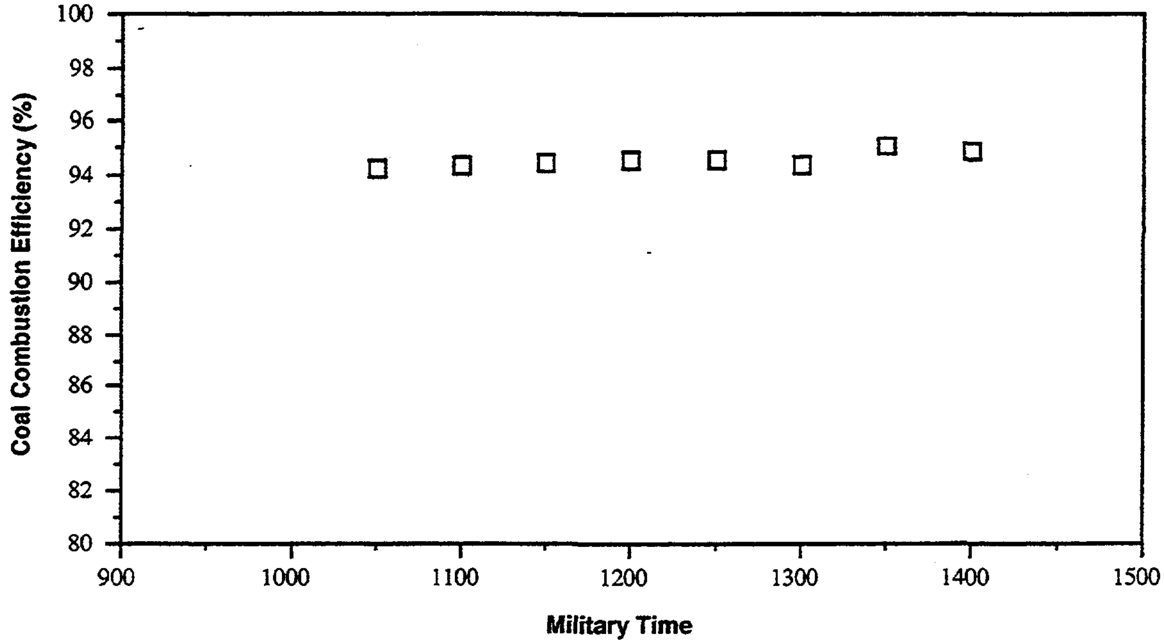


(a)

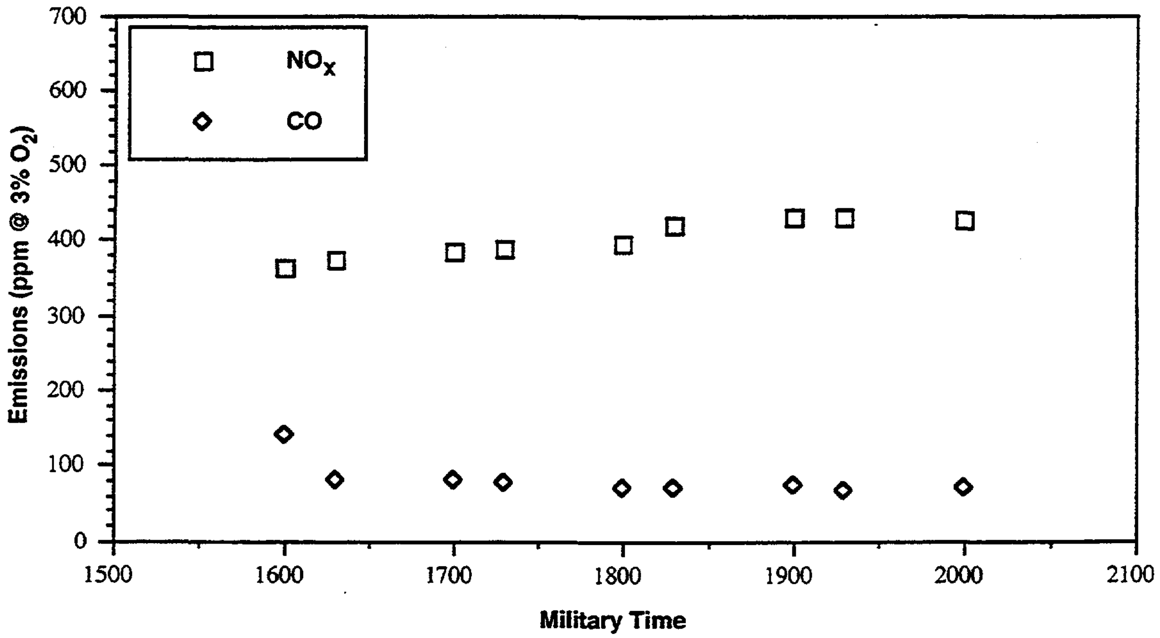


(b)

Figure D-36. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/22/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 380 TO 400 MILL AIR FLOW

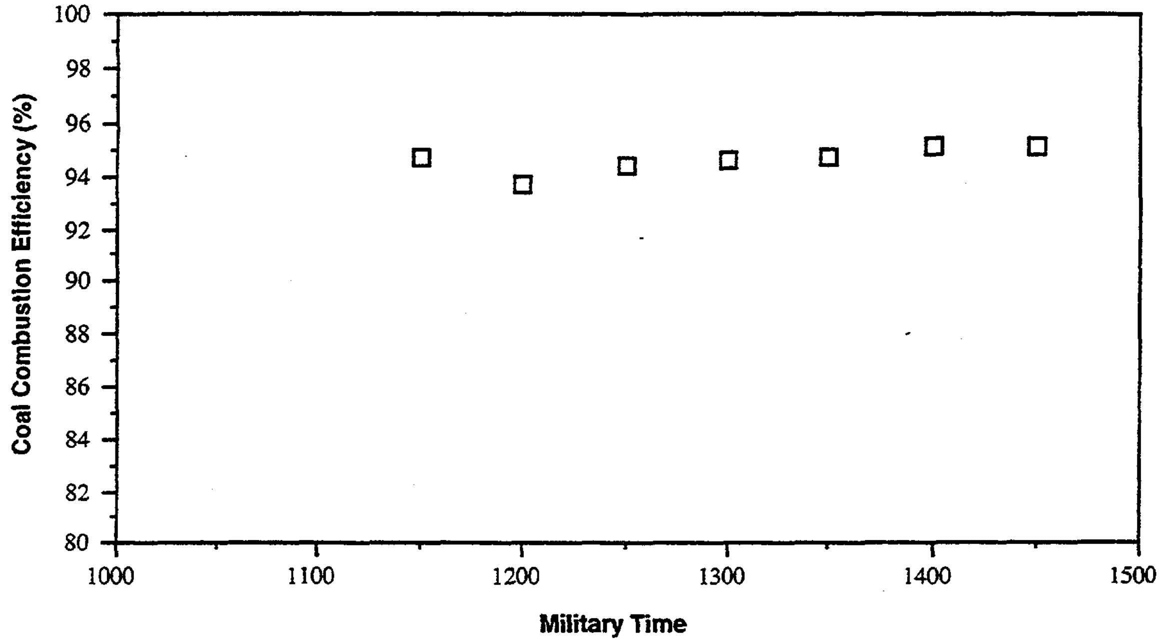


(a)

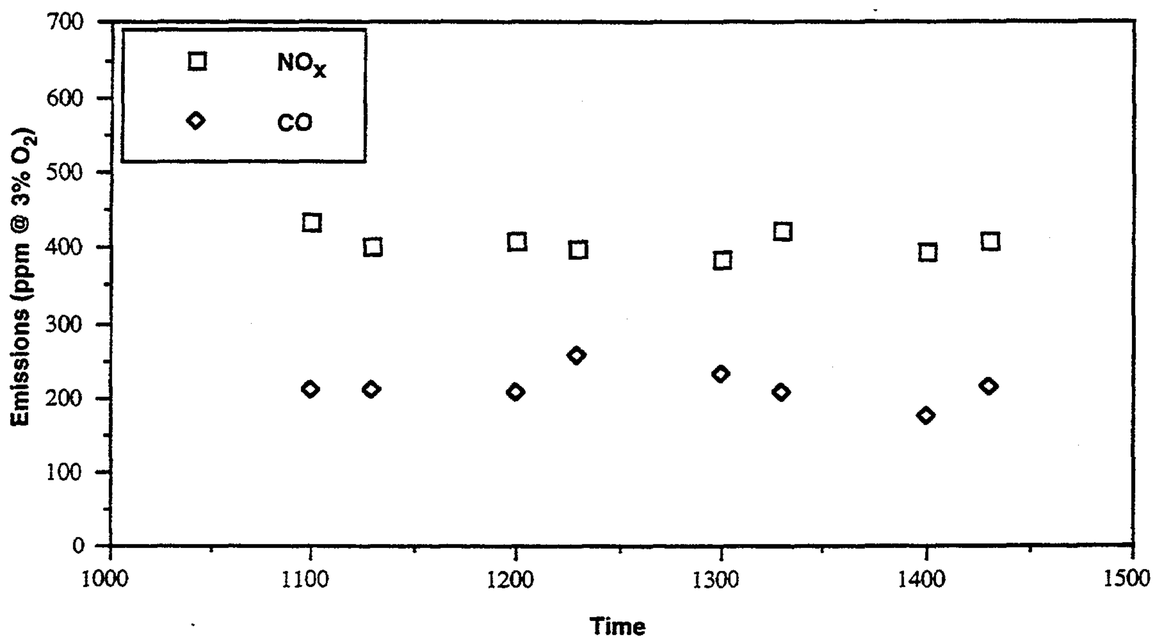


(b)

Figure D-37. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/28/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 385 TO 395 MILL AIR FLOW

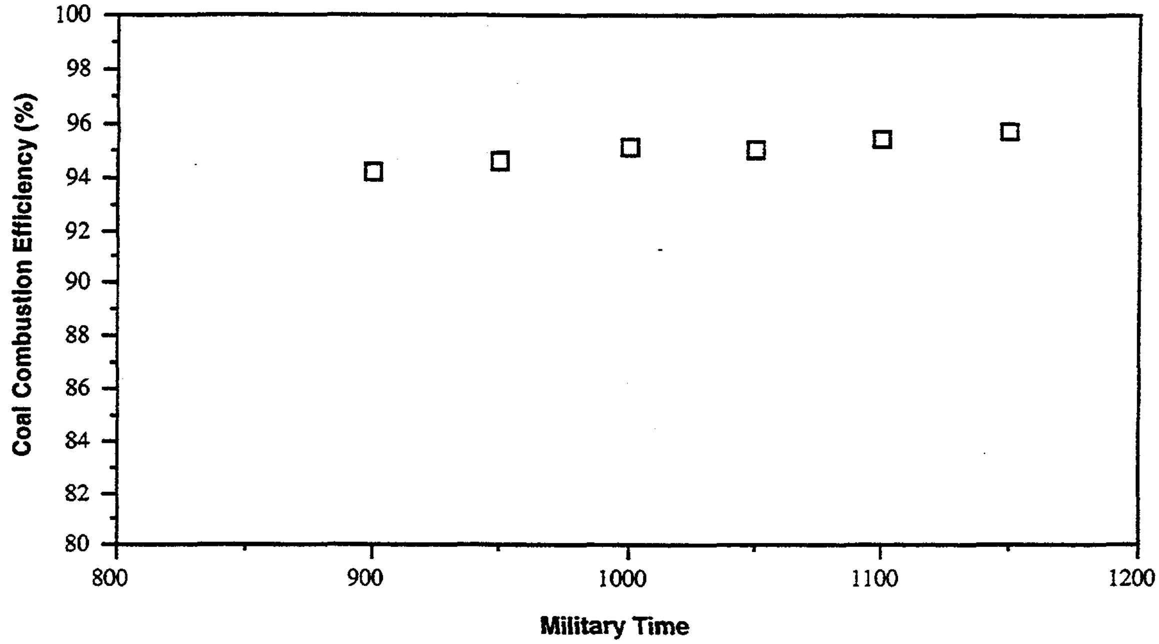


(a)

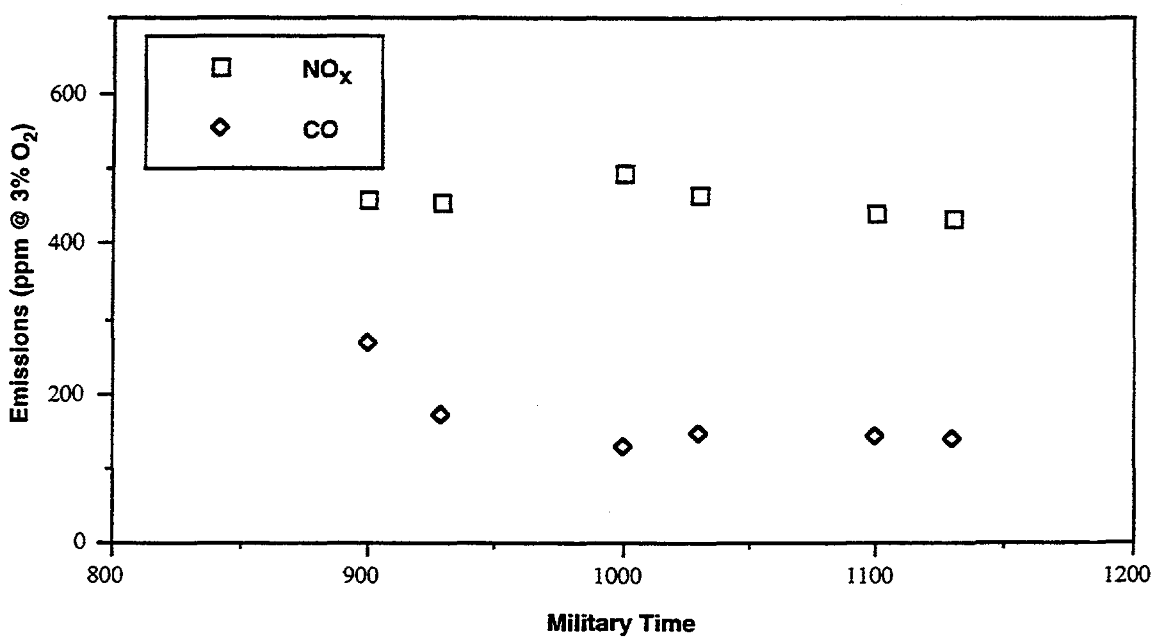


(b)

Figure D-38. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/29/95 WITH DAMPER SETTINGS OF 100/100/50/0, 300 TO 325 ACFM MILL AIR FLOW, AND COAL GUN POSITION OF 36.5"

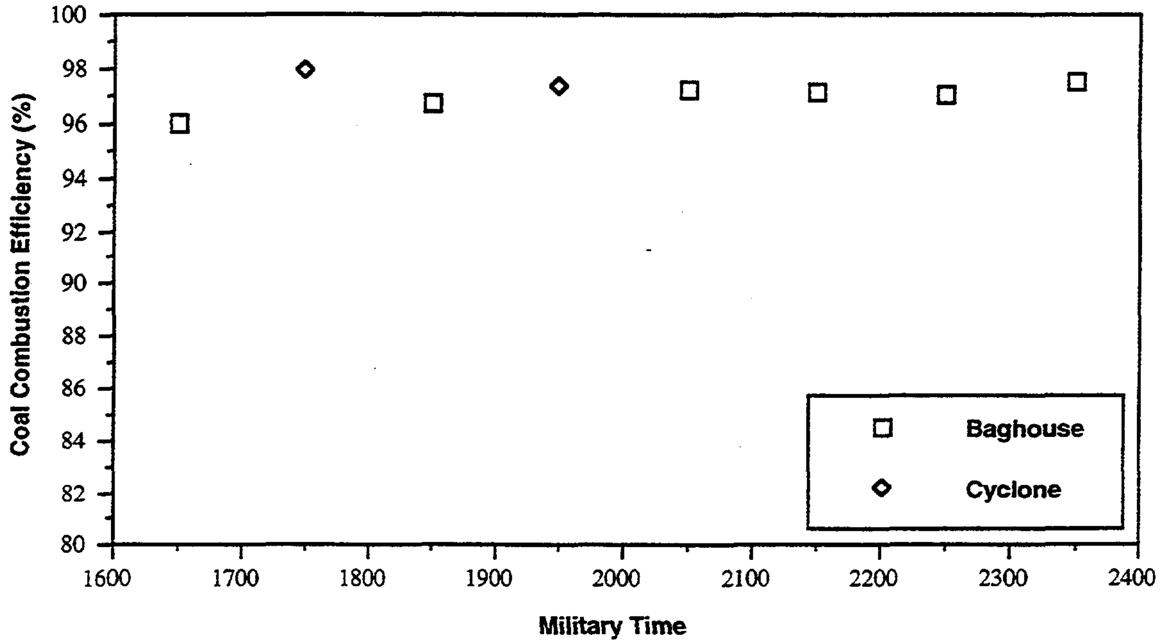


(a)

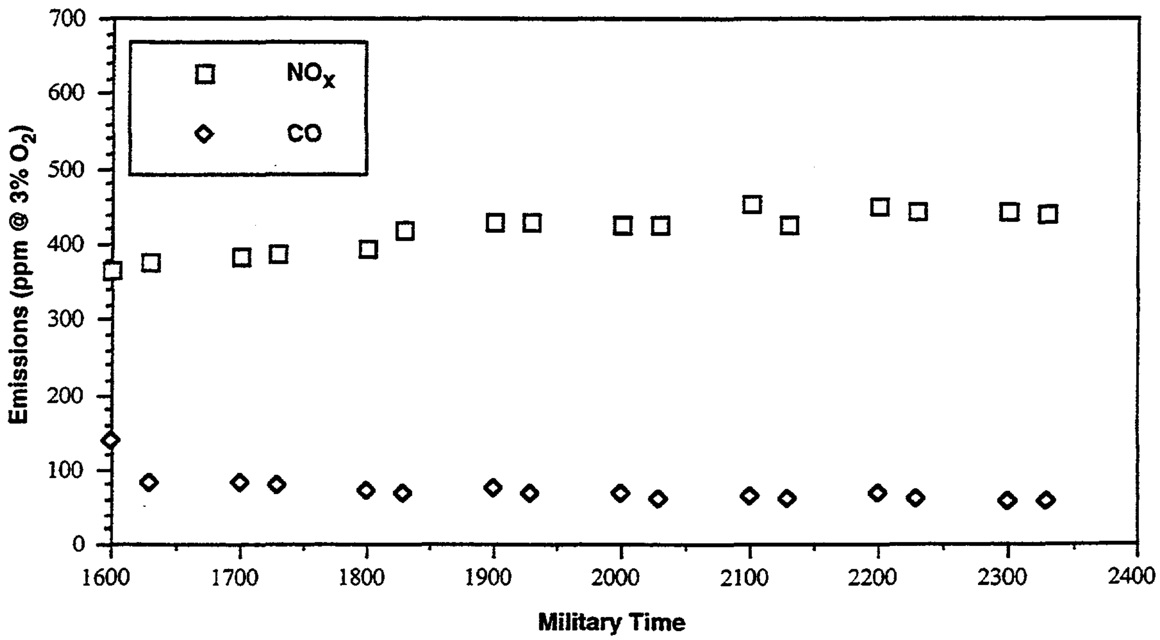


(b)

Figure D-39. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 11/30/95 WITH DAMPER SETTINGS OF 100/100/50/0, 300 TO 320 ACFM MILL AIR FLOW, AND COAL GUN POSITION OF 39.5"



(a)



(b)

Figure D-40. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 12/13/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 360 TO 375 ACFM MILL AIR FLOW

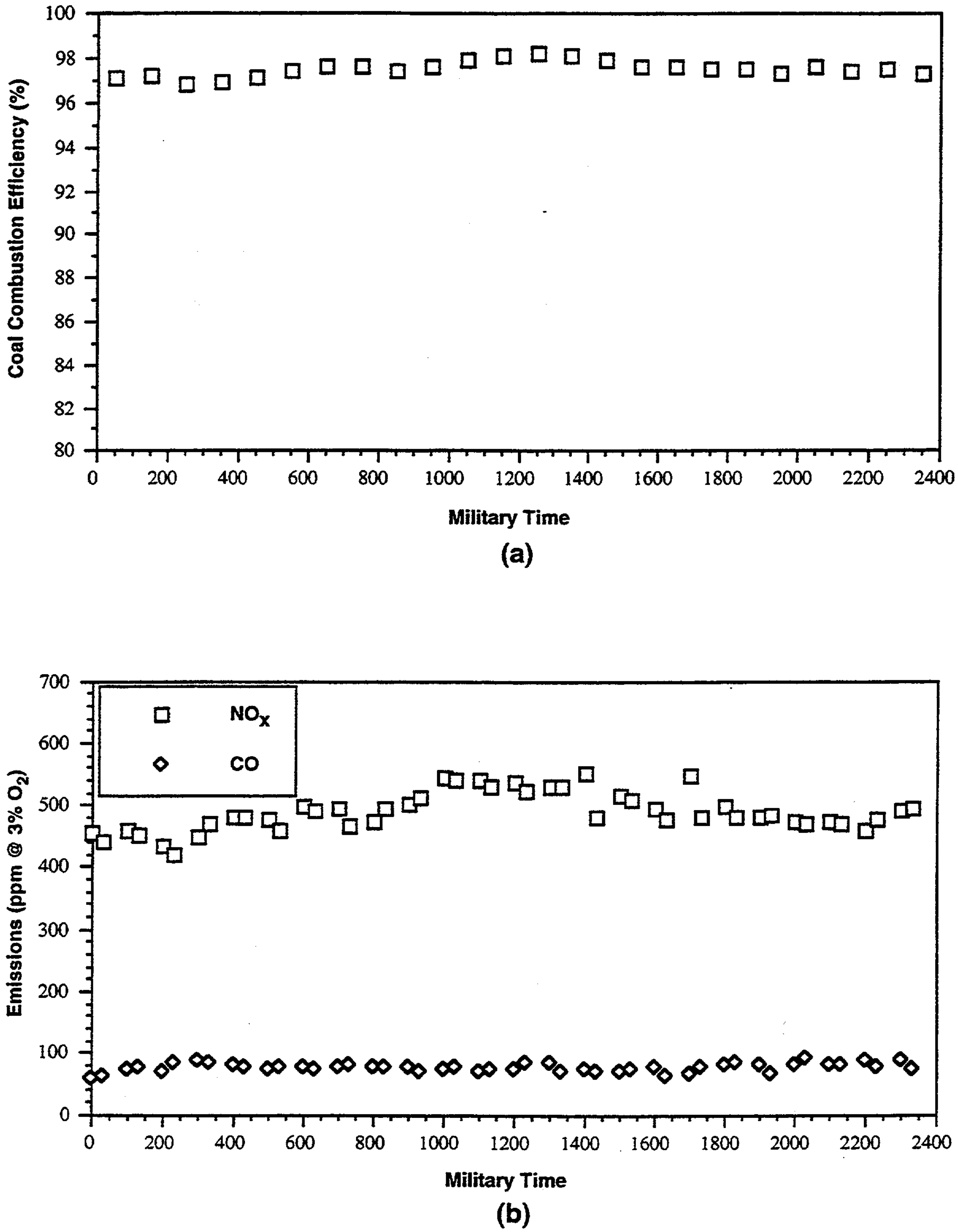


Figure D-41. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 12/14/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 365 TO 385 ACFM MILL AIR FLOW

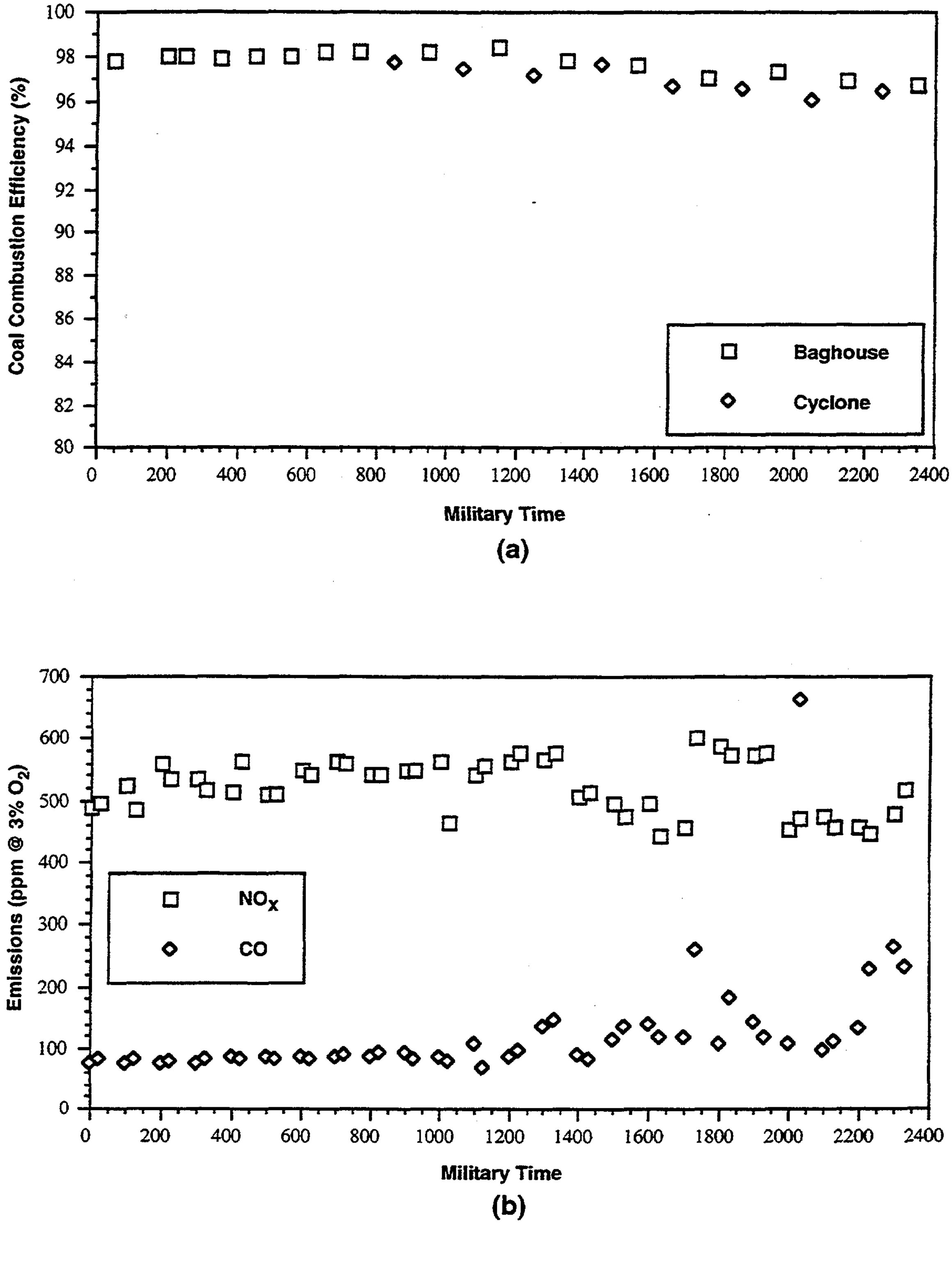


Figure D-42. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 12/15/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 360 TO 395 ACFM MILL AIR FLOW

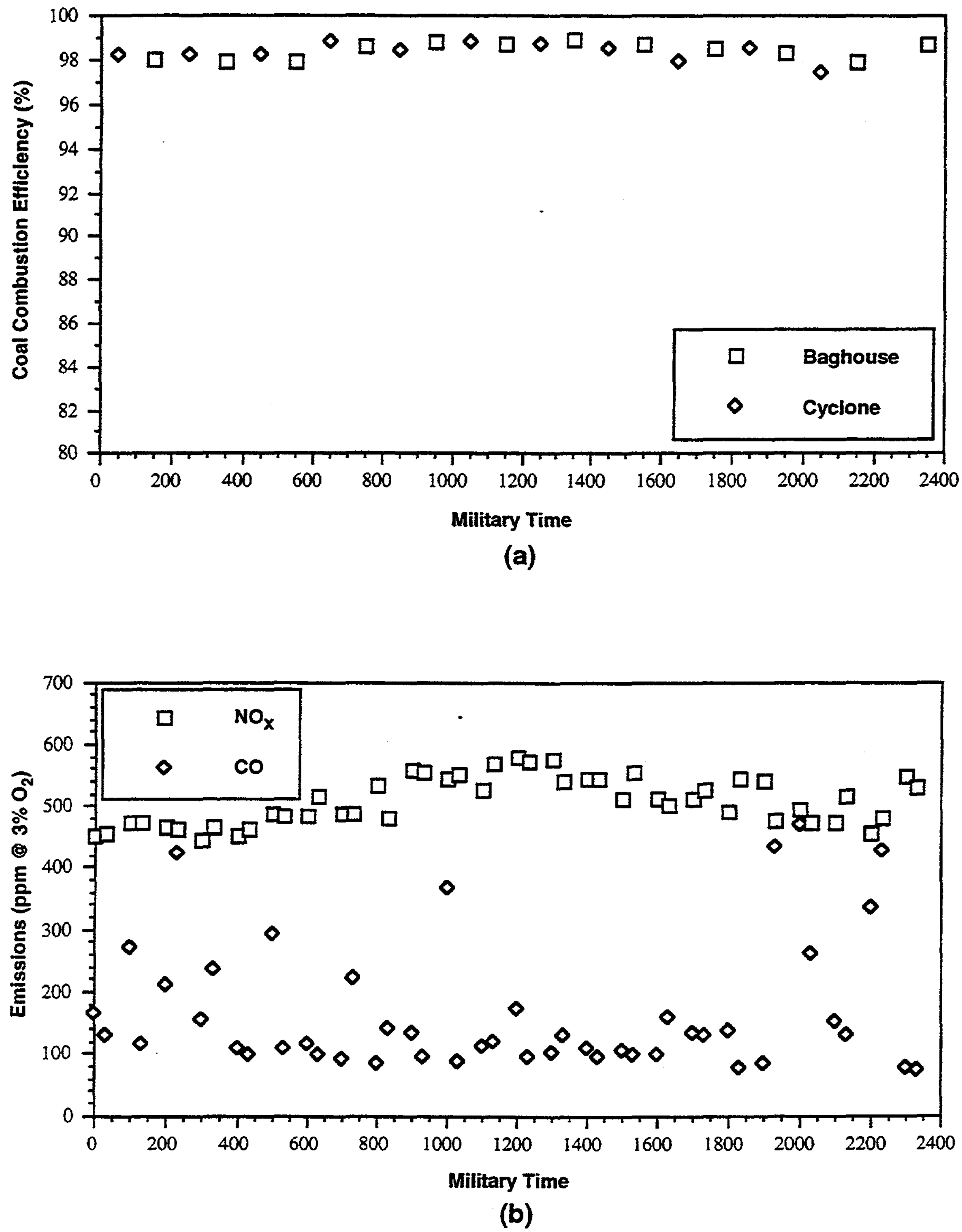
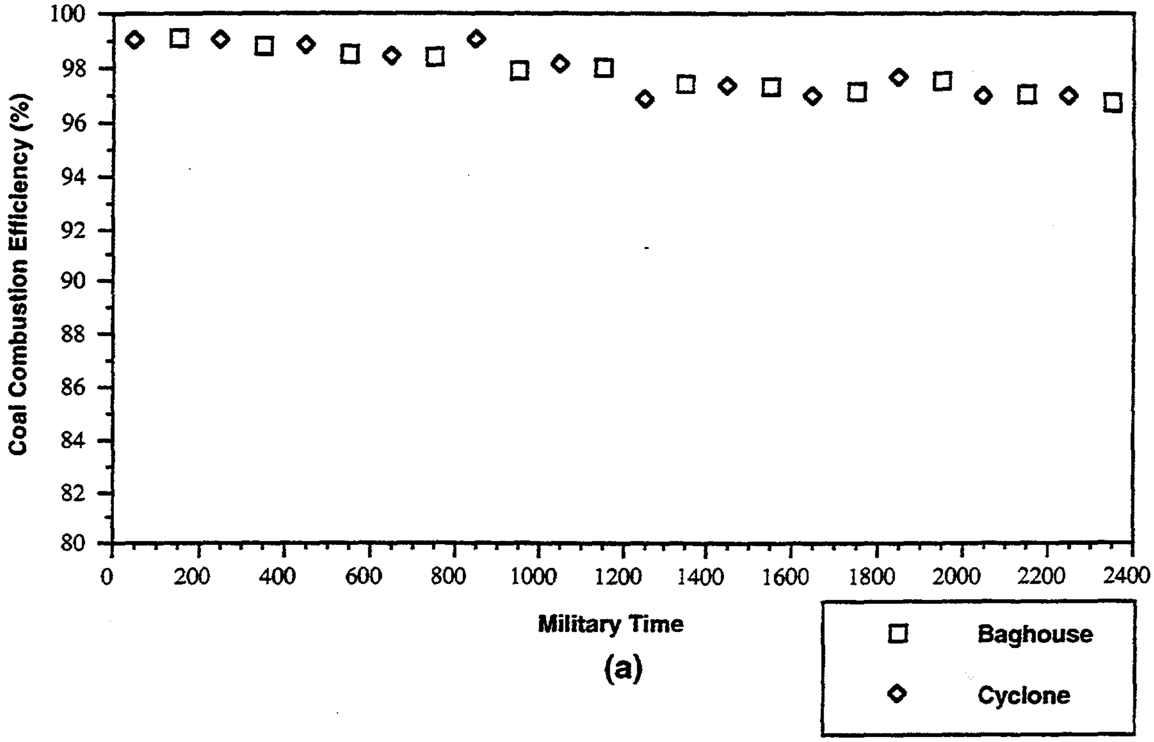
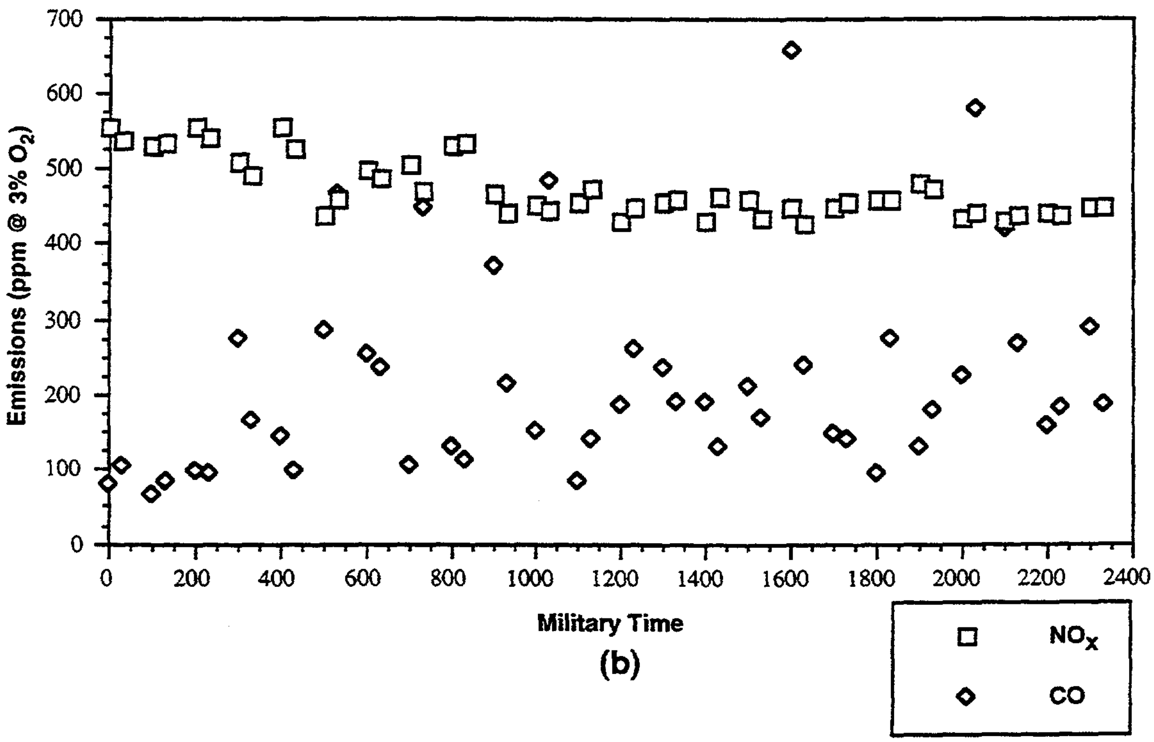


Figure D-43. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 12/16/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 360 TO 385 ACFM MILL AIR FLOW



(a)



(b)

Figure D-44. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 12/17/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 375 TO 390 ACFM MILL AIR FLOW

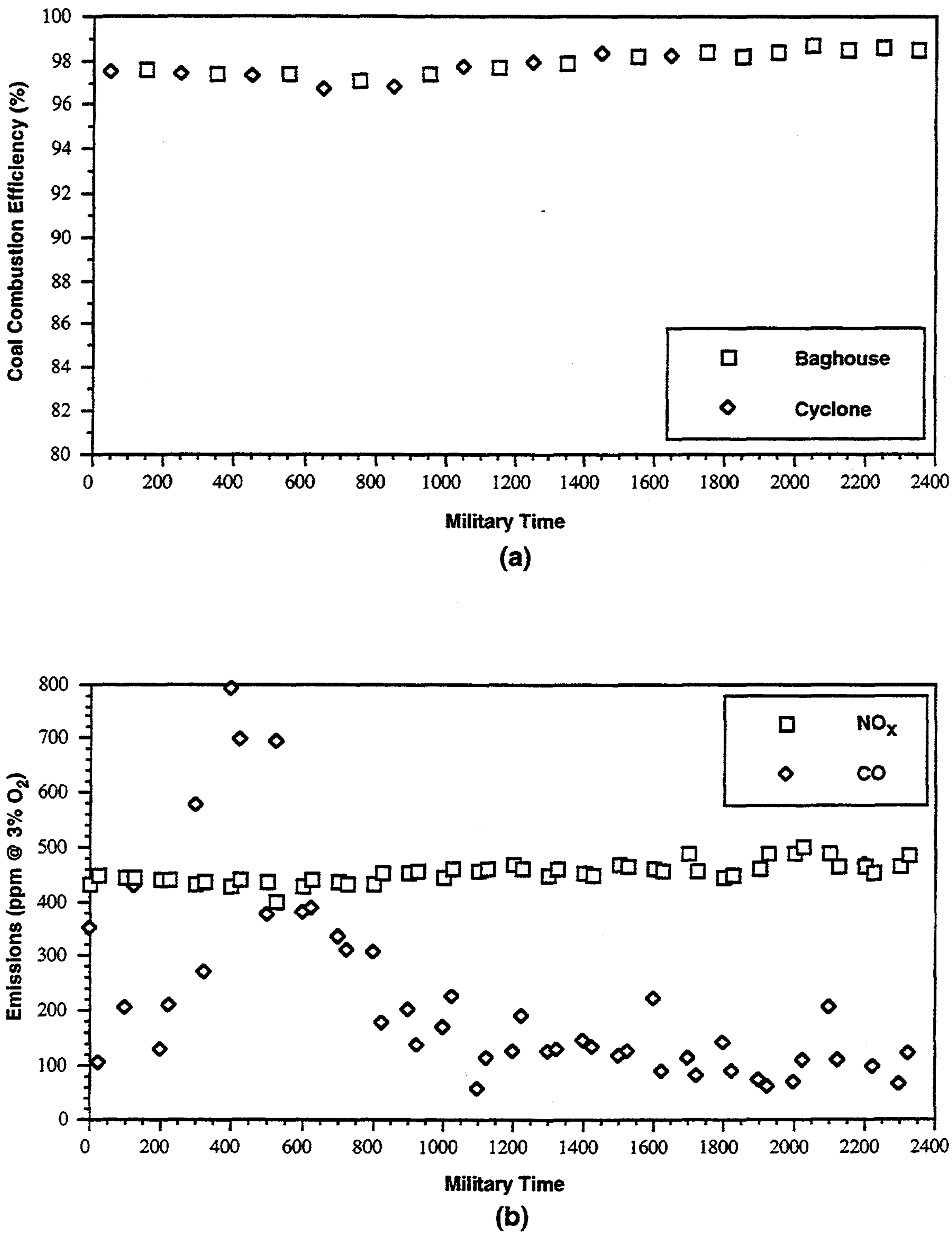


Figure D-45. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 12/18/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 360 TO 395 ACFM MILL AIR FLOW

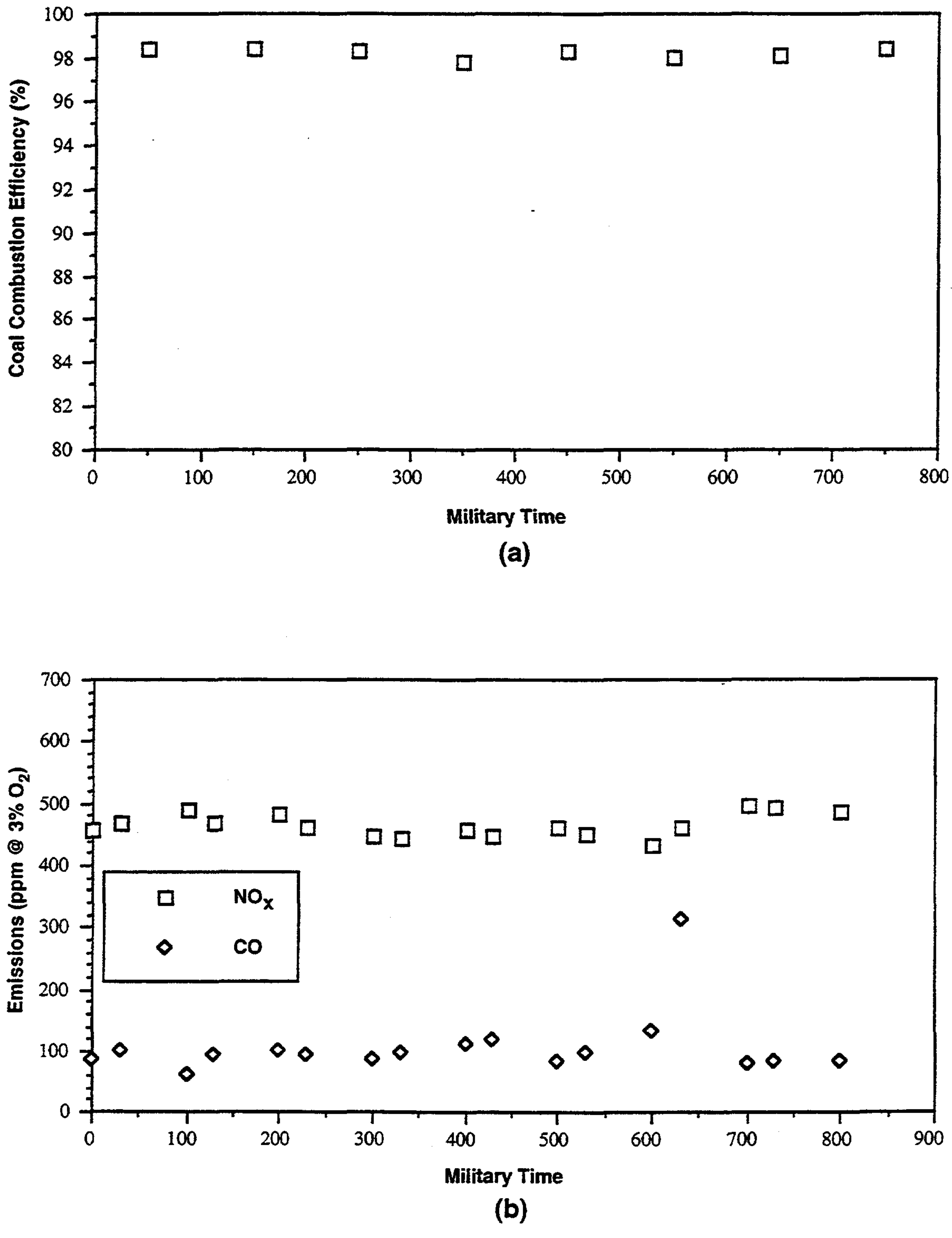


Figure D-46. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 12/19/95 WITH DAMPER SETTINGS OF 100/100/50/0 AND 360 TO 380 ACFM MILL AIR FLOW

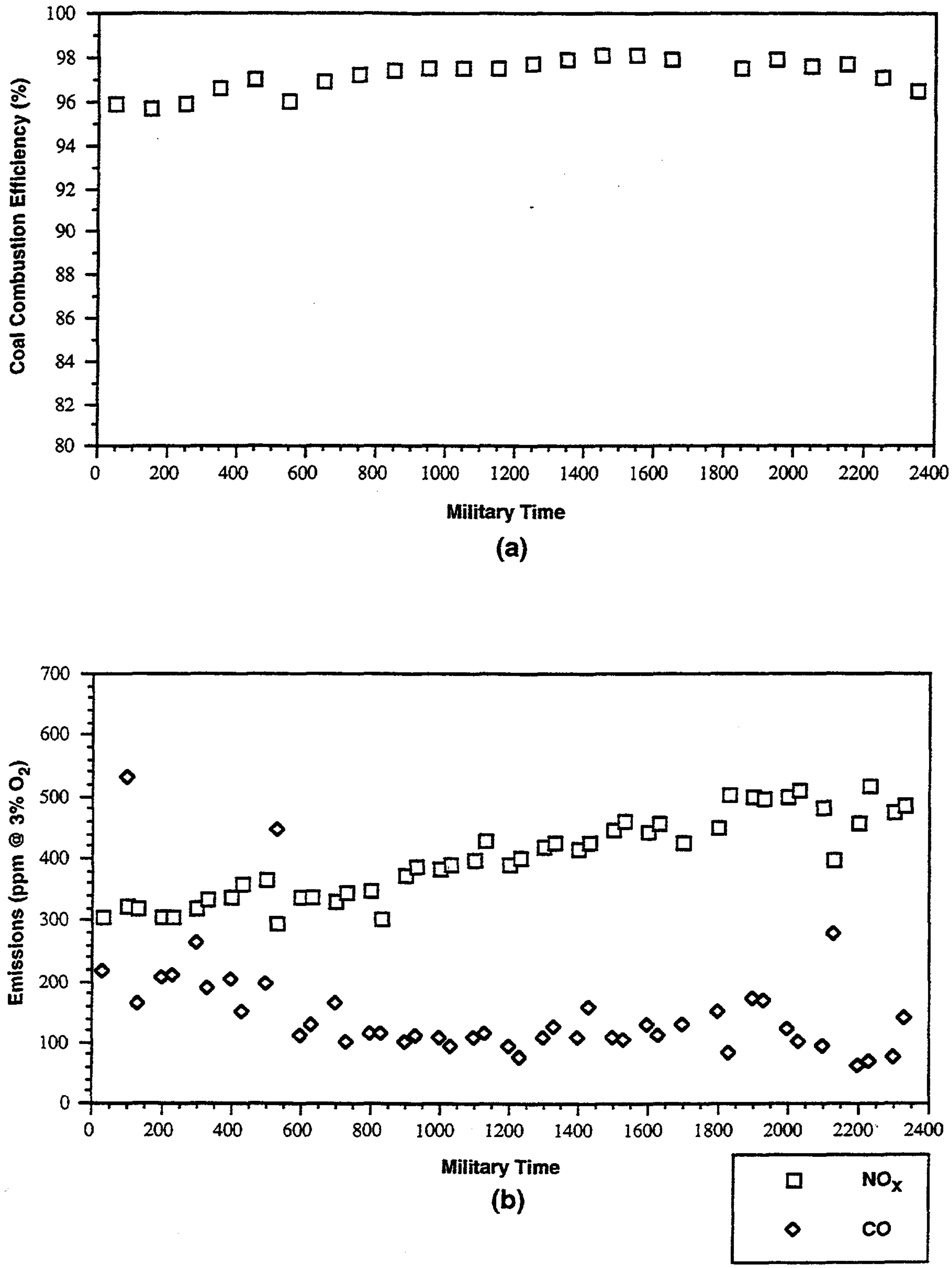
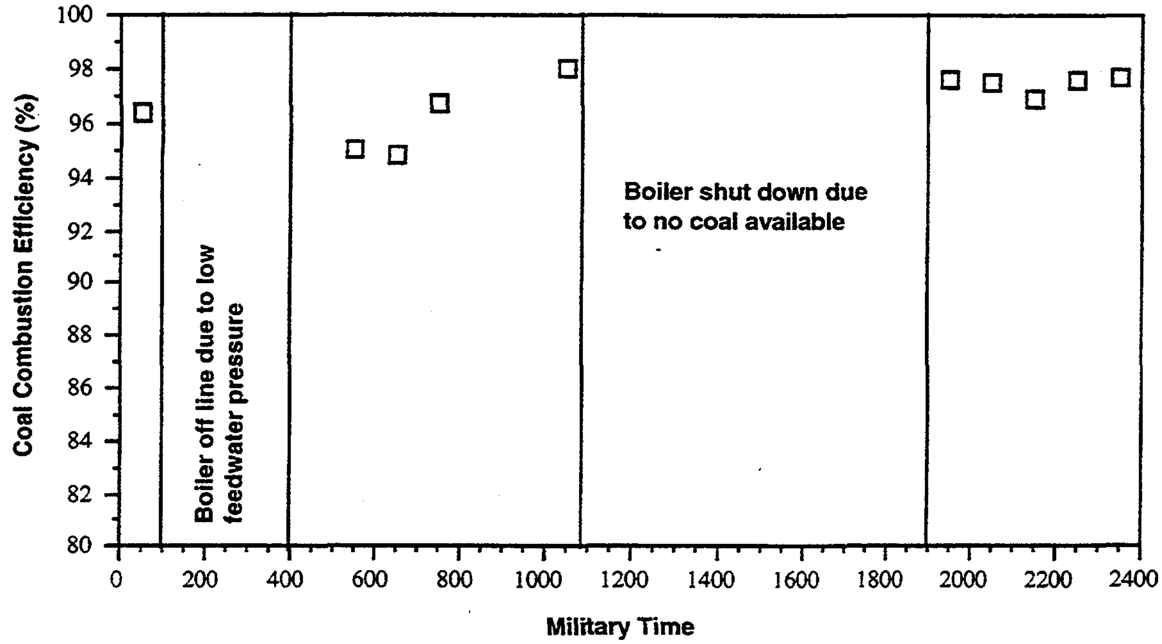
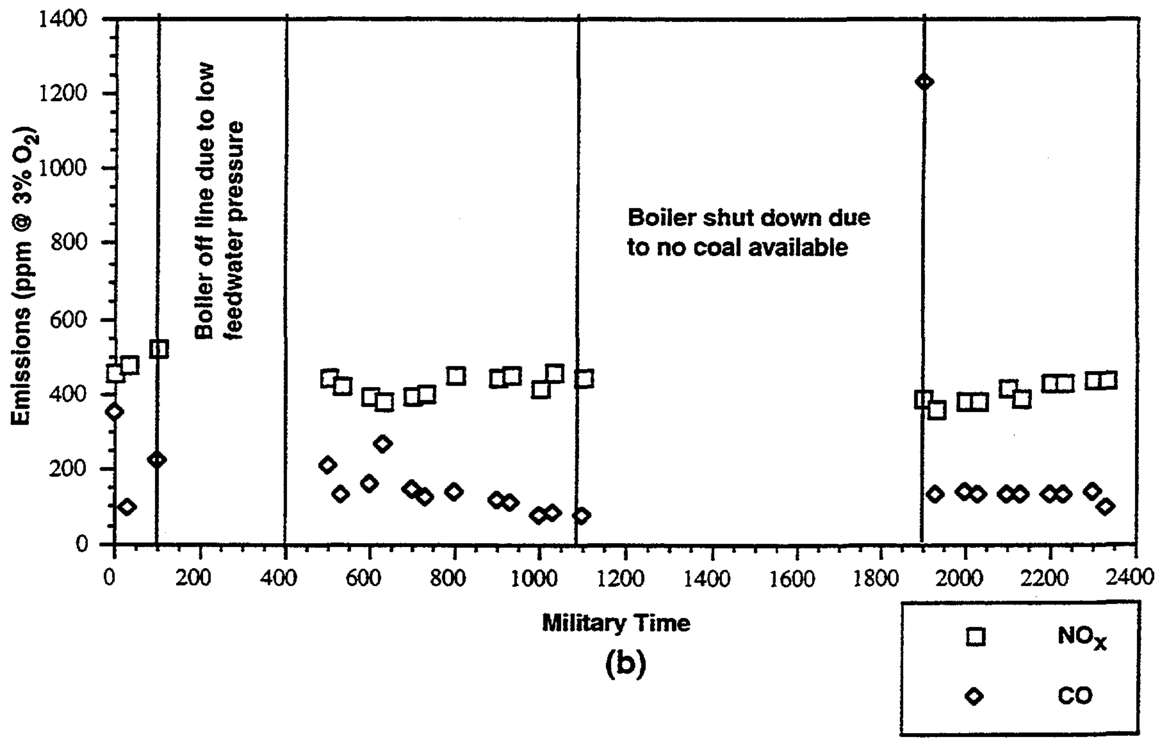


Figure D-47. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 01/09/96 WITH DAMPER SETTINGS OF 100/100/50/0 AND 370 TO 400 ACFM MILL AIR FLOW

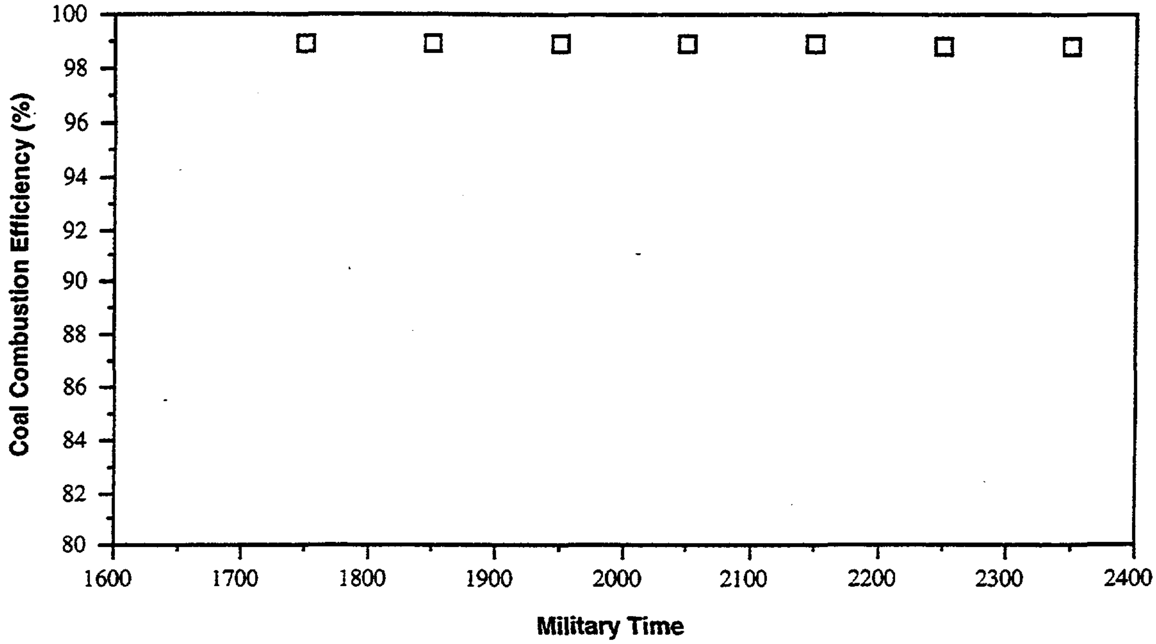


(a)

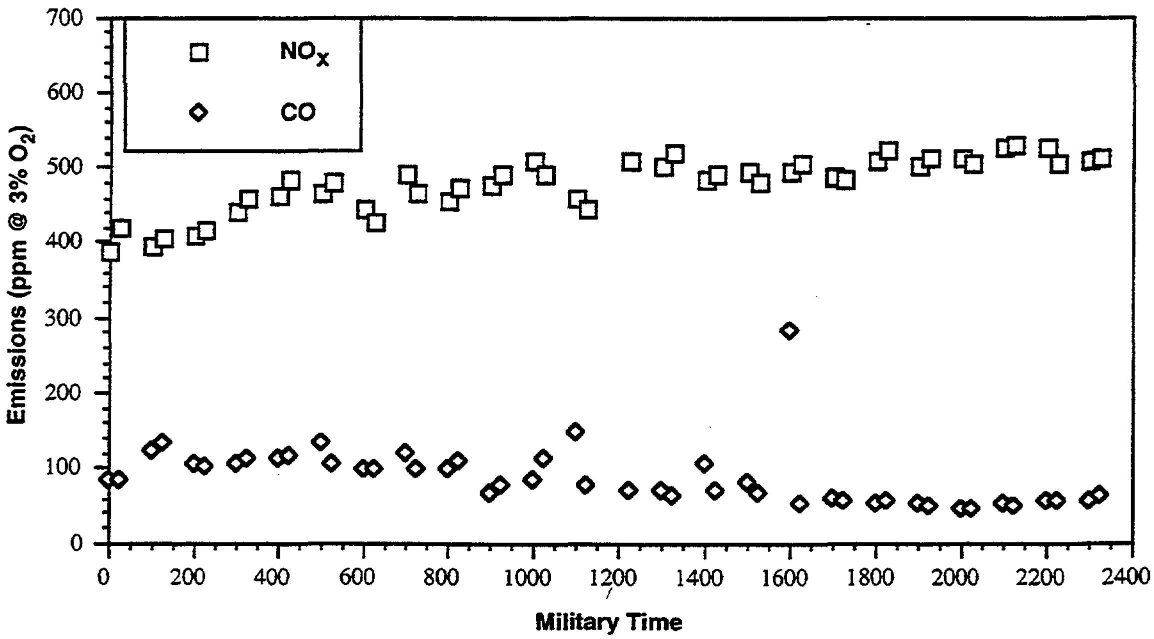


(b)

Figure D-48. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 01/10/96 WITH DAMPER SETTINGS OF 100/100/50/0 AND 365 TO 395 ACFM MILL AIR FLOW



(a)



(b)

Figure D-49. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 01/11/96 WITH DAMPER SETTINGS OF 100/100/50/0 AND 365 TO 395 ACFM MILL AIR FLOW

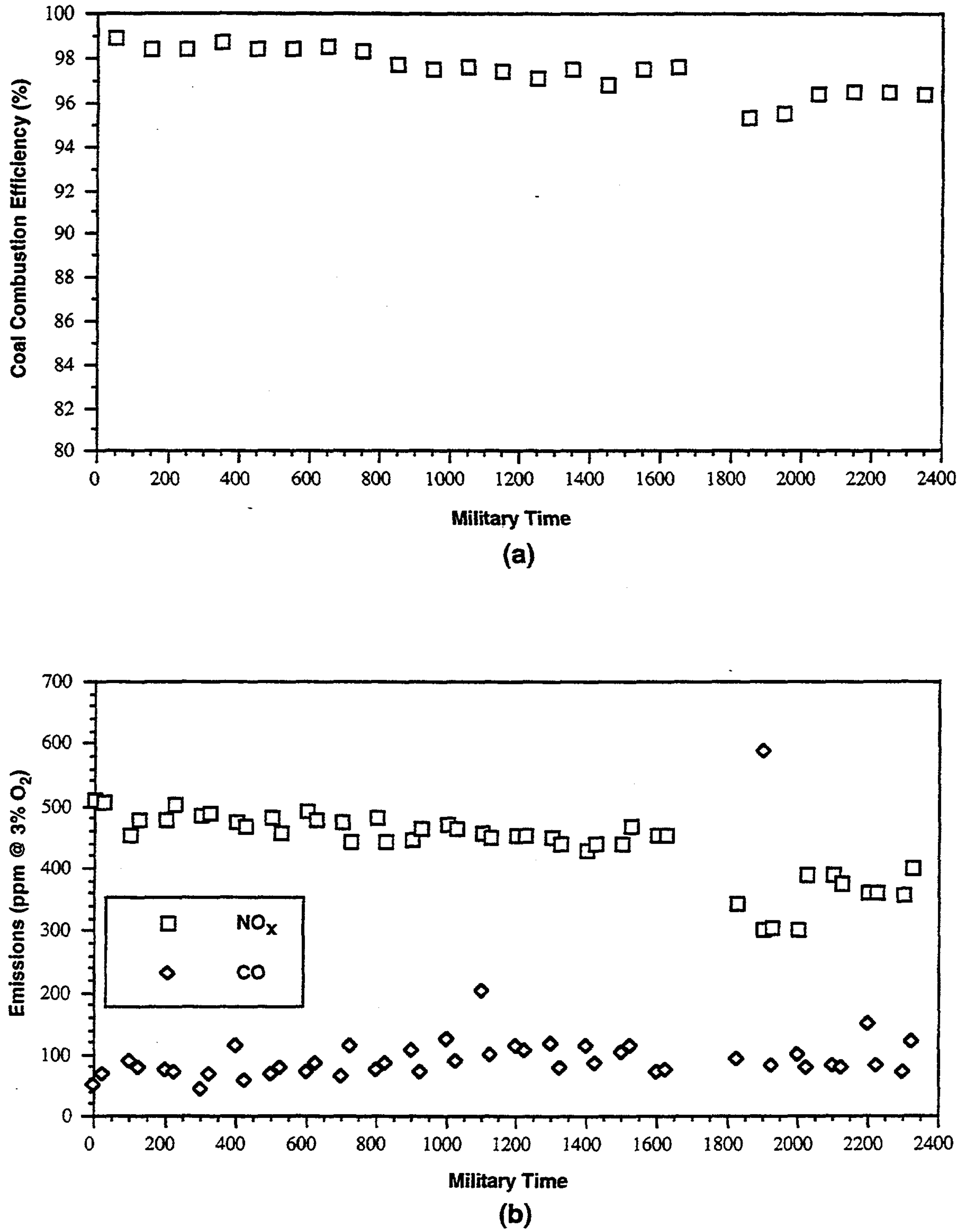
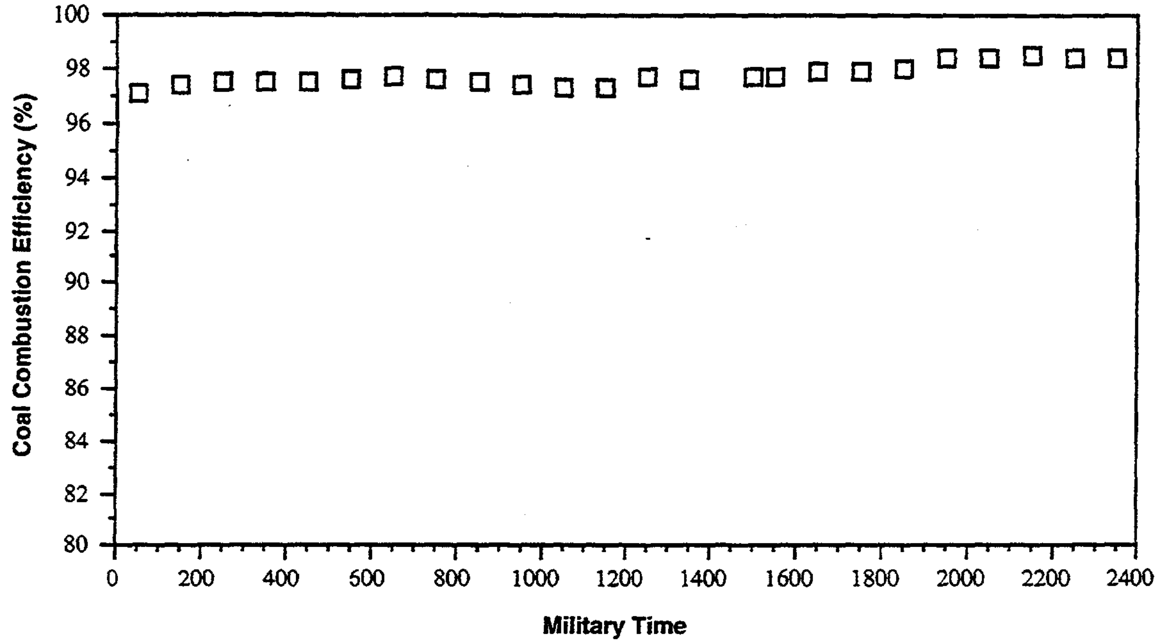
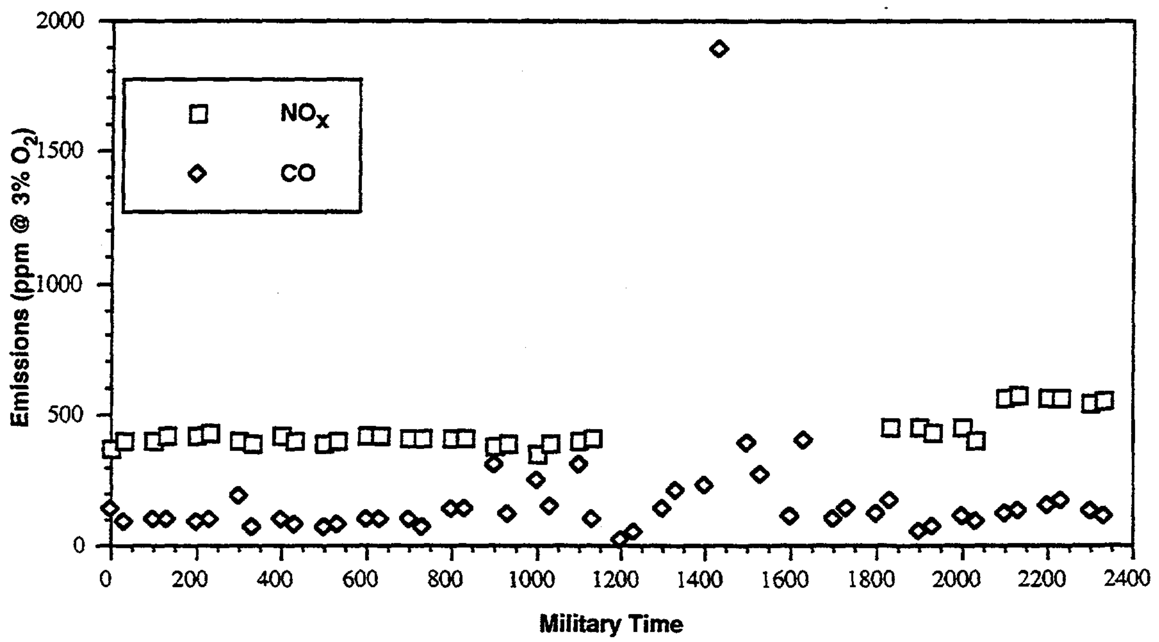


Figure D-50. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 01/12/96 WITH DAMPER SETTINGS OF 100/100/50/0 AND 370 TO 400 ACFM MILL AIR FLOW

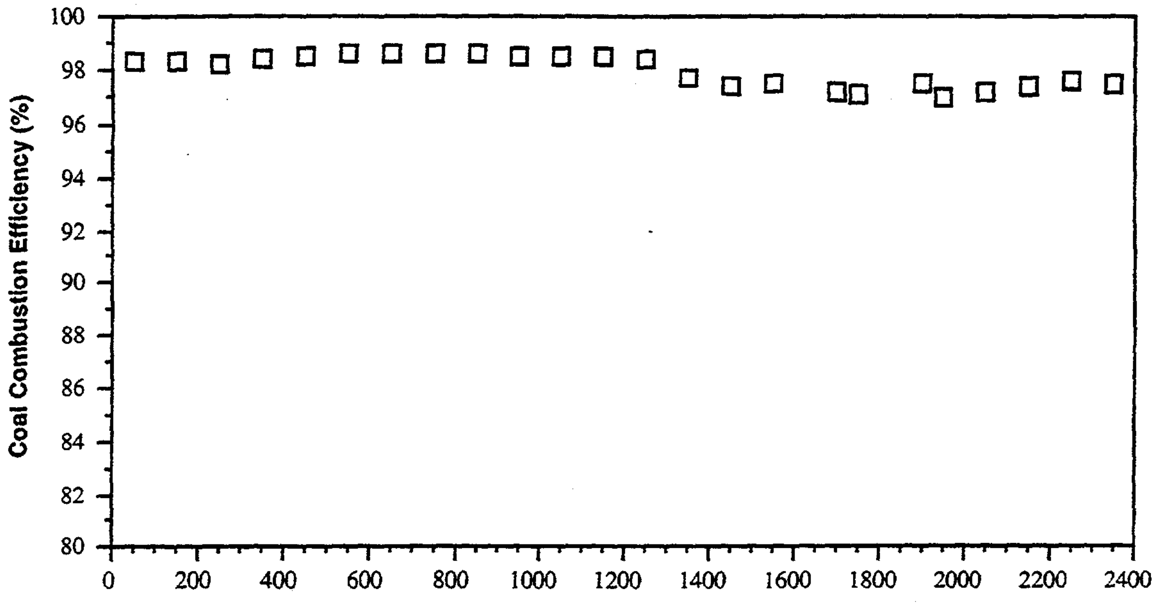


(a)

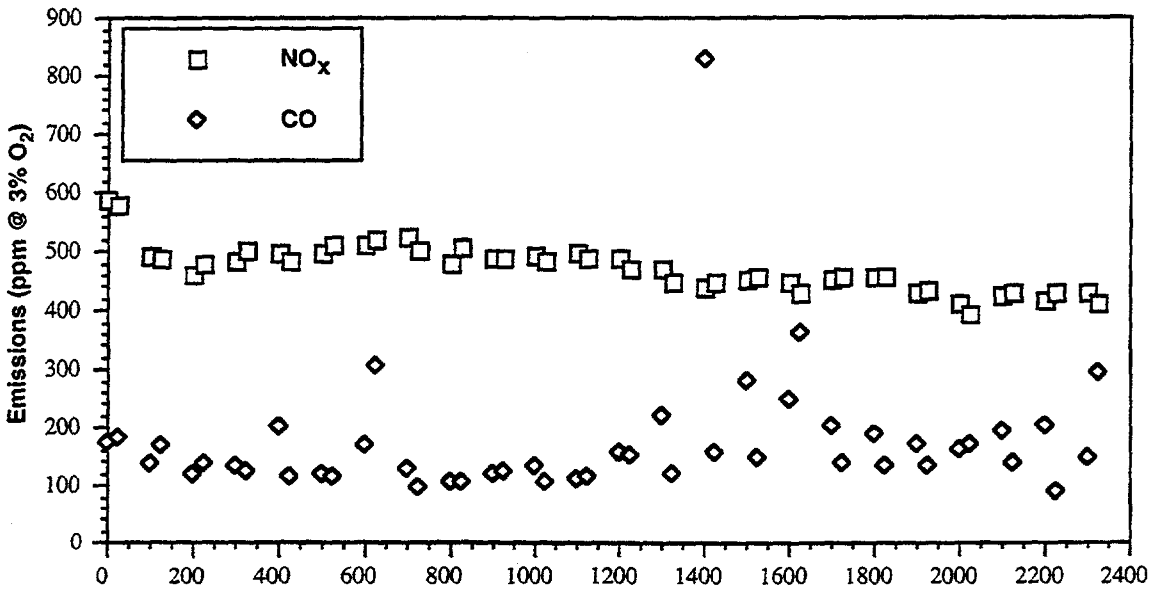


(b)

Figure D-51. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 01/13/96 WITH DAMPER SETTINGS OF 100/100/50/0 AND 370 TO 395 ACFM MILL AIR FLOW

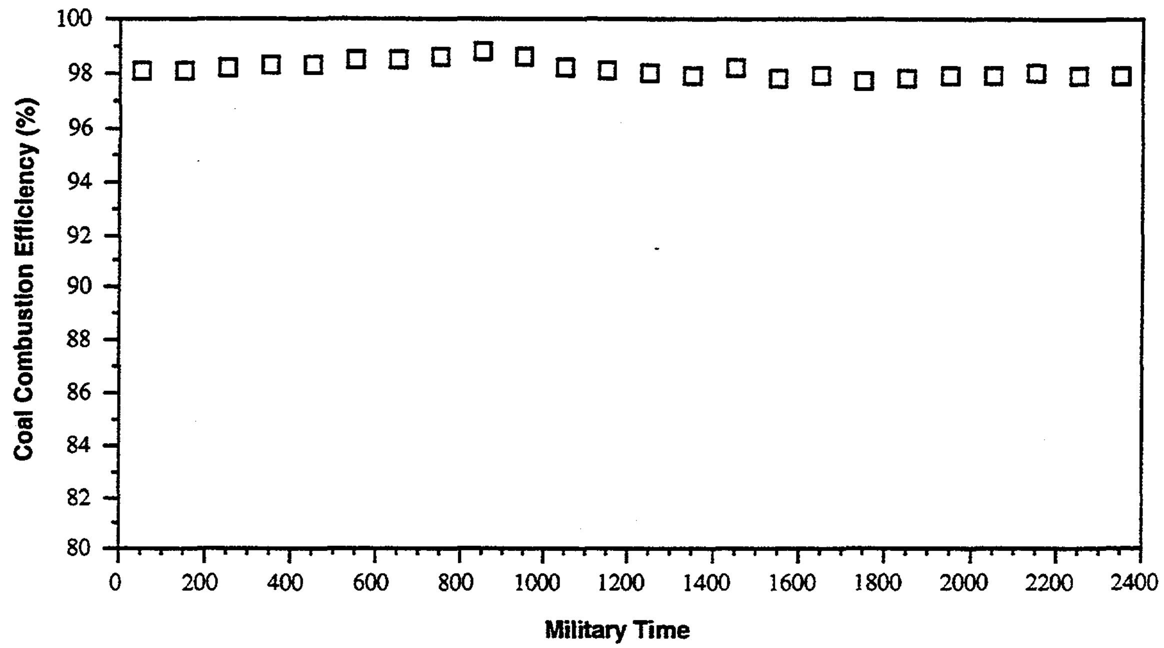


(a)

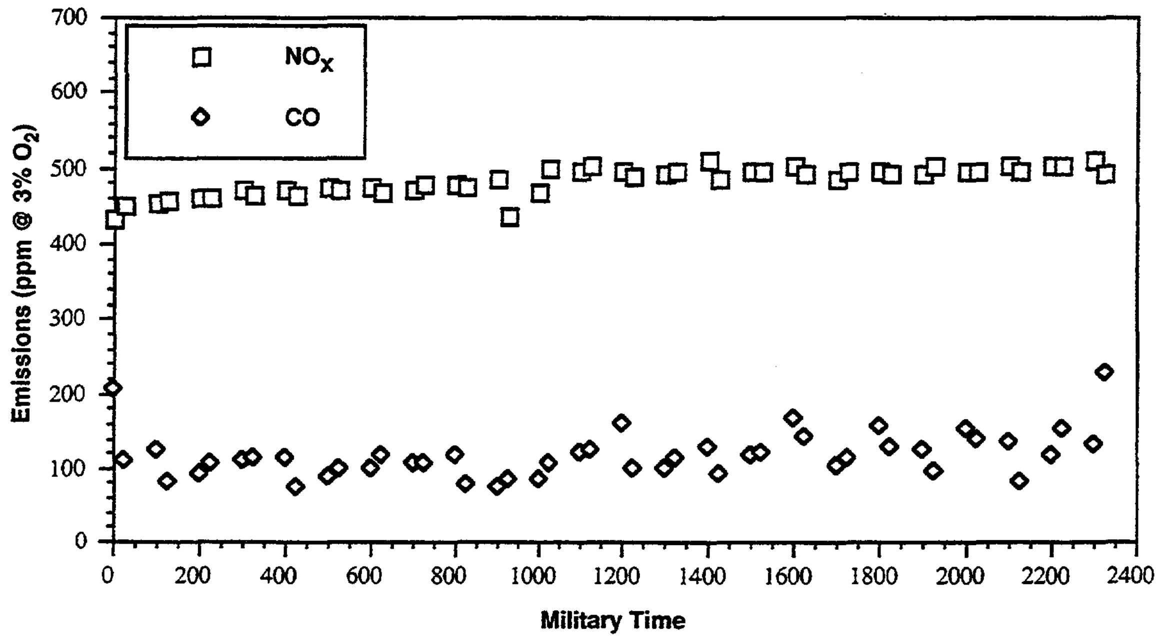


(b)

Figure D-52. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 01/14/96 WITH DAMPER SETTINGS OF 100/100/50/0 AND 375 TO 400 ACFM MILL AIR FLOW

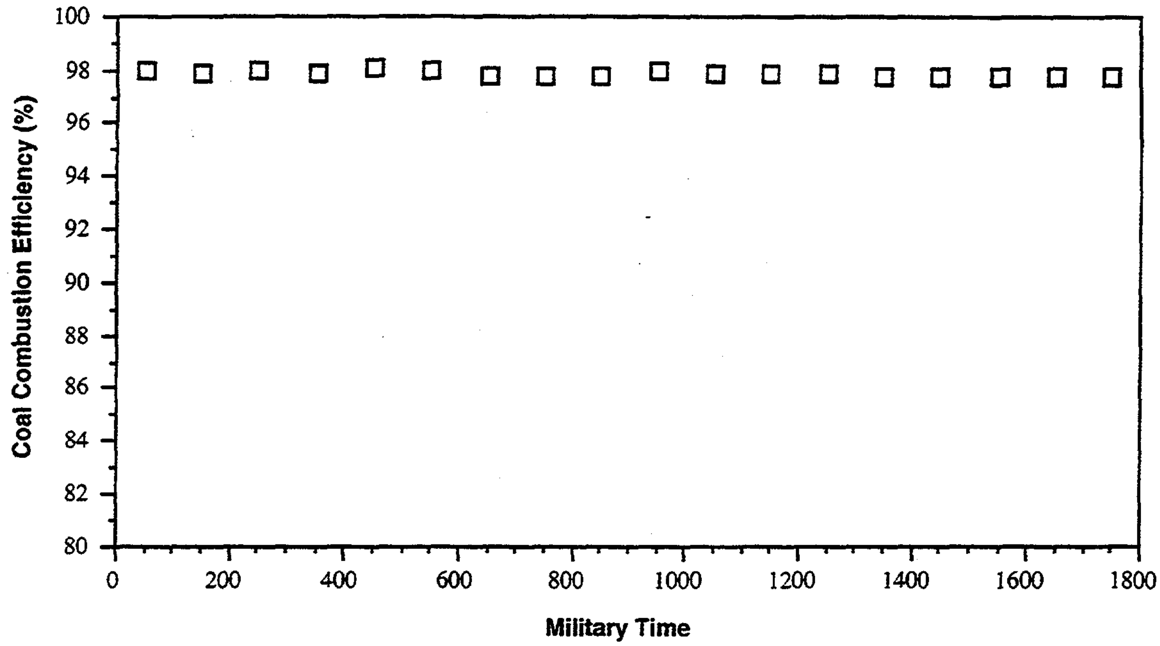


(a)

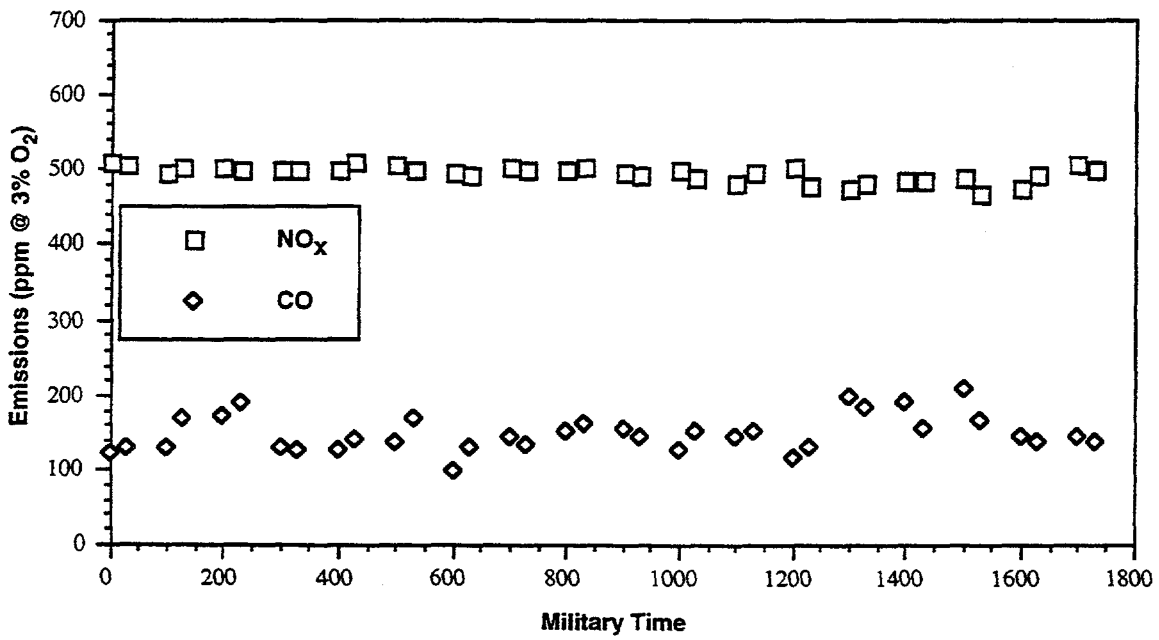


(b)

Figure D-53. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 01/15/96 WITH DAMPER SETTINGS OF 100/100/50/0 AND 375 TO 400 ACFM MILL AIR FLOW



(a)



(b)

Figure D-54. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 01/16/96 WITH DAMPER SETTINGS OF 100/100/50/0 AND 380 TO 405 ACFM MILL AIR FLOW

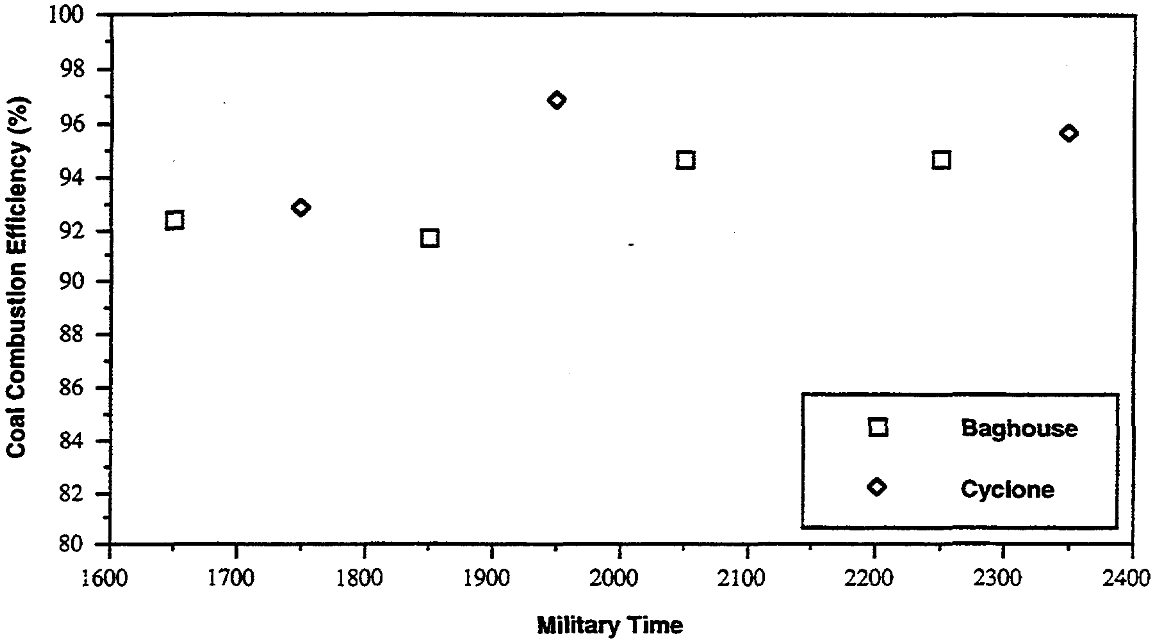


Figure D-55. COAL COMBUSTION EFFICIENCY AS A FUNCTION OF TIME FOR THE TESTING ON 01/22/96 WITH DAMPER SETTINGS OF 100/100/50/0

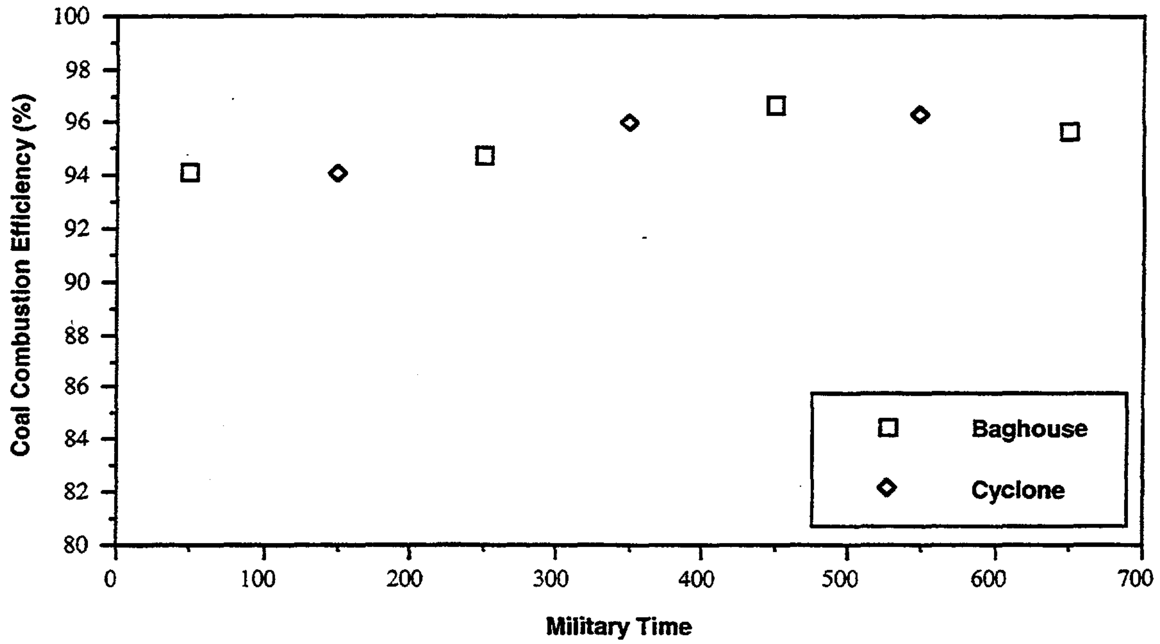
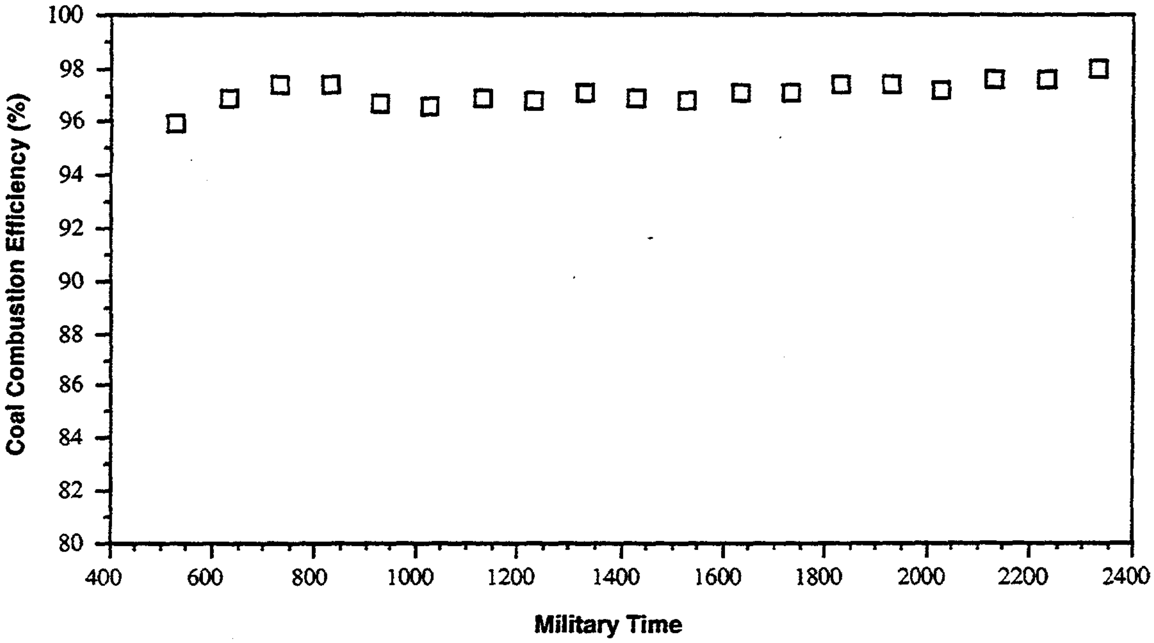
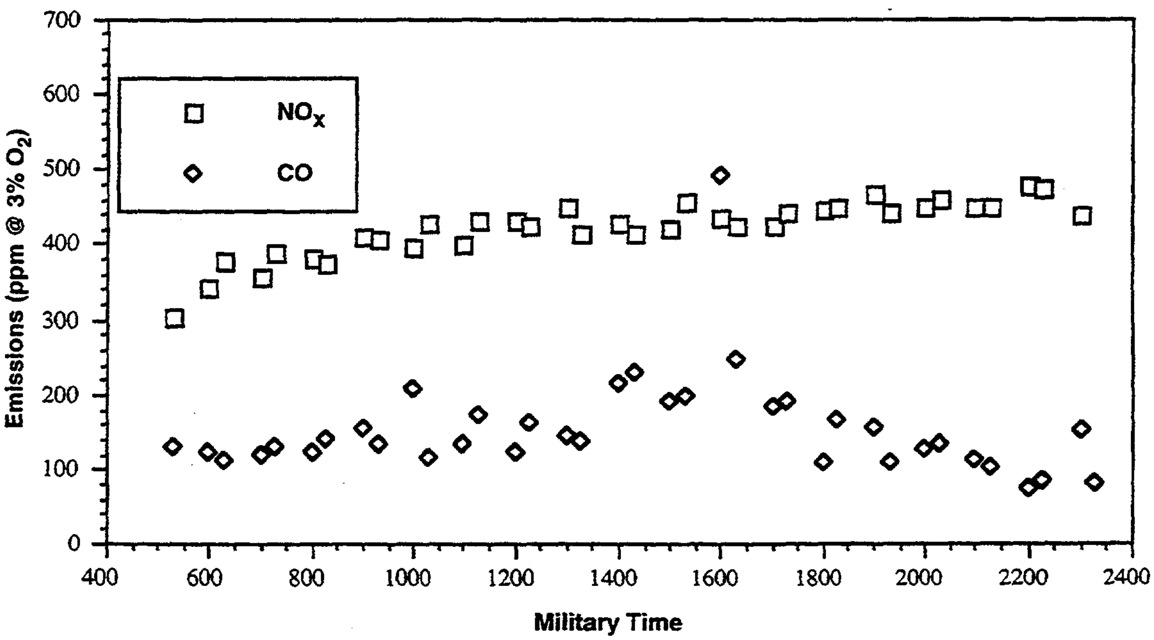


Figure D-56. COAL COMBUSTION EFFICIENCY AS A FUNCTION OF TIME FOR THE TESTING ON 01/23/96 WITH DAMPER SETTINGS OF 100/100/50/0

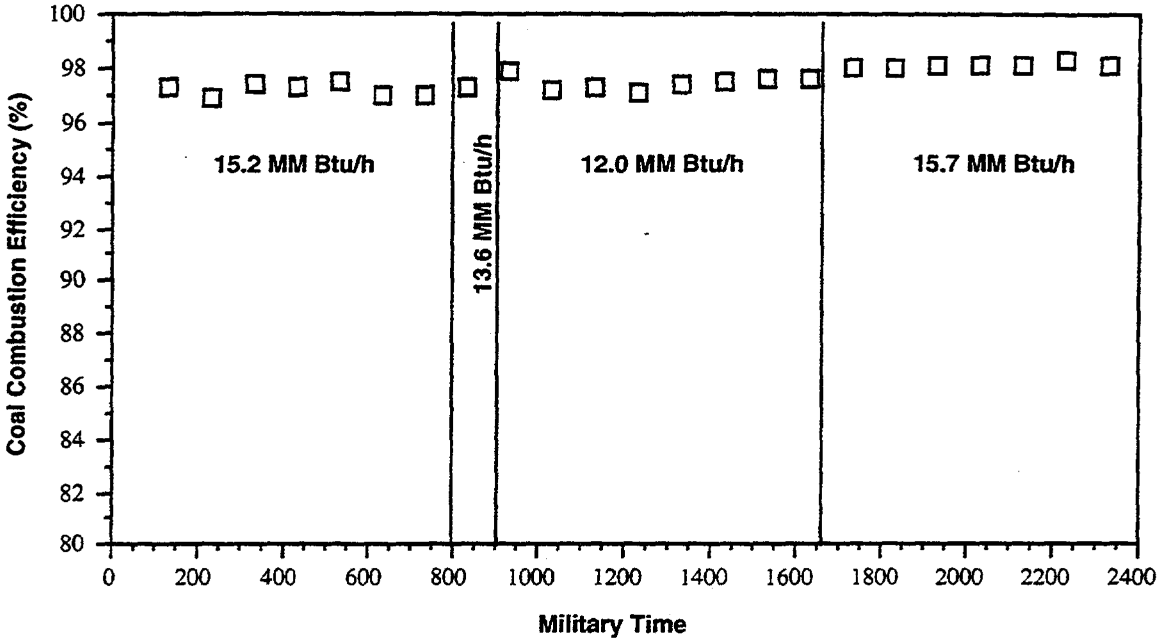


(a)

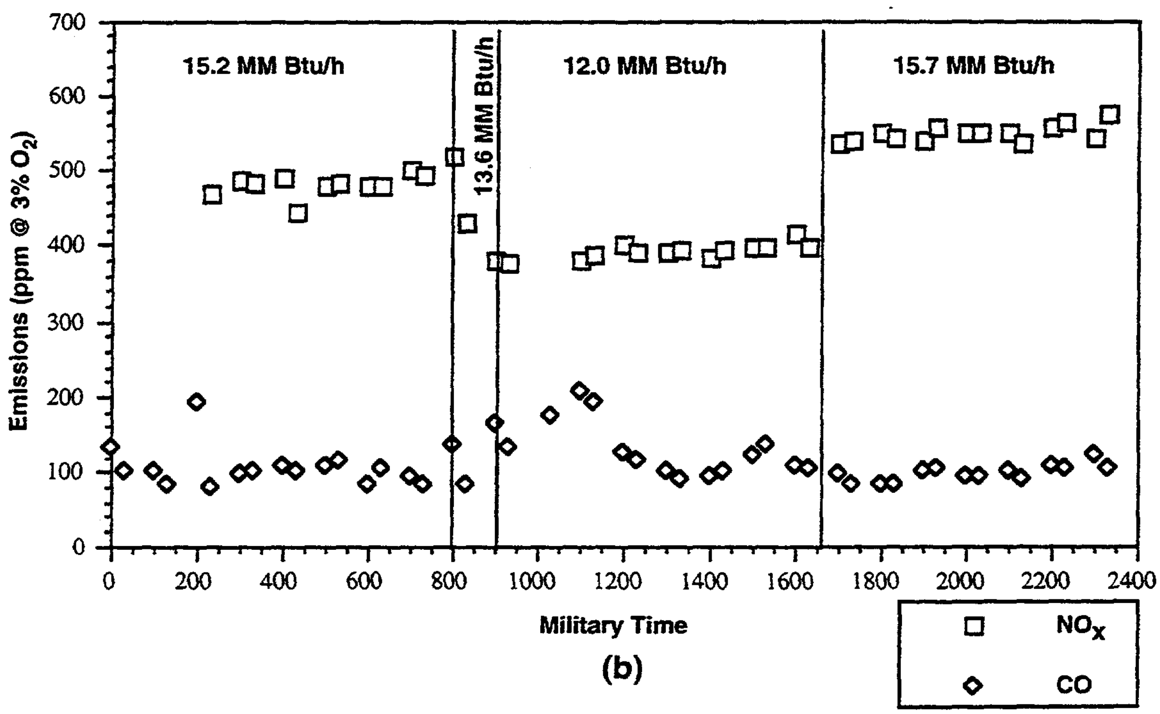


(b)

Figure D-57. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 02/12/96 WITH DAMPER SETTINGS OF 100/100/50/0, 375 TO 405 ACFM MILL AIR FLOW, AND A FIRING RATE OF 15.2 MM Btu/h

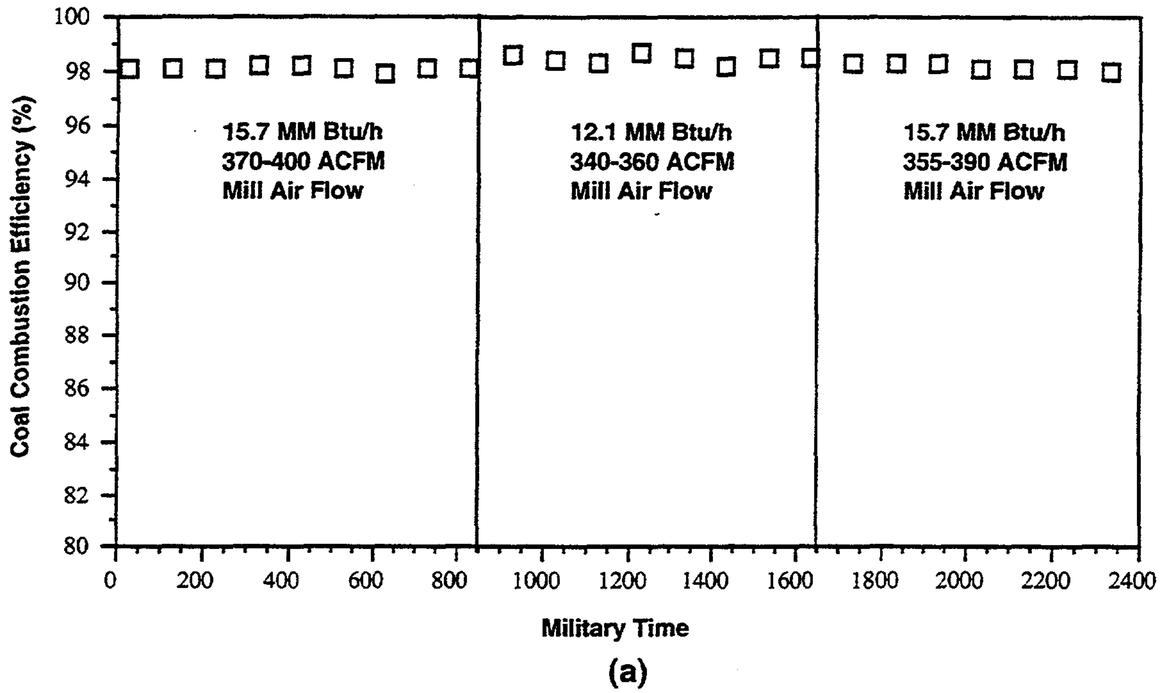


(a)



(b)

Figure D-58. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 02/13/96 WITH DAMPER SETTINGS OF 100/100/50/0, 365 TO 390 ACFM MILL AIR FLOW AND FIRING RATES OF 15.2, 13.6, 12.0, AND 15.7 MM Btu/h



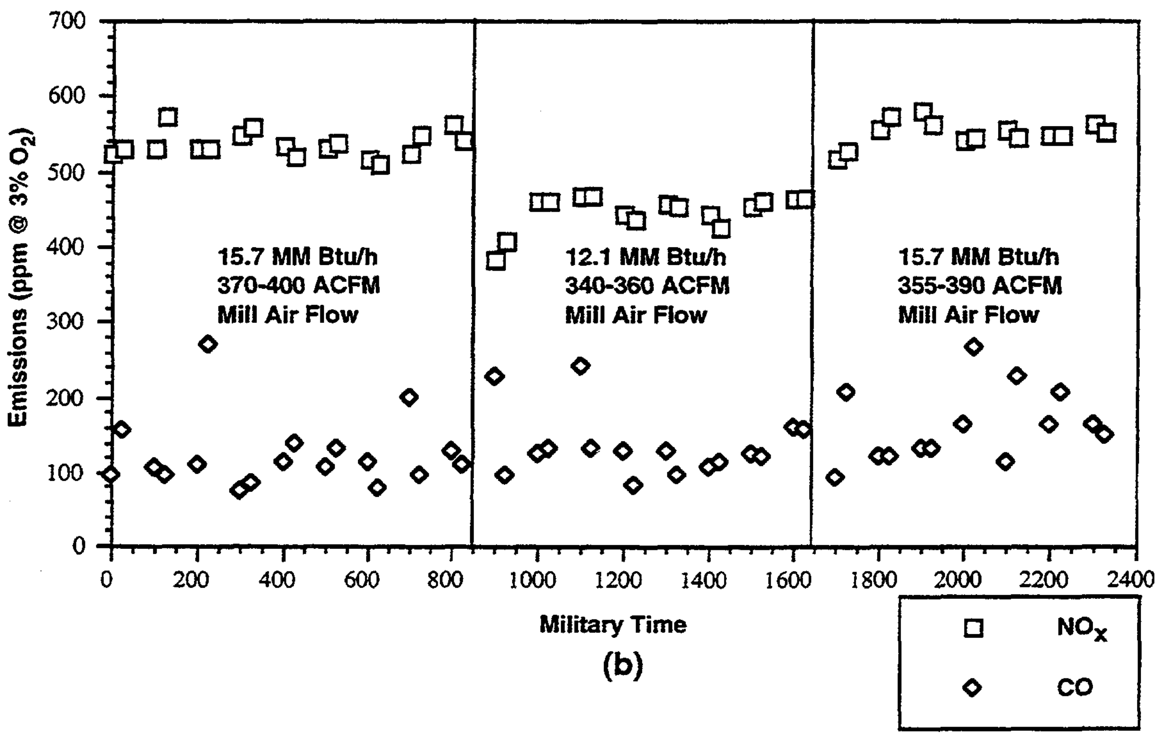


Figure D-59. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 02/14/96 WITH DAMPER SETTINGS OF 100/100/50/0 AND FIRING RATES OF 15.7 AND 12.1 MM Btu/h

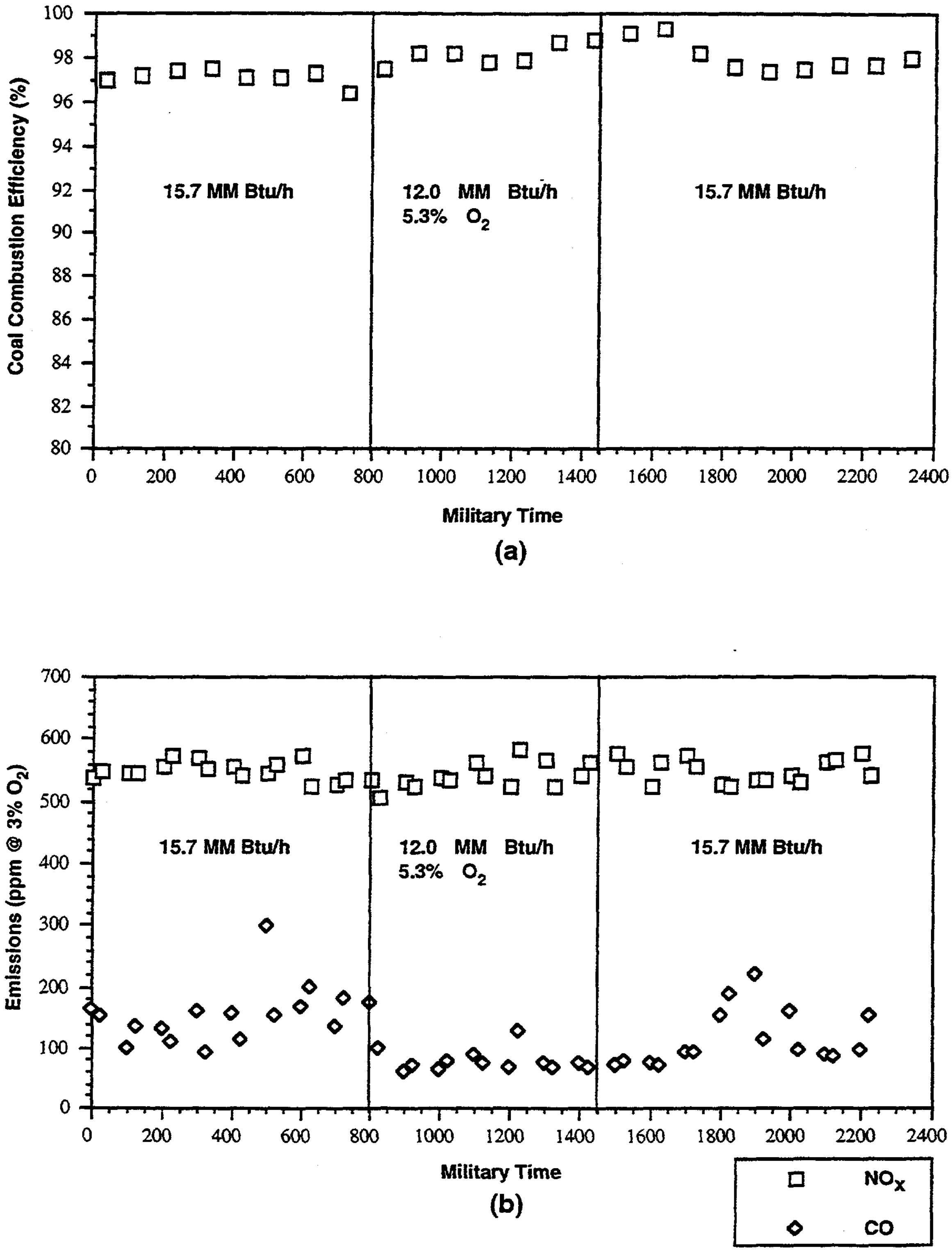


Figure D-60. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 02/15/96 WITH DAMPER SETTINGS OF 100/100/50/0, 350 TO 390 ACFM MILL AIR FLOW, AND FIRING RATES OF 12.0 AND ~15.6 MM Btu/h

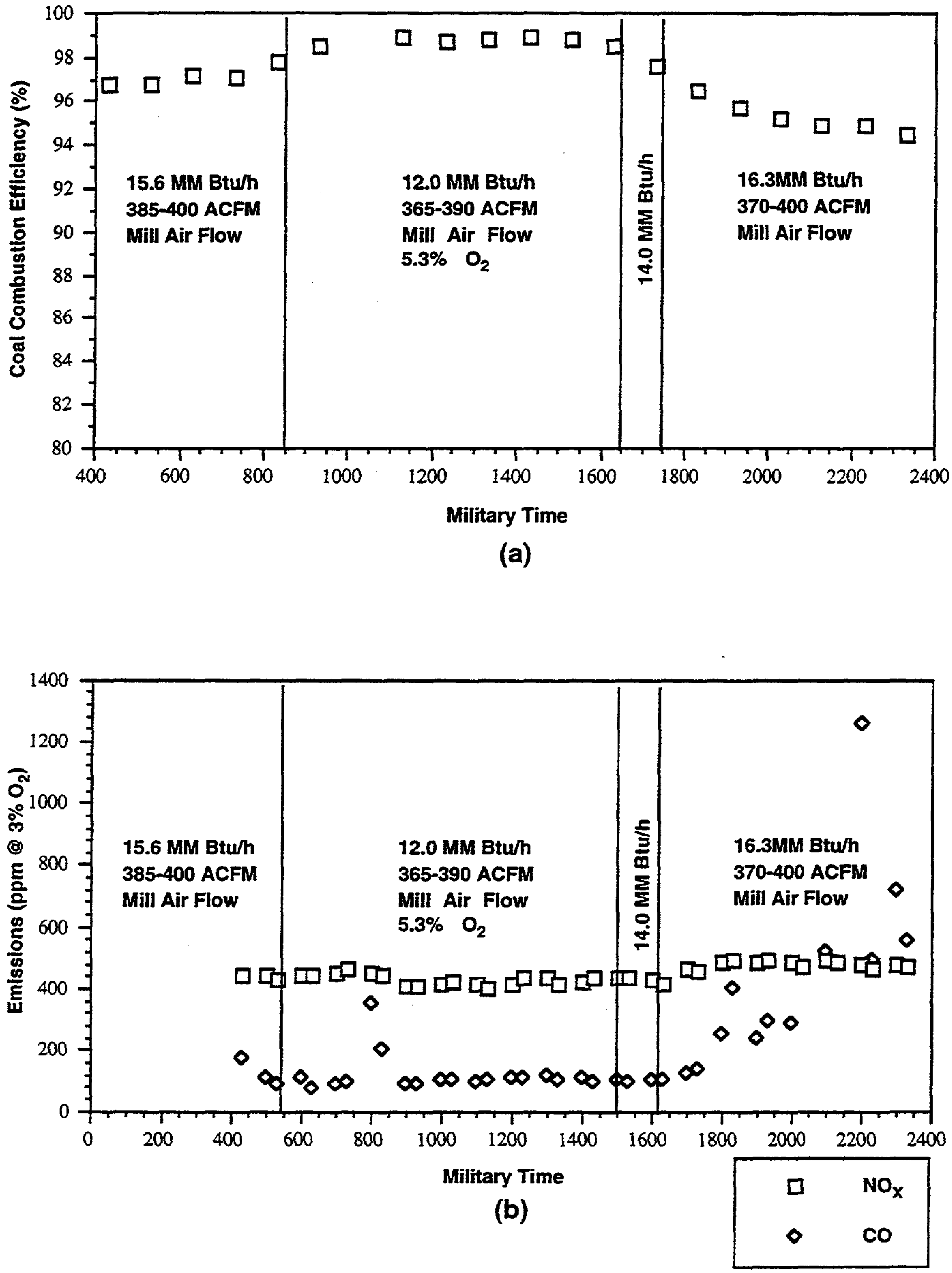


Figure D-61. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 02/16/96 WITH DAMPER SETTINGS OF 100/100/50/0 AND FIRING RATES OF 12.0, 14.0, 15.6, AND 16.3 MM Btu/h

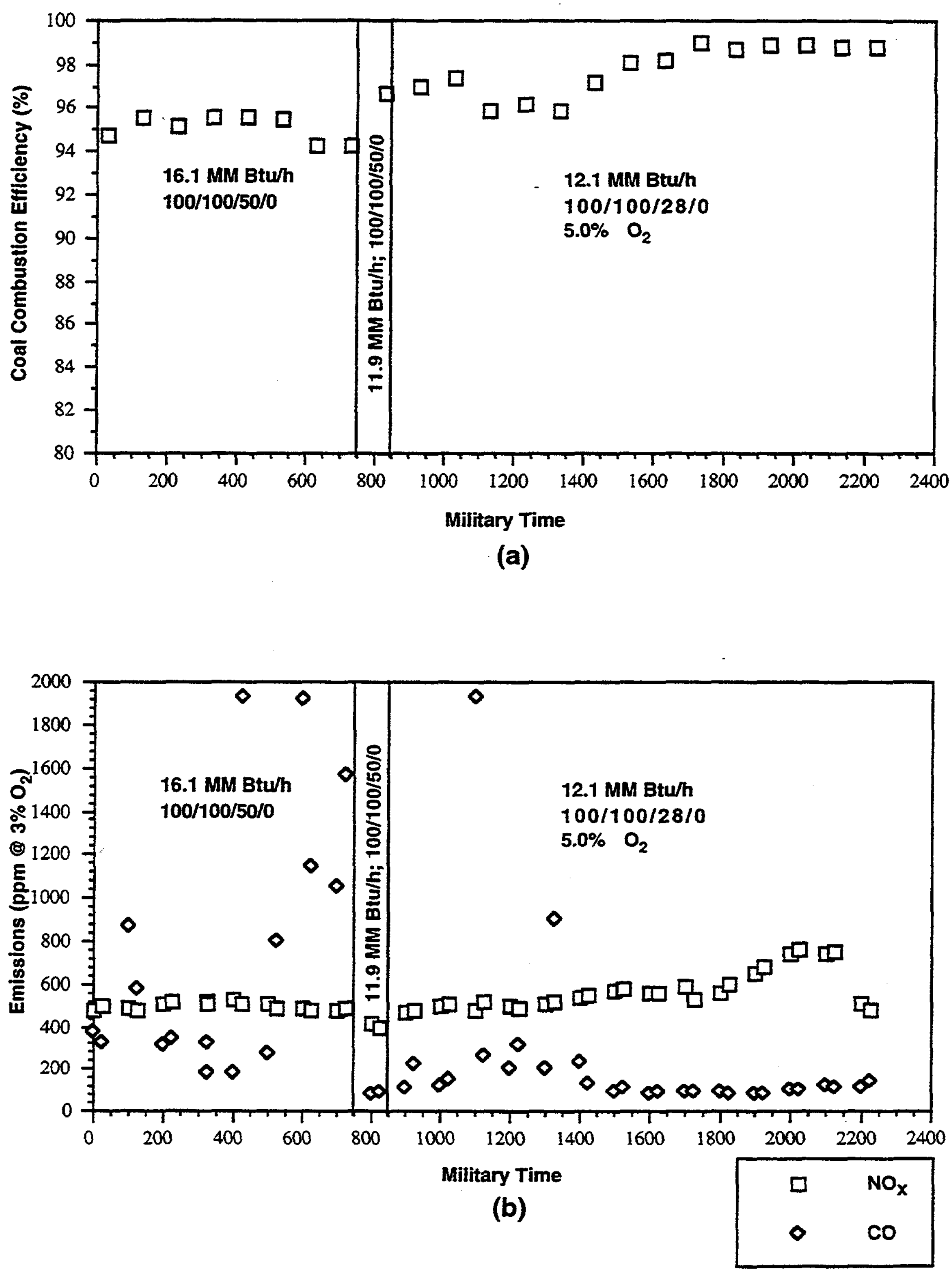


Figure D-62. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 02/17/96 WITH 370 TO 400 ACFM MILL AIR FLOW AND FIRING RATES OF ~12.0 AND 16.1 MM Btu/h

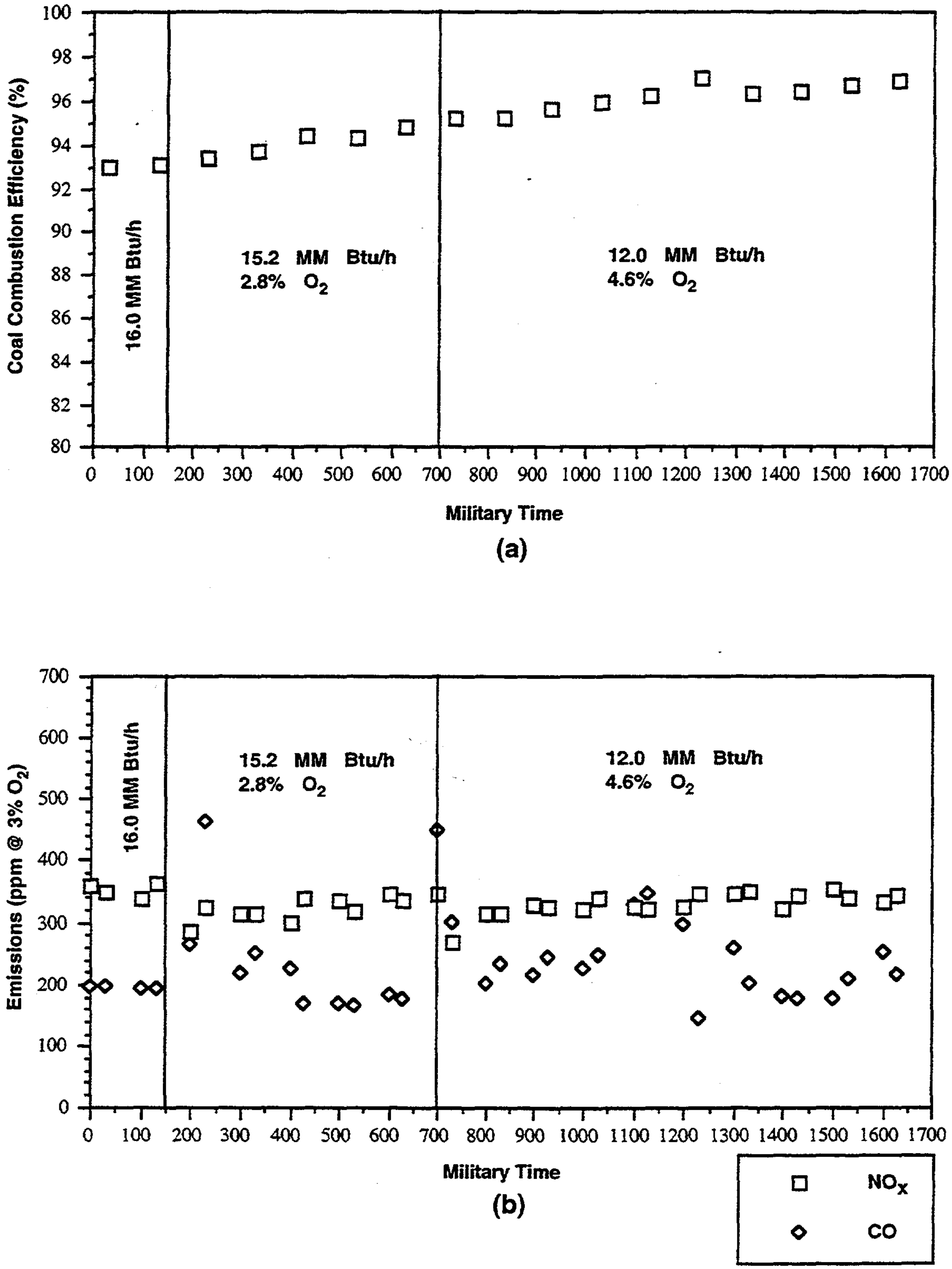


Figure D-63. COAL COMBUSTION EFFICIENCY (a) AND EMISSIONS (b) AS A FUNCTION OF TIME FOR THE TESTING ON 02/19/96 WITH DAMPER SETTINGS OF 100/100/28/0, 350 TO 400 ACFM MILL AIR FLOW, AND FIRING RATES OF 12.0, 15.2, AND 16.0 MM Btu/h