GEORGETOWN UNIVERSITY
ATMOSPHERIC FLUIDIZED BED BOILER
COGENERATION SYSTEM

Received by OSTI

OCT 15 1991

Final Report on Cogeneration Operation

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Washington, DC 20057

August 1991

Prepared for

THE U. S. DEPARTMENT OF ENERGY
AGREEMENT NO. DE-AC02-77CS20068

MASTER

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**GEORGETOWN UNIVERSITY
ATMOSPHERIC FLUIDIZED BED BOILER
COGENERATION SYSTEM**

FINAL REPORT ON COGENERATION OPERATION

BACKGROUND

This report presents the results of one year of operation of the cogeneration system capability of the Georgetown University coal-fired, atmospheric fluidized-bed (AFB) boiler. The cogeneration capability was designed and installed under contract DE-AC02-77CS20068 with the U.S. Department of Energy.

The AFB was designed and installed under a separate contract with the U. S. Department of Energy. The AFB project was funded by DOE to demonstrate that high sulfur coal could be burned in an environmentally acceptable manner in a urban environment such as Georgetown. In addition, operational data from the unit would assist the industry in moving directly into design and construction of commercially warranted industrial size AFB boilers. The boiler began operation in July, 1979. The AFB was designed to generate 100,000 pounds per hour of saturated steam at an operating pressure of either 275 or 625 pounds per square inch (psig). The higher operating pressure capability was installed to accommodate future installation of a back-pressure cogeneration system.

In October, 1982, the U. S Department of Energy provided the authorization to proceed with the final design, construction, testing and one year demonstration of the cogeneration system. A building addition to house the cogenerator was constructed adjacent to the AFB (refer to aerial view of campus, figure 1). Construction was completed in March, 1984. Concurrently with construction, a separate contract was awarded to Mechanical Technology Incorporated, and its subsidiary Turbonectics Energy Inc., to design and install the cogeneration system. The cogeneration facility was turned over to Georgetown in January, 1985. Only limited testing of the unit was accomplished because of problems with the AFB. What testing was done was accomplished by using 270 psi steam from the plant gas boilers.

During the period of construction of the cogeneration system, severe tube erosion became a significant problem in the AFB. Argonne National Laboratories personnel assisted Georgetown University in analyzing the erosion problems and developing solutions. In October 1985, major modifications of the AFB were undertaken through a cooperative agreement with the U.S. Department of Energy to correct the erosion

Figure 1. Aerial View of Georgetown University

problem. The modifications, which encompassed the replacement of the entire convective tube section of the boiler, were completed in early 1986 and the boiler resumed operation in July, 1986.

During the period between January, 1985 - July 1986, the cogeneration system was inoperative. In preparation for placing the cogenerator in service in the latter part of 1986, the turbines were disassembled and inspected. Some corrosion of the turbine rotors was detected, apparently from condensation of plant steam that had backed into the unit through leaking isolation valves during the extended lay-up period, which necessitated removal and rework of the rotors by Turbonectics in Latham, NY. The unit was reassembled in late 1986 and startup operations began in December, 1986 using steam from the AFB. Because of a boiler feed pump failure, the cogenerator was operated on low pressure steam (270 psi) instead of the design pressure (625 psi). Several hundred hours of operation were recorded during December, 1986 and January, 1987 before taking the unit out of service to replace the boiler feed pump and a failed electrical feeder between the plant and the utility connection point. The cogenerator was operated only sporadically during 1987 and early 1988 and then only on reduced pressure steam. It was not until the summer of 1988 that the cogenerator and the AFB were ready together to attempt nominal 600 psi operation.

COGENERATOR SYSTEM DESCRIPTION

A schematic diagram of the installed cogeneration system is depicted in Figure 2.

The synchronous generator package supplied by Turbonectics Inc. is illustrated in Figure 3. The turbine is a high-efficiency, 4026-hp rated, unit with a two-stage radial inflow steam turbine design for normal inlet steam conditions of 625 psig, 493 degree F, dry and saturated, and exhaust pressures of 275 psig and/ or 90 psig. The first stage turbine wheel operates at 31,148 rpm and the second stage at 24,659 rpm. Maximum inlet steam flow is 100,000 lb/h. Each turbine wheel is assembled on a separate pinion which meshes with a single reduction, integral gear to reduce the turbine output shaft speed to 3642 rpm. The turbine is a 50% reaction design utilizing variable angle nozzles on the first stage, with fixed nozzles on the second stage (refer to Figure 4).

The alternating current synchronous generator is rated 2845 KW, 4160 volts, 3556 KVA, horizontal, 3-phase, 60 Hz, 1800 rpm, wye-wound.

The cogenerator is grid-connected with the local utility company, Potomac Electric Power Company (PEPCO), operating in parallel, on one of three electrical feeders servicing the plant. A dry type step-up transformer, 4160V delta to 13.8KV delta, 3500 KVA rated, was incorporated in the system to meet the protection requirements imposed by PEPCO. The original design specified a 13.8KV generator. In addition, a transfer trip activated through a dedicated telephone line was installed at the request of PEPCO to permit the utility to take the cogenerator off line in event of a ground fault on the utility feeder serving the campus.

Figure 2

Figure 3

The design performance curves for both winter and summer operation are shown in Figure 5. In the winter operation the 625 psi steam is passed through both stages and exhausted at 90 psi to meet campus heating requirements. In the summer mode, most of the steam is extracted at 275 psi to run turbine chillers.

PLANT INFORMATION SYSTEM

A computer-based system was installed in the central heating and cooling plant in 1986-87 to monitor AFB and cogenerator operations as well as other plant boilers and equipment (see Figure 6). Locations of the monitored points on the AFB and the cogenerator are shown on Figures 7 and 8. Tables 1 and 2 provide an explanation of the various points.

The monitoring system samples the field points and performs engineering calculations every minute. The data is totaled or averaged in half hour intervals and stored in the computer database. Daily and monthly reports summarizing operations are compiled. An example of the monthly operating report on the AFB and the cogenerator is included in Appendix A.

A separate stand-alone PC system was installed in 1986 to monitor AFB stack opacity and SO₂ and NO_x emissions. The system was designed and installed by Lear Sigler. Samples of the reports generated on a daily basis are included in Appendix B.

COGENERATION SYSTEM OPERATION

As previously indicated, erosion problems with the AFB and other circumstances delayed any significant operation of the cogeneration system until 1987. In addition, the AFB is not operated continuously during any given year because of periods of low steam demand, primarily in the spring and the fall. Therefore, it has not been possible to generate a full one year operation of the cogenerator. The period covered by this report, July through September, 1988 and January through March, 1989 generated the most comprehensive operating data compiled on the cogenerator.

Operating and cost performance data on the AFB and cogenerator for the six months are shown in Table 3. During these six months, the AFB operated for 3,644 hours and the cogenerator, 1,794 hours. More than 778,000 kwh were produced by the cogenerator resulting in a net saving of \$13,240 for the period. The average output per hour of the cogenerator for the period was 434 kw. Due to operational problems, this output is well below the rated capability of the cogenerator, which adversely affected the savings.

New problems with the cogenerator surfaced during the period when the inlet steam pressure was raised above 400 psi. The steam flow throttling and control system on the cogenerator was unable to control the position of the inlet nozzles at the proper

Cogeneration Design Performance Curves

Figure 5

FIGURE 6

Figure 7. Cogenerator Monitor Points

FIGURE 8 FBB MONITORING POINTS

TABLE 1 FBB Monitored Points

<u>Physical Point</u>	<u>Description</u>
FE101	Supply steam orifice flow meter
FE102	Feed water orifice flow meter
FE103	Bed A coal feed
FE104	Bed A lime feed
FE105	Bed B coal feed
FE106	Bed B lime feed
FE107	Bed A air flow
FE108	Bed B air flow
PE101	Supply steam pressure
TE101	Supply steam temperature
TE102	Feed water temperature
TE103	Average bed A temperature
TE104	Average bed B temperature

Table 2 Cogenerator Monitored Points

<u>Physical Point</u>	<u>Description</u>
EE101	Generator KW
EE102	Generator KVAR
FE201	Supply steam orifice flow meter
FE202	Summer extract orifice flow meter
PE201	First stage inlet pressure
PE202	First stage exhaust pressure
PE203	Second stage exhaust pressure
PE204	Second stage nozzle inlet pressure
PE205	Second stage nozzle outlet pressure
TE201	First stage inlet temperature
TE202	First stage exhaust temperature
TE203	Second stage exhaust temperature

TABLE 3
AFB AND COGENERATION
OPERATIONS
07/88 - 03/89

A. FLUIDIZED BED OPERATING DATA	07/88	08/88	09/88	01/89	02/89	03/89	TOTALS
HOURS OPERATED	601.00	603.05	671.50	539.60	671.72	557.28	3,644.15
COAL USED (TONS)	1,184.70	2,047.89	2,271.21	1,547.50	2,059.08	1,766.18	10,876.56
LIMESTONE USED (TONS)	581.70	680.87	787.32	560.73	817.11	725.17	4,152.90
FUEL OIL (GALLONS)		800.00		2,500.00		400.00	3,700.00
ELECTRICAL CONSUMPTION (KWH)	415,371.60	413,708.25	464,006.59	381,431.91	464,130.49	385,060.43	2,523,709.27
MAKE-UP (GALLONS)	360,651.87	513,293.84	1,080,187.86	1,195,499.47	1,806,682.45	1,380,955.86	6,337,271.35
FLY ASH (TONS)	813.01	953.21	1,102.24	785.02	1,143.95	1,015.24	5,812.67
STEAM PRODUCED (KLBS)	25,983.94	44,631.00	49,479.83	33,709.26	45,295.47	38,817.86	237,917.36
STEAM ENERGY (MBTU)	31,240.59	53,688.55	59,565.87	40,532.15	54,493.73	46,678.43	286,199.32
B. COGENERATOR OPERATING DATA							
HOURS OPERATED	121.50	249.88	504.58	507.60	395.10	15.38	1,794.04
KWH PRODUCED	50,815.33	165,389.41	293,842.81	95,872.27	157,101.40	15,068.27	778,089.49
AVERAGE KW	418.23	661.88	582.35	188.87	397.62	979.73	433.71
MODE	SUMMER	SUMMER	SUMMER	WINTER	WINTER	WINTER	COMBINED
HEAT CHARGE (MBTU)	580.59	1,891.10	3,577.38	1,736.99	1,787.16	171.19	9,744.39
C. FBB OPERATING COSTS (INCLUDING COGENERATION)							
FBB MATERIALS	\$ 6,126.95	\$ 3,984.36	\$ 5,865.41	\$ 6,556.15	\$ 483.97	\$ 0.00	\$ 23,016.84
COGENERATION MATERIALS	4,462.00	0.00	0.00	0.00	478.00	0.00	4,940.00
FBB MANHOURS	0.00	0.00	0.00	5,297.42	4,636.10	3,191.73	13,125.25
COGENERATION MANHOURS	0.00	0.00	0.00	797.31	912.98	579.27	2,289.56
FUEL OIL	0.00	456.40	0.00	1,461.00	0.00	232.56	2,149.96
FLYASH	7,317.09	8,578.89	9,920.16	5,495.14	8,007.65	7,106.68	46,425.61
MAKEUP	1,380.09	1,964.20	4,133.52	4,571.59	6,908.75	5,280.78	24,238.94
LIMESTONE	11,634.00	13,617.40	15,746.40	11,214.60	16,342.20	14,503.40	83,058.00
COAL	62,492.93	108,026.20	119,806.33	81,630.63	108,616.47	93,166.00	573,738.54
ELECTRICITY	24,673.07	25,691.28	30,670.84	14,418.13	19,493.48	16,249.55	131,196.35
TOTAL OPERATING COSTS	\$118,086.13	\$162,318.73	\$186,142.65	\$131,441.96	\$165,879.60	\$140,309.96	\$904,179.04
COST/MBTU	3.78	3.02	3.12	3.24	3.04	3.01	3.16
D. COGENERATION OPERATING COSTS (INCLUDED IN C. ABOVE)							
COGENERATION MATERIALS	\$ 4,462.00	\$ 0.00	\$ 0.00	\$ 0.00	\$ 478.00	\$ 0.00	\$ 4,940.00
COGENERATION MANHOURS	0.00	0.00	0.00	797.31	912.98	579.27	2,289.56
MAKEUP	25.65	69.19	248.25	195.91	226.58	19.37	784.94
LIMESTONE	216.21	479.65	945.69	480.60	535.95	53.19	2,711.29
COAL	1,161.40	3,805.06	7,195.27	3,498.24	3,562.14	341.68	19,563.79
COST OF COGENERATION	\$ 5,865.26	\$ 4,353.90	\$ 8,389.21	\$ 4,972.06	\$ 5,715.65	\$ 993.50	\$ 30,289.58
ELECTRICITY GENERATED	3,018.43	10,270.68	19,423.01	3,623.97	6,598.26	635.88	43,570.23
NET SAVINGS COGENERATION	\$ (2,846.82)	\$ 5,916.78	\$ 11,033.80	\$ (1,348.09)	\$ 882.60	\$ (357.62)	\$ 13,280.65

on the cogenerator was unable to control the position of the inlet nozzles at the proper angle. The higher flow rates reflected in August and September were achieved by manually opening the governor and controlling the back pressure by another boiler. In addition, problems were encountered with the feedwater booster pump on the AFB which is used to boost the pressure to approximately 900 psi for 625 psi operation. Georgetown University is continuing to work with the manufacturer, Turbonetics, to correct the throttling and control system problems. A new boiler feedwater pump will be required to achieve operation at pressures above 400 psi.

A performance curve based on the six months of operation is shown in Figure 9. The curve correlates reasonably well with the design performance curves shown in Figure 5. However, because of the operational problems experienced and the low output achieved, performance at higher and more efficient levels of operation was not achievable.

The interface with the utility company has worked without any problems. However, as the cogeneration output rarely exceeds the electrical load on the feeder, there has been only limited export to the utility.

SUMMARY AND CONCLUSIONS

The AFB boiler system was designed to operate at 625 psig so it could serve as the steam source for the future backpressure steam turbine cogenerator. From its startup in 1979 and until the cogenerator was operating, the AFB boiler had no load for operation above 275 psi. When the cogenerator installation was completed in January, 1985, empirically derived solutions for dealing with AFB tube erosion had not been fully resolved and the boiler was not available for 625 psi service, so comprehensive shakedown and performance testing of the cogenerator were foregone.

The cogenerator, after limited initial testing with 270 psi steam, was laid up for an expected short but indeterminate period pending full availability of the AFB. The extensive scope of subsequent AFB modifications delayed its availability until July 1986. At that time, the cogenerator turbine was opened for inspection in preparation for service, and the rotor blade corrosion was discovered, apparently from condensation of plant steam that had backed into the unit through leaking isolation valves. Corrective machining of the rotors delayed concurrent availability of the cogenerator and AFB to December 1986.

Almost two months of operation took place at steam pressures ranging from 300 to 600 psi before other problems developed to preclude all but sporadic elevated pressure operation until the summer of 1988. The most prolonged outages during the period resulted from failure and replacement of the primary electric service cables and the main feedwater pump serving the AFB. The pump failure, a ruptured case, resulted from an underspecified operating pressure not manifested until sustained elevated pressure operations were instituted.

Figure 9

The foregoing illustrates the difficulties in achieving initial operating capability of two interdependent systems each requiring the other to verify performance. Even with technical problems solved, the use of the AFB/cogenerator system is greatly influenced by load characteristics and fuel economics. The system typically cannot be run at least two months in each the late fall and early spring when neither space heating nor air conditioning is imposing sufficient steam load. In the summer, when electricity is premium priced, cogenerator production is limited to that of the first stage because most steam is extracted at 270 psi for air conditioning. In winter, when space heating demand is greatest, the backpressure must be raised to 125 psi to provide adequate flow and residual pressure at campus buildings, thus reducing turbine power.

The University's steam demand varies between 30,000 and 130,000 pph and can be satisfied by any two, often one, of its three 100,000 pph boilers. Though coal is economically and stably priced, it must be hauled almost 200 miles by truck to Georgetown and entails the use of limestone and disposal of ash from the AFB. Those commodities and the 800 KW differential of electric consumption generally still yield a favorable cost of steam production by the AFB in winter when gas or #6 oil used in the other two boilers is seasonably high priced. But in the non-heating season, gas and oil may have a lower equivalent price (as they do in summer 1991), and at other times, AFB operation may be advantageous only if the cogenerator compensates for its additional electrical demand.

In summary, the cogenerator system and its operations are completely interdependent with the AFB. Its installation was conceived at a time when dire predictions were commonplace for runaway pricing on fuel oil and consequent matching escalation for domestic natural gas. The relative stability of domestic coal pricing gives the AFB and cogenerator system status as a long term hedge against excessive oil and gas pricing. Despite the back and forth fits and starts to achieve initial concurrent operation of the systems, they have been shaken down to where they provide reliable service when called upon. The cogenerator system in particular is a relatively compact and trouble free installation that has demonstrated the feasibility of applying new technology machinery in an institutional setting. University plant personnel now operate the unit with confidence, and in an era of dwindling utility system reserve, the cogenerator constitutes a contingency asset of increasing value.

APPENDIX A

SAMPLE OF AFB/COGENERATOR MONTHLY OPERATING REPORT

FBB INPUT

RUNTIME..... (HOURS)	COAL..... (TONS)	LIMESTONE..... (TONS)	OIL..... (GALLONS)	ELECTRICITY..... (KWH)	MAKE-UP..... (GALLONS)
671.7167	2059.0837	817.1133	0	464130.4922	1806682.4534
(1)	(2)	(3)	(4)	(5)	(6)

FBB OUTPUT

FLY ASH..... (TONS)	STEAM PRODUCED..... (KLBS)	STEAM ENERGY..... (MBTU)	APPARENT HHV..... (BTU/LB.)	THERMAL EFFICIENCY..	OVERALL EFFICIENCY....
1143.9586	45295.4786	54493.7286	13232.519	76.4032	74.2906
(7)	(8)	(9)	(10)	(11)	(12)

COGENERATOR

TURBINE RUNTIME..... (HOURS)	HEATCHARGE..... (MBTU)	GENERATOR RUNTIME... (HOURS)	ELECTRICITY PROD.... (KWH)	MODE.....	EFFICIENCY.....
517.6167	1787.1559	395.1	157101.4008	WINTER	30.0023
(13)	(14)	(15)	(16)	(17)	(18)

PRICING

AVE. KWH..... (\$/KWH)	COAL..... (\$/TON)	LIMESTONE..... (\$/TON)	ASH REMOVAL..... (\$/TON)	FUEL OIL..... (\$/gallon)	WATER..... (\$/100 cu. ft.)
.042	52.75	20	7	.5814	2.868
(19)	(20)	(21)	(22)	(23)	(24)

MATERIALS AND MAN-HOURS

FBB MATERIALS	FBB MAN HOURS	COGEN MATERIALS	COGEN MAN HOURS
\$483.97	\$4,636.10	\$478.00	\$912.98
(25)	(26)	(27)	(28)

COST ASSESSMENT WIHTOUT CO-GEN

COAL, LIME, ASH, OIL .. (\$/MBTU)	PLUS ELECTRICITY.... (\$/MBTU)	PLUS MAKEUP..... (\$/MBTU)	PLUS MATERIALS..... (\$/MBTU)	PLUS MAN HOURS..... (\$/MBTU)
2.44	2.7981	2.9253	2.9341	3.0192
(29)	(30)	(31)	(32)	(33)

COST ASSESSMENT WITH CO-GEN

COAL, LIME, ASH, OIL .. (\$/MBTU)	PLUS ELECTRICITY.... (\$/MBTU)	PLUS MAKEUP..... (\$/MBTU)	PLUS MATERIALS..... (\$/MBTU)	PLUS MAN HOURS..... (\$/MBTU)
2.5228	2.7677	2.8991	2.9174	3.0226
(34)	(35)	(36)	(37)	(38)

FBB Monthly Cost Analysis Description

- (1) Totalized virtual point. In real time the FBB status is determined by basically from steam differential (FE101).
- (2) Totalized coal consumption (FE103 and FE105).
- (3) Totalized lime consumption (FE104 and FE106).
- (4) Manual entry
- (5) Totalized calculated value. All of the plant feeders are totalized. Since the FBB feeders serve some other major equipment auxiliaries, in real time, FBB electrical consumption is assessed by normalization.
- (6) Calculated value. The meter which serves the three boilers is totalized. As the report generated, the make-up is normalized among the three via their run time and steam output.
- (7) Calculated value which is the product of item (3) and the constant (1.4).
- (8) Totalized calculated value. In real time, steam flow is calculated by each sampled steam differential pressure (FE101) and compensated by the pressure (PE101) and temperature (TE101).
- (9) Totalized calculated value. In real time, based on pressure (PE101), the enthalpy is looked up from the steam table and then multiplied by the steam flow.
- (10) Calculated value which is the ratio of steam energy (item 9) to the energy input (the product of total coal input and HHV of coal which is 13527 BTU/lb)
- (11) Calculated value which is the ratio of the difference of steam energy (item 9) and the feed water energy; to the coal energy input.
- (12) Calculated value. Electrical energy input is included in the above calculation of item (11).
- (13) Totalized virtual point. In real time, turbine status is determined basically from steam differential pressure (FE201).

- (14) Totalized virtual point. In real time, enthalpies are looked up and total steam energy consumed is calculated.
- (15) Totalized virtual point. In real time, the generator status is basically determined from the electrical transducer (EE201).
- (16) Totalized electrical consumption (EE201).
- (17) Totalized virtual point. In real time, the mode is determined by the second stage steam extract differential (FE202).
- (18) Calculated value. It is the ratio of the electrical output (item 16) to the energy input (item 14).
- (19) Calculated value. It is the ratio of campus electrical bill to the campus electrical consumption.
- (20) through (24) are manual entries for that month.
- (25) Total materials charged against FBB for that month from the Purchasing System.
- (26) Total maintenance man-hour cost charged against FBB for that month from the Work Order System.
- (27) Total materials charged against cogenerator for that month from the Purchasing System.
- (28) Total maintenance man-hour cost charged against cogenerator for that month from the Work Order System.
- (29) Calculated value. It is the ratio of total fuel (coal, lime, ash and oil) cost to the steam energy produced by FBB (item 9).
- (30) Calculated value. The FBB electrical consumption cost is included to the above unit cost calculation of item (29).
- (31) Calculated value. The make up consumption cost is included to the above unit cost calculation of item (30).
- (32) Calculated value. The materials cost charged to FBB is included to the above unit cost calculation of item (31).
- (33) Calculated value. The maintenance man hour cost charged to FBB is included to the above unit cost calculation of item (32).

- (34) Calculated value. It is the ratio of total fuel cost to the difference of steam energy produced by FBB (item 9) and energy consumed by the cogenerator (item 14).
- (35) Calculated value. The net electrical (difference between item 5 and item 16) consumption cost is included to the above unit cost calculation of item (34).
- (36) Calculated value. The make up consumption cost is included to the above unit cost calculation of item (35).
- (37) Calculated value. The materials cost charged to FBB and cogenerator is included to the above unit cost calculation of item (36).
- (38) Calculated value. The maintenance man hour cost charged to FBB and cogenerator is included to the above unit cost calculation of item (37).

APPENDIX B

SAMPLES OF AFB EMISSIONS REPORT

OPACITY EMISSIONS MEASUREMENT SUMMARY FOR UNIT #1

REPORTING PERIOD
 BEGINS: 0000 2/11/88
 ENDS: 2400 2/11/88

GEORGETOWN UNIVERSITY
 WASHINGTON, D.C.

LIMIT, 6-MIN AVG = 20.0%
 HOUR EXCL. LIMIT = 27.0%
 ? (?? DATA) # (SHORT SAMP)
 * (VIOLATION)

HOUR	I	PERIOD ENDING AT :MM	I	LAST	LAST
		: 6 :12 :18 :24 :30 :36 :42 :48 :54 :60		ZERO	SPAN
0	I	.6 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4	I	.0	27.1
1	I	.4 .4 .3 .3 .3 .3 .3 .3 .3 .4	I	.0	27.1
2	I	.4 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4	I	.0	27.1
3	I	.5 .5 .5 .5 .5 .5 .4 .4 .4 .4 .4	I	.0	27.1
4	I	.4 .4 .3 .4 .4 .4 .3 .3 .3 .3 .3	I	.0	27.1
5	I	.4 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4	I	.0	27.1
6	I	.4 .4 .4 .5 .5 .5? .5 .5 .5 .4	I	.0	27.1
7	I	.4 .4 .4 .5 .5 .5 CM .5 .5 .6 .6	I	.0	27.1
8	I	.5 .5? .5? .4? .3? .3? .3? .3? .3? .4?	I	.0	27.1
9	I	.4 .4 M .4 M .4 M .5 M .5 M .5 M .5 M .5 M	I	.0	27.1
10	I	.5 .5 .5 .5 .5 .5 .4 .3 .3 .3 .3	I	.0	27.1
11	I	.3 .3 .3 .3 .3 .3 .3 .4 .4 .4 .4	I	.0	27.1
12	I	.4 .4 .4 .4 .4 .5 .5 .5 .5 .4 .4	I	.0	27.1
13	I	.4 .4 .4 .4 .4 .4 .4 .5 .5 .6 .6	I	.0	27.1
14	I	.5 .5 .5 .5 .4 .4 .4 .4 .4 .4 .4	I	.0	27.1
15	I	.4 .4 .4 .4 .4 .4 .4 .4 .4 .4 .3	I	.0	27.1
16	I	.3 .3 .3 .3 .3 .3 .4 .4 .4 .4 .4	I	.0	27.1
17	I	.4 .5 .5 .5 .5 .4 .4 .4 .4 .4 .4	I	.0	27.1
18	I	.5 .5 .5 .4 .4 .4 .4 .4 .4 .4 .4	I	.0	27.1
19	I	.5 .5 .5 .5 .5 .5 .5 .4 .3 .3 .3	I	.0	27.1
20	I	.3 .3 .3 .3 .3 .3 .3 .3 .3 .3 .3	I	.0	27.1
21	I	.3 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4	I	.0	27.1
22	I	.4 .4 .4 .5 .5 .5 .4 .4 .4 .4 .4	I	.0	27.1
23	I	.4 .4 .4 .4 .4 .4 .4 .4 .4 .4 .4	I	.0	27.1

NUMBER OF 6-MIN OPACITY VIOLATIONS = 0
 OUT OF SERVICE HRS:MIN = 0: 0
 LAST SYSTEM INITIALIZATION 9:21:56 6/30/91

SO2 EMISSIONS MEASUREMENT SUMMARY FOR UNIT #1

REPORTING PERIOD
 BEGINS: 0000 2/11/88
 ENDS: 2400 2/11/88

GEORGETOWN UNIVERSITY
 WASHINGTON, D.C.

LIMIT, 3-HR = .8 LBS/MBTU
 # FLAG (SHORT SAMPLE)
 ? FLAG (?? DATA)
 * FLAG (VIOLATION)

HOUR	SO2 3-HR	RC	SULFUR DIOXIDE					I	% O2	OXYGEN			I	FW	BWA	TEMP	% LOSS
			SO2 #/MBTU	SO2 PPM	LAST ZERO	LAST SPAN	LAST ZERO			LAST SPAN	LAST ZERO	LAST SPAN					
22			.57	216	0	197	I	6.4	14.4	18.5	I	10680	2.7	329	2.3		
23			.51	190	0	197	I	6.6	14.4	18.5	I	10680	2.7	329	2.4		
0	.53		.51	189	0	197	I	6.7	14.4	18.5	I	10680	2.7	328	2.5		
1	.53		.57	214	0	197	I	6.5	14.4	18.5	I	10680	2.7	326	2.3		
2	.56		.61	227	0	197	I	6.5	14.4	18.5	I	10680	2.7	327	2.3		
3	.59		.60	225	0	197	I	6.5	14.4	18.5	I	10680	2.7	327	2.3		
4	.62		.64	240	0	197	I	6.4	14.4	18.5	I	10680	2.7	326	2.3		
5	.62		.62	230	0	197	I	6.6	14.4	18.5	I	10680	2.7	329	2.4		
6	.64		.66	247	C	197	I	6.5	C	6.8	18.5	I	10680	2.7	334	2.4	
7	.65		.68	252		197	I	6.6		6.8	18.5	I	10680	2.7	341	2.5	
8	.73		.85	344	2	197	I	5.4	6.8	18.5	I	10680	2.7	344	1.9		
9	.69		.54	201	2	197	I	6.6	6.8	18.5	I	10680	2.7	344	2.6		
10	.63		.49	182	2	197	I	6.7	6.8	18.5	I	10680	2.7	347	2.6		
11	.54		.59	225	2	197	I	6.2	6.8	18.5	I	10680	2.7	343	2.3		
12	.50		.41	153	2	197	I	6.6	6.8	18.5	I	10680	2.7	338	2.5		
13	.46		.37	134	2	197	I	6.8	6.8	18.5	I	10680	2.7	333	2.6		
14	.38		.36	134	2	197	I	6.5	6.8	18.5	I	10680	2.7	332	2.4		
15	.37		.37	140	2	197	I	6.5	6.8	18.5	I	10680	2.7	327	2.3		
16	.39		.44	167	2	197	I	6.3	6.8	18.5	I	10680	2.7	324	2.2		
17	.41		.41	152	2	197	I	6.6	6.8	18.5	I	10680	2.7	328	2.4		
18	.46		.52	192	2	197	I	6.6	6.8	18.5	I	10680	2.7	330	2.4		
19	.49		.54	205	2	197	I	6.3	6.8	18.5	I	10680	2.7	337	2.3		
20	.53		.52	197	2	197	I	6.3	6.8	18.5	I	10680	2.7	331	2.3		
21	.51		.47	174	2	197	I	6.5	6.8	18.5	I	10680	2.7	329	2.4		
22	.47		.41	155	2	197	I	6.5	6.8	18.5	I	10680	2.7	328	2.4		
23	.42		.39	147	2	197	I	6.5	6.8	18.5	I	10680	2.7	328	2.4		

(0) SO2 ROLLING 3-HR VIOLATIONS

CONVERSION FACTORS: (FW)
 (CW) = PPM * 1.659 * 10EXP-7

OUT OF SERVICE HH:MM 0: 0

0: 0

LAST SYSTEM INITIALIZATION 9:21:56 6/30/91

NOX EMISSIONS MEASUREMENT SUMMARY FOR UNIT #1

REPORTING PERIOD
 BEGINS: 0000 2/11/88
 ENDS: 2400 2/11/88

GEORGETOWN UNIVERSITY
 WASHINGTON, D.C.

LIMIT, 3-HR = .7 LBS/MBTU
 # FLAG (SHORT SAMPLE)
 ? FLAG (?? DATA)
 * FLAG (VIOLATION)

HOUR	NOX 3-HR	RC	I	NOX #/MBTU	NITROGEN NO PPM	OXIDES LAST ZERO	LAST SPAN	I	% O2	OXYGEN LAST ZERO	LAST SPAN	I	FW	BWA	TEMP	% LOSS
22			I	.61	313	0	130	I	6.4	14.4	18.5	I	10680	2.7	329	2.3
23			I	.62	312	0	130	I	6.6	14.4	18.5	I	10680	2.7	329	2.4
0	.62		I	.63	312	0	130	I	6.7	14.4	18.5	I	10680	2.7	328	2.5
1	.62		I	.62	312	0	130	I	6.5	14.4	18.5	I	10680	2.7	326	2.3
2	.62		I	.62	312	0	130	I	6.5	14.4	18.5	I	10680	2.7	327	2.3
3	.62		I	.62	312	0	130	I	6.5	14.4	18.5	I	10680	2.7	327	2.3
4	.61		I	.61	312	0	130	I	6.4	14.4	18.5	I	10680	2.7	326	2.3
5	.62		I	.62	313	0	130	I	6.6	14.4	18.5	I	10680	2.7	329	2.4
6	.62		I	.62	316	C	3	130	I	6.5	18.5	I	10680	2.7	334	2.4
7	.63		I	.64	320	3	130	I	6.6	6.8	18.5	I	10680	2.7	341	2.5
8	.62		I	.61	331	3	130	I	5.4	6.8	18.5	I	10680	2.7	344	1.9
9	.63		I	.65	325	3	130	I	6.6	6.8	18.5	I	10680	2.7	344	2.6
10	.63		I	.65	325	3	130	I	6.7	6.8	18.5	I	10680	2.7	347	2.6
11	.64		I	.62	322	3	130	I	6.2	6.8	18.5	I	10680	2.7	343	2.3
12	.64		I	.64	321	3	130	I	6.6	6.8	18.5	I	10680	2.7	338	2.5
13	.63		I	.64	317	3	130	I	6.8	6.8	18.5	I	10680	2.7	333	2.6
14	.63		I	.63	317	3	130	I	6.5	6.8	18.5	I	10680	2.7	332	2.4
15	.63		I	.62	313	3	130	I	6.5	6.8	18.5	I	10680	2.7	327	2.3
16	.62		I	.61	311	3	130	I	6.3	6.8	18.5	I	10680	2.7	324	2.2
17	.62		I	.62	313	3	130	I	6.6	6.8	18.5	I	10680	2.7	328	2.4
18	.62		I	.62	313	3	130	I	6.6	6.8	18.5	I	10680	2.7	330	2.4
19	.62		I	.61	315	3	130	I	6.3	6.8	18.5	I	10680	2.7	337	2.3
20	.61		I	.61	311	3	130	I	6.3	6.8	18.5	I	10680	2.7	331	2.3
21	.61		I	.61	309	3	130	I	6.5	6.8	18.5	I	10680	2.7	329	2.4
22	.61		I	.61	309	3	130	I	6.5	6.8	18.5	I	10680	2.7	328	2.4
23	.61		I	.61	309	3	130	I	6.5	6.8	18.5	I	10680	2.7	328	2.4

(0) NOX ROLLING 3-HR VIOLATIONS

CONVERSION FACTORS: (FW)
 (CW) = PPM * 1.194 * 10EXP-7

OUT OF SERVICE HH:MM 0: 0

0: 0

LAST SYSTEM INITIALIZATION 9:21:56 6/30/91

END

**DATE
FILMED**

12/10/91