DEMONSTRATION OF A FULL-SCALE RETROFIT OF THE ADVANCED HYBRID PARTICULATE COLLECTOR TECHNOLOGY

TECHNICAL PROGRESS REPORT

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ABSTRACT

The Advanced Hybrid Particulate Collector (AHPC), developed in cooperation between W.L. Gore & Associates and the Energy & Environmental Research Center (EERC), is an innovative approach to removing particulates from power plant flue gas. The AHPC combines the elements of a traditional baghouse and electrostatic precipitator (ESP) into one device to achieve increased particulate collection efficiency. As part of the Power Plant Improvement Initiative (PPII), this project is being demonstrated under joint sponsorship from the U.S. Department of Energy and Otter Tail Power Company. The EERC is the patent holder for the technology, and W.L. Gore & Associates is the exclusive licensee.

The project objective is to demonstrate the improved particulate collection efficiency obtained by a full-scale retrofit of the AHPC to an existing electrostatic precipitator. The full-scale retrofit is installed on an electric power plant burning Powder River Basin (PRB) coal, Otter Tail Power Company's Big Stone Plant, in Big Stone City, South Dakota. The $13.4 million project was installed in October 2002. Project related testing will conclude in November 2004.

The following Technical Progress Report has been prepared for the project entitled "Demonstration of a Full-Scale Retrofit of the Advanced Hybrid Particulate Collector Technology" as described in DOE Award No. DE-FC26-02NT41420. The report presents the operation and performance results of the system.

POINT OF CONTACT

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TABLE OF CONTENTS

Section **Page**

TABLE OF CONTENTS .... **V**

LIST OF ACRONYMS .... **VII**

EXECUTIVE SUMMARY **1**

PROJECT NOMENCLATURE DISCUSSION **2**

1.0 INTRODUCTION **3**

1.1 HISTORY OF DEVELOPMENT 5
1.2 DESIGN OF THE PERFORATED PLATE *ADVANCED HYBRID*™ FILTER CONFIGURATION 5
1.3 PRESSURE DROP THEORY AND PERFORMANCE EVALUATION CRITERIA 9
1.4 9000-ACFM PILOT-SCALE RESULTS 13
1.5 FULL-SCALE DESIGN AND DIFFERENCES BETWEEN FULL AND PILOT SCALE 17

2.0 EXPERIMENTAL **20**

2.1 INDEPENDENT CHARACTERISTICS 20
2.1.1 Independent Characteristic Chart 20
2.1.2 Bag Layout 21
2.2.1 Dependent Data 22
2.2.2 Instrument Location Diagram 24
2.2.3 Data Retrieval 25
2.2.4 Data Reduction 25

3.0 RESULTS AND DISCUSSION **26**

3.1 GENERAL RESULTS AND DISCUSSION 26

4.0 CONCLUSIONS **32**

5.0 APPENDICES **33**

APPENDIX A - COMMENTS ON ANOMALIES OF GRAPHICAL DATA **34**

APPENDIX B – GRAPHICAL & TABULAR PERFORMANCE DATA **35**

B1 GROSS PLANT LOAD 35
B2 FLUE GAS FLOW (KSCFM) 36
B3 FLUE GAS FLOW (KACFM) 37
B4 INLET GAS TEMPERATURE 38
B5 TUBESHEET DP 39
B6 FLANGE-TO-FLANGE DP 40
B7 AIR-TO-CLOTH RATIO 41
B8 OPACITY 42
B9 NO_X EMISSIONS 43
B10 SO_2 EMISSIONS 44
B11 OUTLET GAS TEMPERATURE 45
B12 OUTLET PRESSURE 45

B12 OUTLET PRESSURE 46
B13 TEMPERATURE PER CHAMBER 47
B14 FUEL BURN RECORD 51
B15 FUEL ANALYSIS RECORD 54
B16 ASH ANALYSIS RECORD 57
B17 ULTIMATE COAL ANALYSIS 58
B18 PHOTOGRAPHS 59
B19 ESP POWER BY CHAMBER 61
B20 ESP TABULAR DATA 65
B21 PULSE COUNTER READINGS 66
B22 COMPRESSED AIR FLOW 67
B23 BAG LAYOUT DIAGRAM 68
B25 W.L. GORE REPORT ON BAG ANALYSIS 70

LIST OF ACRONYMS

A/C	air-to-cloth ratio
AG	(Swiss, translation roughly is Incorporation or consolidation)
AHPC	advanced hybrid particulate collector
APS	aerodynamic particle sizer
COHPAC	compact hybrid particulate collector
CPC	condensation particle counter
DOE	U.S. Department of Energy
EERC	Energy & Environmental Research Center
EPA	U.S. Environmental Protection Agency
ePTFE	expanded polytetrafluoroethylene
ESP	electrostatic precipitator
FF	fabric filter
HEPA	high-efficiency particulate air
HiPPS	high-performance power system
MWh	megawatt hours
µm	micrometer
NSPS	New Source Performance Standards
O&M	operating and maintenance
OEMs	original equipment manufacturers
OTP	Otter Tail Power Company
P&ID	Piping and Intrumentation Diagram
PID	Proportional-Integral-Derivative
PJBH	pulse-jet baghouse
PM	particulate matter
PPS	polyphenylene sulfide
PRB	Powder River Basin
PJFF	pulse-jet fabric filter
P-84	aromatic polyimide fiber
QAPP	quality assurance project plan
RGFF	reverse-gas fabric filter
SCA	specific collection area
SMPS	scanning mobility particle sizer
TR	transformer-rectifier
UND	University of North Dakota
W.C.	water column

EXECUTIVE SUMMARY

This document summarizes the operational results of a project titled "Demonstration of a Full-Scale Retrofit of the Advanced Hybrid Particulate Collector Technology". The Department of Energy's National Energy Technology Laboratory awarded this project under the Power Plant Improvement Initiative Program.

The advanced hybrid particulate collector (AHPC) was developed with funding from the U.S. Department of Energy (DOE). The AHPC combines the best features of electrostatic precipitators (ESPs) and baghouses in novel manner. The AHPC combines fabric filtration and electrostatic precipitation in the same housing, providing major synergism between the two methods, both in particulate collection and in transfer of dust to the hopper. The AHPC provides ultrahigh collection efficiency, overcoming the problem of excessive fine-particle emissions with conventional ESPs, and solves the problem of reentrainment and recollection of dust in conventional baghouses.

Big Stone Power Plant operated a 2.5 MWe slipstream AHPC (9000 scfm) for 1½ years. The AHPC demonstrated ultrahigh particulate collection efficiency for submicron particles and total particulate mass. Collection efficiency was proven to exceed 99.9% by one to two orders of magnitude over the entire range of particles from 0.01 to 50 µm. This level of control is well below any current particulate emission standards. These results were achieved while operating at significantly higher air-to-cloth ratios (up to 12 ft/min compared to 4 ft/min) than standard pulse-jet baghouses. To achieve 99.99% control of total particulate and meet possible stricter fine-particle standards, the AHPC is being demonstrated as the possible economic choice over either ESPs or baghouses.

Otter Tail Power Company and its partners, Montana-Dakota Utilities and NorthWestern Energy, installed the AHPC technology into an existing ESP structure at the Big Stone Power Plant. The overall goal of the project is to demonstrate the AHPC concept in a full-scale application. Specific objectives are to demonstrate 99.99% collection of all particles in the 0.01 to 50 µm size range, low pressure drop, overall reliability of the technology and long-term bag life.

Bag failures have occurred during this quarter of demonstration. Nearly all of the PPS bags have shown some type of material failure. Failed bags were replaced in a majority of the compartments during the wash outage in December. New materials are being tested to increase the existing number of options for installation into the system.

PROJECT NOMENCLATURE DISCUSSION

When this technology was originally developed, the device was referred to as the "Advanced Hybrid Particulate Collector". Since the original development, from concept to an attempt at a commercial demonstration, the name of the technology has changed to "Advanced Hybrid™". This name was trademarked by W.L. Gore and Associates, Inc. to aid in the commercialization effort and tries to maintain the continuity of the successful history to date. Either "Advanced Hybrid Particulate Collector" (AHPC) or "Advanced Hybrid™" refers to the same process and equipment.

1.0 INTRODUCTION

The *Advanced Hybrid*™ filter combines the best features of ESPs and baghouses in a unique approach to develop a compact but highly efficient system. Filtration and electrostatics are employed in the same housing, providing major synergism between the two collection methods, both in the particulate collection step and in the transfer of dust to the hopper. The *Advanced Hybrid*™ filter provides ultrahigh collection efficiency, overcoming the problem of excessive fine-particle emissions with conventional ESPs, and solves the problem of reentrainment and re-collection of dust in conventional baghouses.

The goals for the *Advanced Hybrid*™ filter are as follows: > 99.99% particulate collection efficiency for particle sizes ranging from 0.01 to 50 μm, applicable for use with all U.S. coals, and cost savings compared to existing technologies.

The electrostatic and filtration zones are oriented to maximize fine-particle collection and minimize pressure drop. Ultrahigh fine-particle collection is achieved by removing over 90% of the dust before it reaches the fabric and using a GORE-TEX® membrane fabric to collect the particles that reach the filtration surface. Charge on the particles also enhances collection and minimizes pressure drop, since charged particles tend to form a more porous dust cake. The goal is to employ only enough ESP plate area to precollect approximately 90% of the dust. ESP models predict that 90%–95% collection efficiency can be achieved with full-scale precipitators with a specific collection area (SCA) of less than 100 ft^2/kacfm (1, 2). FF models predict that face velocities greater than 12 ft/min are possible if some of the dust is precollected and the bags can be adequately cleaned. The challenge is to operate at high A/C ratios (8–14 ft/min) for economic benefits while achieving ultrahigh collection efficiency and controlling pressure drop. The combination of GORE-TEX® membrane filter media (or similar membrane filters from other manufacturers), small SCA, high A/C ratio, and unique geometry meets this challenge.

Studies have shown that FF collection efficiency is likely to deteriorate significantly when the face velocity is increased (3, 4). For high collection efficiency, the pores in the filter media must be effectively bridged (assuming they are larger than the average particle size). With conventional fabrics at low A/C ratios, the residual dust cake serves as part of the collection media, but at high A/C ratios, only a very light residual dust cake is acceptable, so the cake cannot be relied on to achieve high collection efficiency. The solution is to employ a sophisticated fabric that can ensure ultrahigh collection efficiency and endure frequent high-energy cleaning. In addition, the fabric should be reliable under the most severe chemical environment likely to be encountered (such as high SO_3).

Assuming that low particulate emissions can be maintained through the use of advanced filter materials and that 90% of the dust is precollected, operation at face velocities in the range of 8–14 ft/min should be possible, as long as the dust can be effectively removed from the bags and transferred to the hopper without significant redispersion and re-collection. With pulse-jet cleaning, heavy residual dust cakes are not typically a problem because of the fairly high cleaning energy that can be employed. However, the high cleaning energy can lead to significant redispersion of the dust and subsequent re-collection on the bags. The combination of a very high-energy pulse and a very light dust cake tends to make the problem of redispersion much worse. The barrier that limits operation at high A/C ratios is not so much the dislodging of dust from the bags as it is the transferring of the dislodged dust to the hopper. The *Advanced Hybrid*™ filter achieves enhanced bag cleaning by employing electrostatic effects to precollect a significant portion of the dust and by trapping in the electrostatic zone the redispersed dust that comes off the bags following pulsing.

1.1 History of Development

The *Advanced Hybrid*™ filter concept was first proposed to DOE in September 1994 in response to a major solicitation addressing air toxics. DOE has been the primary funder of the *Advanced Hybrid*™ filter development since that time, along with significant cost-sharing from industrial cosponsors. Details of all of the results have been reported in DOE quarterly technical reports, final technical reports for completed phases, and numerous conference papers. A chronology of the significant development steps for the *Advanced Hybrid*™ filter is shown below.

- September 1994 - *Advanced Hybrid*™ filter concept proposed to DOE
- October 1995 - September 1997 - Phase I - *Advanced Hybrid*™ filter successfully demonstrated at 0.06-MW (200-acfm) scale
- March 1998 - February 2000 - Phase II - *Advanced Hybrid*™ filter successfully demonstrated at 2.5-MW (9000-acfm) scale at Big Stone Plant
- September 1999 - August 2001 - Phase III - *Advanced Hybrid*™ filter commercial components tested and proven at 2.5-MW scale at Big Stone Plant
- Summer 2000 – Minor electrical damage on bags first observed
- January–June 2001 – To prevent electrical damage, the *Advanced Hybrid*™ filter perforated plate configuration was developed, tested, and proven to be superior to the original design
- July 2001 - December 2004 - Mercury Control with the *Advanced Hybrid*™ Filter - Extensive additional testing of the perforated plate concept was conducted with the 2.5-MW pilot unit

1.2 Design of the Perforated Plate *Advanced Hybrid*™ Filter Configuration

After bag damage was observed in summer 2000, extensive experiments were carried out at an Energy & Environmental Research Center (EERC) laboratory to investigate the interactions between electrostatics and bags under different operating conditions. The 200-acfm *Advanced Hybrid*™ filter was first operated without fly ash under cold-flow conditions with air. The effects of electrode type, bag type, plate-to-plate spacing, the relative distance from the electrodes to plates compared to the distance from the electrodes to the bags (spacing ratio), and various grounded grids placed between the electrodes and bags were all evaluated. Several of the conditions from the cold-flow tests were selected and further evaluated in hot-flow coal combustion tests. While all of these tests resulted in very low current to the bags, there appeared to be a compromise in overall *Advanced Hybrid*™ filter performance for some configurations.

A configuration that appeared to have promise was a perforated plate design in which a grounded perforated plate was installed between the discharge electrodes and the bags to protect the bags. On the opposite side of the electrodes, another perforated plate was installed to simulate the geometric arrangement where each row of bags would have perforated plates on both sides, and no solid plates were used. The discharge electrodes were then centered between perforated plates located directly in front of the bags. With this arrangement, the perforated plates function both as the primary collection surface and as a protective grid for the bags. With the 200-acfm *Advanced Hybrid*™ filter, the perforated plate configuration produced results far better than in any previous *Advanced Hybrid*™ filter tests and provided adequate protection of the bags.

Based on the 200-acfm results, a perforated plate configuration was designed and installed on the 9000-acfm slipstream pilot unit at the Big Stone Power Plant. The differences between the new perforated plate design and the previous *Advanced Hybrid*™ filter can be seen by comparing Figure 1 with Figure 2. Figure 1 is a simplified top view of the 9000-acfm *Advanced Hybrid*™ filter configuration at the start of Phase III, which had a plate-to-plate spacing of 23.6 in. For the perforated plate configuration (Figure 2), the bag spacing was not changed, allowing use of the same tube sheet as in the previous configuration (Figure 1). However, the distance from the discharge electrodes to the perforated plates as well as the distance from the bags to the perforated plates can be reduced without compromising performance. Therefore, one of the obvious advantages of the perforated plate configuration is the potential to make the *Advanced Hybrid*™ filter significantly more compact than the earlier design.

Another difference is that directional electrodes are not required with the perforated plate design. With the previous design, directional electrodes (toward the plate) were needed to prevent possible sparking to the bags. This means that conventional electrodes can be used with the *Advanced Hybrid*™ filter. Electrode alignment is also less critical because an out-of-alignment electrode would simply result in potential sparking to the nearest grounded perforated plate, whereas with the old design, an out-of-alignment electrode could result in sparking to a bag and possible bag damage.

While the perforated plate configuration did not change the overall *Advanced Hybrid*™ filter concept (precollection of > 90% of the dust and enhanced bag cleaning), the purpose of the plates did change. The perforated plates serve two very important functions: as the primary collection surface and as a protective grid for the bags. With approximately 45% open area, there is adequate collection area on the plates to collect the precipitated dust while not restricting the flow of flue gas toward the bags during normal filtration. During pulse cleaning of the bags, most of the reentrained dust from the bags is forced back through the perforated plates into the ESP zone. The 9000-acfm results as well as the 200-acfm results showed better ESP collection than the previous design while maintaining good bag cleanability. The better

ESP collection efficiency is likely the result of forcing all of the flue gas through the perforated plate holes before reaching the bags. This ensures that all of the charged dust particles pass within a maximum of one-half of the hole diameter distance of a grounded surface. In the presence of the electric field, the particles then have a greater chance of being collected. In the old *Advanced Hybrid*™ filter design, once the gas reached the area between the electrodes and bags, it would be driven toward the bags rather than the plates, and a larger fraction of the dust was likely to bypass the ESP zone.

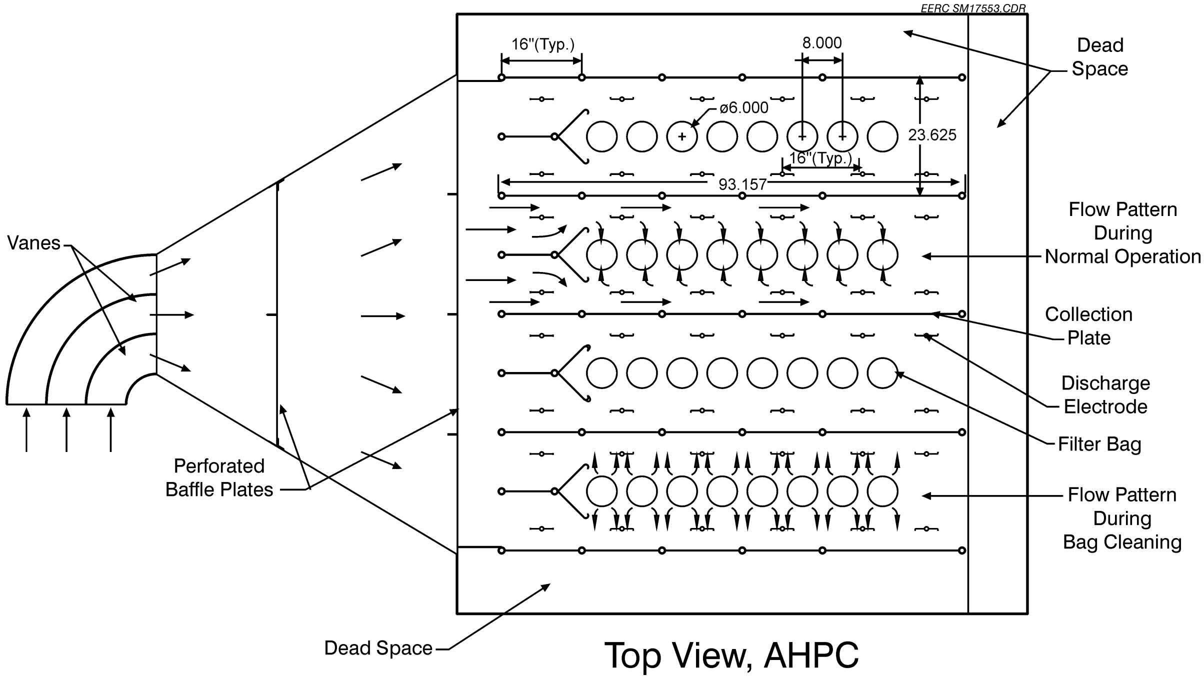


Figure 1. Top view of the old configuration for the 9000-acfm *Advanced Hybrid*™ filter at Big Stone.

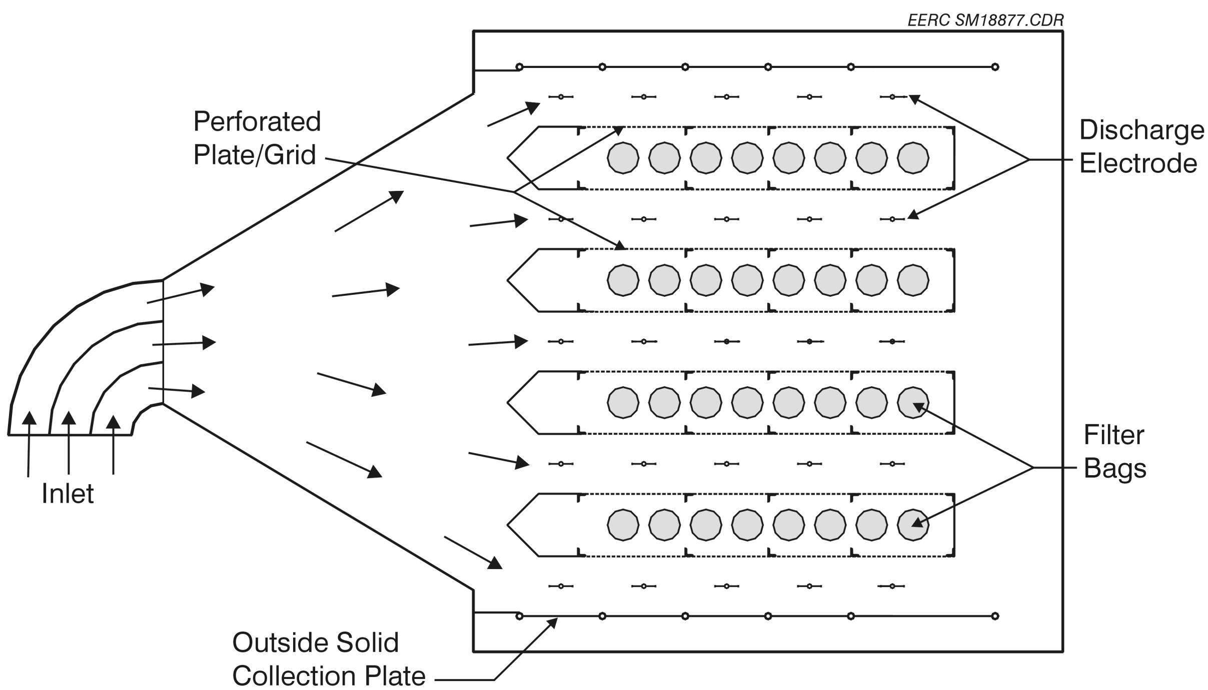


Figure 2. Top view of the perforated plate configuration for the 9000-acfm *Advanced Hybrid*™ filter.

1.3 Pressure Drop Theory and Performance Evaluation Criteria

Pressure drop across the bags is one of the main operational parameters that defines overall performance. It must be within capacity limits of the boiler fans at the maximum system flow rate. Since acceptable pressure drop is so critical to successful operation, a detailed discussion of the theory and factors that control pressure drop follows.

For viscous flow, pressure drop across a FF is dependent on three components:

$$dP = K_f V + K_2 W_R V + \frac{K_2 C_i V^2 t}{7000} \qquad \text{[Eq. 1]}$$

where:

dP = differential pressure across baghouse tube sheet (in. W.C.)
K_f = fabric resistance coefficient (in. W.C.-min/ft)
V = face velocity or A/C ratio (ft/min)
K_2 = specific dust cake resistance coefficient (in. W.C.-ft-min/lb)
WR = residual dust cake weight (lb/ft^2)
C_i = inlet dust loading (grains/acf)
t = filtration time between bag cleaning (min)

The first term in Eq. 1 accounts for the pressure drop across the fabric. For conventional fabrics, the pore size is quite large, and the corresponding fabric permeability is high, so the pressure drop across the fabric alone is negligible. To achieve better collection efficiency, the pore size can be significantly reduced, without making fabric resistance a significant contributor to pressure drop. The GORE-TEX® membrane filter media allows for this optimization by providing a microfine pore structure while maintaining sufficient fabric permeability to permit operation at high A/C ratios. A measure of the new fabric permeability is the Frazier number which is the volume of gas that will pass through a square foot of fabric sample at a pressure drop of 0.5 in. W.C. The Frazier number for new GORE-TEX® bags is in the range from 4 to 8 ft/min. Through the filter, viscous (laminar) flow conditions exist, so the pressure drop varies directly with flow velocity. Assuming a new fabric Frazier number of 6 ft/min, the pressure drop across the fabric alone would be 1.0 in. W.C. at an A/C ratio (filtration velocity) of 12 ft/min.

The second term in Eq. 1 accounts for the pressure drop contribution from the permanent residual dust cake that exists on the surface of the fabric. For operation at high A/C ratios, the bag cleaning must be sufficient to maintain a very light residual dust cake and ensure that the pressure drop contribution from this term is reasonable. The contribution to pressure drop from this term is one of the most important indicators of longer-term bag cleanability.

The third term in Eq. 1 accounts for the pressure drop contribution from the dust accumulated on the bags since the last bag cleaning. K_2 is determined primarily by the fly ash particle-size distribution and the porosity of the dust cake. Typical K_2 values for a full dust loading of pulverized coal (pc)-fired fly ash range from about 4 to 20 in. W.C.-ft-min/lb but may, in extreme cases, cover a wider range. Within this term, the bag-cleaning interval, t, is the key performance indicator. The goal is to operate with as long of a bag-cleaning interval as possible, since more frequent bag pulsing can lead to premature bag failure and require more energy consumption from compressed air usage. An earlier goal for the pilot-scale tests was to operate with a pulse interval of at least 10 min while operating at an A/C ratio of 12 ft/min. While this goal was exceeded in the pilot-scale tests, a pulse interval of only 10 min is now considered too short to demonstrate good *Advanced Hybrid*™ filter performance over a longer period. With a shorter pulse interval, the *Advanced Hybrid*™ filter does not appear to make the best use of the electric field, because of the reentrainment that occurs just after pulsing. Current thought is that a pulse interval of at least 60 min is needed to demonstrate the best long-term performance.

Total tube sheet pressure drop is another key indicator of overall performance of the *Advanced Hybrid*™ filter. Here, the goal was to operate with a tube sheet pressure drop of 8 in. W.C. at an A/C ratio of 12 ft/min. Note that the average pressure drop is not the same as the pulse-cleaning trigger point. For many of the previous and current tests, the pulse trigger point was set at 8 in. W.C., but the average pressure drop was significantly lower.

To help analyze filter performance, the terms in Eq. 1 can be normalized to the more general case by dividing by velocity. The dP/V term is commonly referred to as drag or total tube sheet drag, D_T:

$$\frac{dP}{V} = D_T = K_f + K_2 W_R + \frac{K_2 C_i V t}{7000} \qquad \text{[Eq. 2]}$$

The new fabric drag and the residual dust cake drag are typically combined into a single term called residual drag, D_R:

$$D_T = D_R + \frac{K_2 C_i V t}{7000} \qquad \text{[Eq. 3]}$$

The residual drag term then is the key indicator of how well the bags are cleaning over a range of A/C ratios, but may still be somewhat dependent on A/C ratio. For example, it may be more difficult to overcome a dP of 10 in. W.C. to clean the bags than cleaning at a dP of 5 in. W.C. For most baghouses, the residual drag typically climbs somewhat over time and must be monitored carefully to evaluate the longer-term performance. Current thought is that excellent *Advanced Hybrid*™ filter performance can be demonstrated with a residual drag value of 0.6 or lower.

Between bag cleanings, from the second term in Eq. 3, the drag increases linearly with K_2 (dust cake resistance coefficient), C_i (inlet dust concentration), V (filtration velocity), and t (filtration time). For conventional baghouses, the C_i term is easily determined from an inlet dust loading measurement, and approximate K_2 values can be determined from the literature or by direct measurement. However, for the *Advanced Hybrid*™ filter, the concentration of the dust that reaches the bags is generally not known and would be very difficult to measure experimentally. From the Phase I laboratory tests, results indicated approximately 90% of the dust was precollected and did not reach the fabric. However, this amount is likely to fluctuate significantly with changes to the electrical field and with the dust resistivity. Since C_i is not known, for evaluation of *Advanced Hybrid*™ filter performance, the K_2 and C_i can be considered together:

$$K_2C_i = \frac{(D_T - D_R)7000}{Vt} \qquad \text{[Eq. 4]}$$

Evaluation of K_2C_i can help in assessing how well the ESP portion of the *Advanced Hybrid*™ filter is functioning, especially by comparing with the K_2C_i during short test periods in which the ESP power was shut off. For the Big Stone ash, the K_2C_i value has typically been about 20 without the ESP field. For the 9000-acfm pilot *Advanced Hybrid*™ filter, longer-term K_2C_i values of 1.0 have been demonstrated with the ESP field on, which is equivalent to 95% precollection of the dust by the ESP. Again, the goal is to achieve as low of a K_2C_i value as possible; however, good *Advanced Hybrid*™ filter performance can be demonstrated with K_2C_i values up to 4, but this is interdependent on the residual drag and filtration velocity.

Eq. 4 can be solved for the bag-cleaning interval, t, as shown in Eq. 5. The bag-cleaning interval is inversely proportional to the face velocity, V, and the K_2C_i term and directly proportional to the change in drag before and after cleaning (delta drag). The delta drag term is dependent on the cleaning set point or maximum pressure drop as well as the residual drag. The face velocity, delta drag, and K_2C_i terms are relatively independent of each other and should all be considered when the bag-cleaning interval is evaluated. However, as mentioned above, the drag may be somewhat dependent on velocity if the dust does not clean off the bags as well at high velocity as at low velocity. Similarly, the K_2C_i is somewhat dependent on velocity for a constant plate collection area. At the greater flow rates, the SCA of the precipitator is reduced, which will result in a greater dust concentration, C_i, reaching the bags.

$$t = \frac{(D_T - D_R)7000}{VK_2C_i} \qquad \text{[Eq. 5]}$$

By evaluating these performance indicators, the range in possible A/C ratios can be calculated by using Eq. 1. For example, using the acceptable performance values of a 60-min pulse interval and a residual drag of 0.6, Eq. 1 predicts that a K_2C_i value of 2.33 would be needed when operating at an A/C ratio of 10 ft/min and a pulse trigger of 8 in. W.C. Obviously, deterioration in the performance of one indicator can be offset by improvement in another. Results to date show that performance is highly sensitive to the A/C ratio and that excellent *Advanced Hybrid*™ filter performance can be achieved as long as a critical A/C ratio is not exceeded. If the A/C ratio is pushed too high, system response is to more rapidly pulse the bags. However, too rapid of pulsing tends to make the residual drag increase faster and causes the K_2C_i to also increase, both of which lead to poorer performance. The design challenge is to operate the *Advanced Hybrid*™ filter at the appropriate A/C ratio for a given set of conditions.

1.4 9000-acfm Pilot-Scale Results

During the summer of 2002 the 9000-acfm *Advanced Hybrid*™ filter was operated from June 28 through early September with minimal changes to the operating parameters. This is the longest time the pilot unit was operated without interruption and is the best example of the excellent performance demonstrated with the 9000-acfm *Advanced Hybrid*™ filter. One of the main objectives of the summer 2002 tests was to assess the effect of carbon injection for mercury control on longer-term *Advanced Hybrid*™ filter performance. In order to achieve steady-state *Advanced Hybrid*™ filter operation prior to starting carbon injection, the *Advanced Hybrid*™ filter was started with new bags on June 28 and operated continuously until the start of the carbon injection for mercury control in August. Operational parameters are given in Table 1, and the bag-cleaning interval, pressure drop, and K_2C_i data from June 28 to September 3 are shown in Figures 3-5. The daily average pressure drop data increased slightly with time as would be expected after starting with new bags. When the carbon was started on August 7, there was no perceptible change in pressure drop. The bag-cleaning interval was somewhat variable as a result of temperature and load swings, but, again there was no increase when the carbon feed was started. The K_2C_i values are an indication of the amount of dust that reaches the bags and subsequently relate to how well the ESP portion of the *Advanced Hybrid*™ filter is working. Again, there was no perceptible change when the carbon was started. These data show that the *Advanced Hybrid*™ filter can be expected to provide good mercury removal with upstream injection of carbon without any adverse effect on performance.

From August 21 to August 26, the *Advanced Hybrid*™ filter current was deliberately reduced to 25 mA compared to the normal 55 mA setting (see Figures 3-5) to see if good mercury removal could be maintained. The bag-cleaning interval dropped to about one-half, and the K_2C_i value approximately doubled, which would be expected. Both of these indicate that about twice as much dust reached the bags at 25 mA compared to 55 mA. However, almost no effect on pressure drop was seen. This implies that it should be possible to optimize *Advanced Hybrid*™ filter operational parameters to get the best overall mercury removal while maintaining good *Advanced Hybrid*™ filter performance.

Table 1. 2.5-MW *Advanced Hybrid*™ Filter Test Parameters and Operational Summary, June 28 - September 2, 2002

A/C Ratio	10 ft/min
Pulse Pressure	70 psi
Pulse Duration	200 ms
Pulse Sequence	87654321 (multibank)
Pulse Trigger	8.0 in. W.C.
Pulse Interval	260 - 400 min
Temperature	260° - 320°F
Rapping Interval	15 - 20 min
Voltage	58 - 62 kV
Current	55 mA

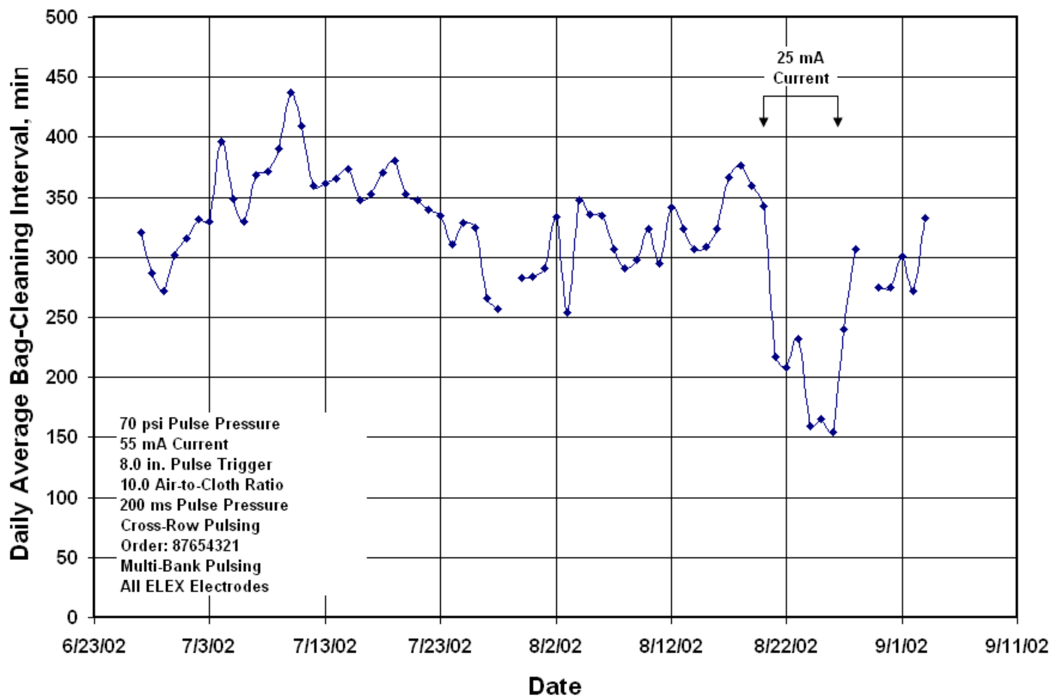


Figure 3. Daily average bag-cleaning interval for summer 2002 tests with the 9000-acfm *Advanced Hybrid*™ filter.

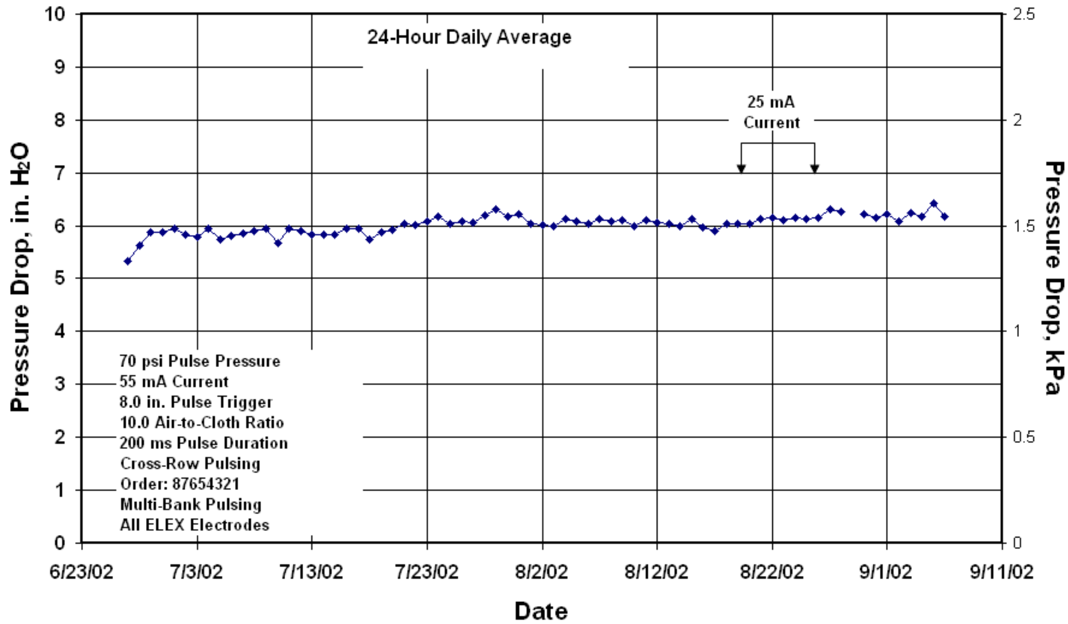


Figure 4. Daily average pressure drop for summer 2002 tests with the 9000-acfm *Advanced Hybrid*™ filter.

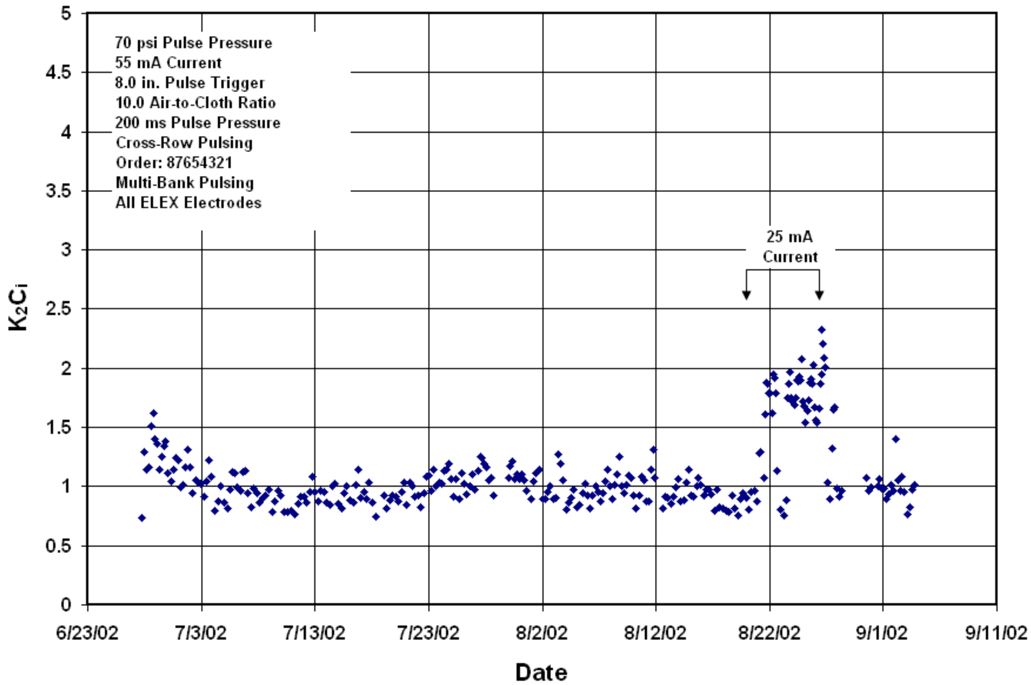


Figure 5. K_2C_i for summer 2002 tests with the 9000-acfm *Advanced Hybrid*™ filter.

A summary of the results in Table 2 shows the excellent operational performance achieved with the 9000-acfm at an A/C ratio of 10 ft/min.

Table 2. Summary of 9000-acfm Pilot-Scale Results from Summer 2002

A/C Ratio	10 ft/min
Average dP	~6 in. W.C.
Bag-Cleaning Interval	2–5 hr
Residual Drag	0.4–0.5
K_2C_i	0.9–1.5

The 9000-acfm pilot *Advanced Hybrid*™ filter was also used to vary the operational parameters to assess the most critical effects. One of the most important findings was the observed significant effect of the pulse interval on the K_2C_i value, as shown in Figure 6. The large increase in K_2C_i at the lowest pulse intervals indicates that the benefit of the electric field is diminished at lower pulse intervals. This indicates that for good *Advanced Hybrid*™ filter performance, a minimum allowable pulse interval should be established. Based on Figure 6, a 60 min pulse interval would be a good minimum performance goal.

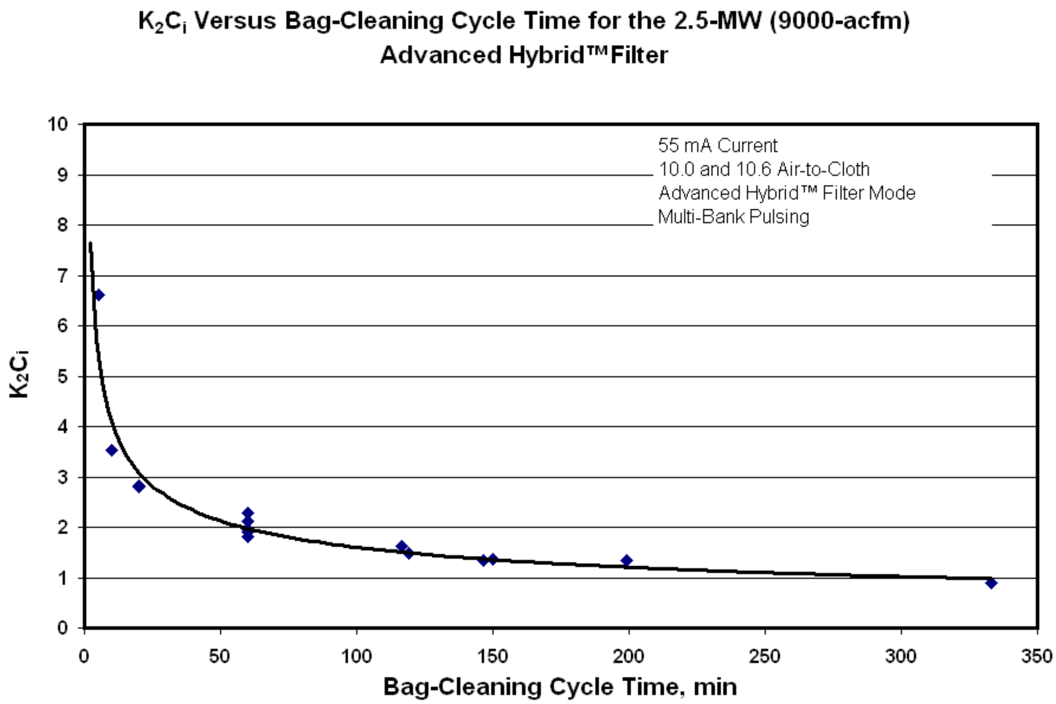


Figure 6. Effect of pulse interval on K_2C_i for 9000-acfm pilot *Advanced Hybrid*™ filter.

1.5 Full-Scale Design and Differences Between Full and Pilot Scale

The original ESP at Big Stone consisted of a Lurgi-Wheelabrator design with four main chambers and four collecting fields in series within each chamber. Only the last three fields in each chamber were converted into an *Advanced Hybrid*™ filter while the first field was unchanged (Figure 7). Since the ESP plates are 40 ft high, but the *Advanced Hybrid*™ filter bags are only 23 ft long, there is a large open space between the bottom of the bags and the hoppers (Figure 8). The outer six compartments (Figure 7) are arranged with 20 rows and 21 bags per row, while the six inner compartments have 19 rows with 21 bags per row. The total number of planned bags for the 12 compartments was 4914. However, because of a spacing limitation from the electrode rapping mechanism, a total of 81 bags had to be removed, so the total number of bags in service is 4834.

The main differences between the 2.5-MW pilot *Advanced Hybrid*™ filter and the full-scale Big Stone *Advanced Hybrid*™ filter are as follows:

- The pilot unit has a small precollection zone consisting of one discharge electrode, while the full-scale unit has no precollection zone (without the first field on). The effect would be better ESP collection (lower K_2C_i) in the pilot unit. The pilot unit has shorter bags, 15 ft versus 23 ft for the full-scale *Advanced Hybrid*™ filter. The expected result would be better bag cleaning with the pilot unit (lower residual drag).

- The full-scale *Advanced Hybrid*™ filter has an ESP plate spacing of 12 in. compared to 13.5 in. for the pilot-scale unit. The expected result is somewhat better ESP collection efficiency.

- The entrance velocity of the flue gas is 4–8 ft/s for the full-scale unit versus 2 ft/s in the pilot-scale unit. The expected effect is better ESP collection efficiency with the pilot unit.

- The pilot unit has very uniform side inlet flow distribution while the full-scale *Advanced Hybrid*™ filter has flow from the side for the first *Advanced Hybrid*™ filter compartment and from the bottom in the back 2 compartments.

In the pilot unit all of the flow is uniformly distributed from the side and none of the flow comes from the bottom. In the full-scale *Advanced Hybrid*™ filter, flow entering the first *Advanced Hybrid*™ filter chamber comes from the side (similar to the pilot unit). The flow to the back two compartments must first travel below the first *Advanced Hybrid*™ filter compartment and then either directly up from the bottom into the compartment or up from the bottom into the areas between compartments and then horizontally into the compartments (Figure 9).

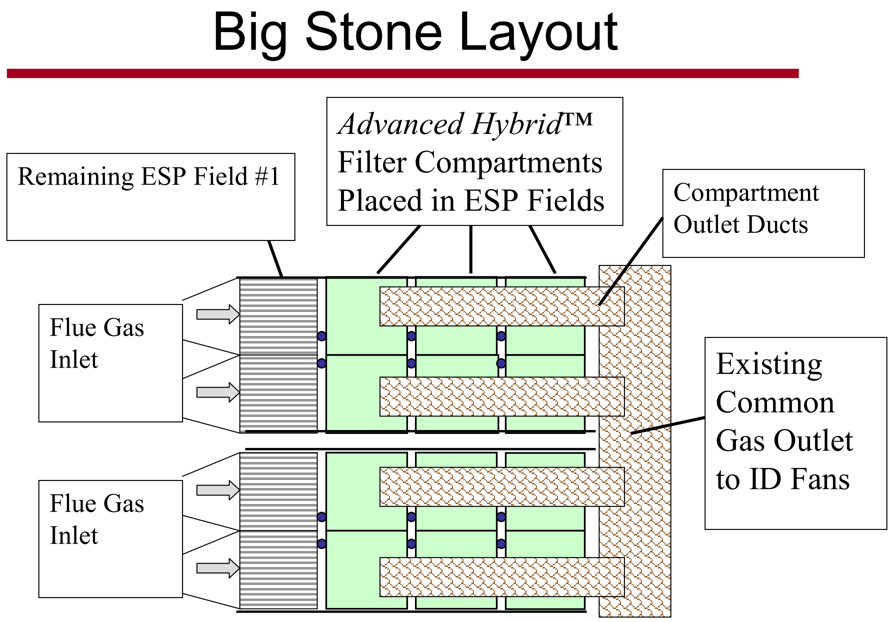


Figure 7. Top view of the *Advanced Hybrid*™ filter full-scale retrofit configuration at Big Stone.

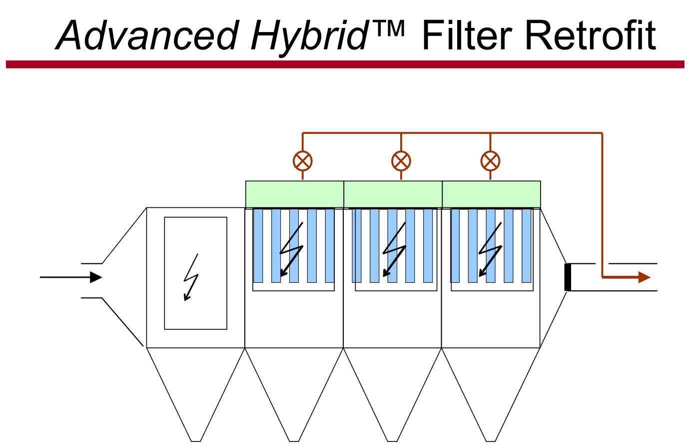


Figure 8. Side view of the *Advanced Hybrid*™ filter full-scale retrofit configuration at Big Stone.

2.0 EXPERIMENTAL

2.1 Independent Characteristics

2.1.1 Independent Characteristic Chart

The following chart lists the specific independent characteristics of the Advanced Hybrid System. If changes are made to the independent data, they will be described in the section listed under the "Notes" column.

Table 3.

Data	Status	Notes
ESP Collecting Surface	170,500 ft^2	Unchanged
# of Discharge Electrodes	2,706	Unchanged
# of Filter Bags	4834	Unchanged
Filter Bag Dimensions	7 Meters Long, 6 Inches Diameter	Unchanged
Filter Bag Surface Area	36.07 ft^2	Unchanged
Filter Bag Material	See 2.1.2	Changed
Pulse Pressure	80 psi	Unchanged
Cleaning Mode	Threshold Control	Unchanged
TR Rating of AH Field	1500 ma, 55 kV	Unchanged
TR Rating of Inlet ESP Field	2000 ma, 55 kV	Unchanged
Inlet ESP Field Data		
Inlet Field Dimensions[1]	45 gas passages, 40 feet high, 14 feet deep/chamber	Unchanged
Inlet Field Plate Area[1]	50,400 ft^2	Unchanged
Inlet Field Electrodes[1]	Wheelabrator bed frame "Star" Electrodes	Unchanged

[1]The inlet field was left in place. The design is the original configuration as installed in 1975. It is not the intention to operate the inlet field, however it was left in place as an added benefit of the system.

2.1.2 Bag Layout

The following is a description of the number and type of bags in the system. Some plugging of bags may occur, but in general, this should be an accurate description of the system with regards to filtration distribution. A diagram of the bag layout is included in Appendix B23.

Table 4 Bag Layout and Type Description prior to December outage

Compartment	Number of Bags	Bag Type
Chamber 1A Field 2	100/313	GORE-TEX™ Felt/GORE-TEX™ Membrane /Cond. PPS Felt/ GORE-TEX™ Membrane
Chamber 1A Field 3	413	PPS Felt/GORE-TEX™ Membrane
Chamber 1A Field 4	413	PPS Felt/GORE-TEX™ Membrane
Chamber 1B Field 2	392	GORE-TEX™ Felt/GORE-TEX™ Membrane
Chamber 1B Field 3	392	PPS Felt/GORE-TEX™ Membrane[1]
Chamber 1B Field 4	393	PPS Felt/GORE-TEX™ Membrane
Chamber 2A Field 2	81/312	GORE-TEX™ Felt/GORE-TEX™ Membrane /Cond. PPS Felt/ GORE-TEX™ Membrane
Chamber 2A Field 3	393	GORE-TEX™ Felt/GORE-TEX™ Membrane
Chamber 2A Field 4	393	PPS Felt/GORE-TEX™ Membrane
Chamber 2B Field 2	413	GORE-TEX™ Felt/GORE-TEX™ Membrane
Chamber 2B Field 3	413	Cond. PPS Felt/ GORE-TEX™ Membrane
Chamber 2B Field 4	413	PPS Felt/GORE-TEX™ Membrane

Table 5 Bag Layout and Type Description after December outage (changes highlighted)

Compartment	Number of Bags	Bag Type
Chamber 1A Field 2	100/313	GORE-TEX™ Felt/GORE-TEX™ Membrane /Cond. PPS Felt/ GORE-TEX™ Membrane
Chamber 1A Field 3	413	PPS Felt/GORE-TEX™ Membrane
Chamber 1A Field 4	413	PPS Felt/GORE-TEX™ Membrane
Chamber 1B Field 2	392	GORE-TEX™ Felt/GORE-TEX™ Membrane
Chamber 1B Field 3	392	Washed GORE-TEX™ Felt/GORE-TEX™ Membrane (originally installed 10/2002)
Chamber 1B Field 4	393	NOMEX felt/PTFE membrane
Chamber 2A Field 2	81/312	GORE-TEX™ Felt/GORE-TEX™ Membrane /Cond. PPS Felt/ GORE-TEX™ Membrane
Chamber 2A Field 3	393	GORE-TEX™ Felt/GORE-TEX™ Membrane
Chamber 2A Field 4	393	Washed GORE-TEX™ Felt/GORE-TEX™ Membrane (originally installed 10/2002)
Chamber 2B Field 2	413	GORE-TEX™ Felt/GORE-TEX™ Membrane
Chamber 2B Field 3	413	Cond. PPS Felt/ GORE-TEX™ Membrane
Chamber 2B Field 4	413	P-84 felt/PTFE Membrane

2.2 Dependent Characteristics

2.2.1 Dependent Data

The dependent data is largely presented in graphical format in the Appendix. The specific data points that are instrumented and presented are as follows;

Plant Gross Load: Continuously monitored TDC-3000 calculated value based on the generator output voltage and current. When the plant trips offline or shuts down for maintenance, the plant gross load will be zero.

Total Flue Gas Flow: Continuously monitored using United Science Inc.'s Ultra Flow 100 ultrasonic flow monitor. The flow monitor is located at the stack midlevel (see position #6 on the figure in 2.2.2). The readout of the flow monitor is in kscfm using 68°F and 29.92 in HG as standard conditions. The flow is converted to kacfm using the following equation:

$$\text{Gas Flow (kacfm)} = \frac{\text{(Gas Flow(kscfm)*(460 + Inlet Gas Temp}^{\circ}\text{ F)}}{(460+68^{\circ}\text{ F})} * \frac{29.92\text{ in HG}}{\text{(28.56 in HG + AHPC outlet Pressure)}}$$

Inlet Flue Gas Temperature: Continuously monitored using a grid of Type E thermocouples. The thermocouples are located at the AHPC inlet (see position #1 on the figure in 2.2.2). There are eight thermocouples at the inlet of each of the four AHPC chambers for a total of 32 thermocouples.

Tubesheet Differential Pressure: Continuously monitored on two of the twelve compartments. Pressure taps above and below the tubesheet (see positions #3 and #4 on the figure in 2.2.2) are equipped with Honeywell 3000 Smart DP Transmitters.

Flange–Flange Differential Pressure: Continuously monitored using two Honeywell 3000 Smart DP Transmitters at the AHPC inlet (see position # 2 in the figure in 2.2.2) and two Honeywell 3000 Smart DP Transmitters at the AHPC outlet (see position #5 on Diagram 1). Continuously calculated by the TDC- 3000 by taking the difference between the flue gas pressure at the AHPC inlet and outlet.

Air-to-Cloth Ratio: Calculated by dividing the Gas Flow (acfm) by the total surface area of the bags.

Opacity: Continuously measured by the plant opacity monitor, Monitor Labs Model #LS541. Opacity is measured in the Plant Stack, position 6 on the figure in 2.2.2. Position 6 is approximately at the 300 ft. level from grade.

Flue Gas Outlet Pressure: Continuously monitored using two Honeywell 3000 Smart DP Transmitters at the AHPC outlet (see position #5 in the figure in 2.2.2). The inlet pressure can be determined by the difference between the outlet pressure, and the flange-to-flange pressure drop.

Temperature per Chamber: See Inlet Temperature above.

ESP Power Consumption: Continuously monitored with a watt-hour meter to each chamber.

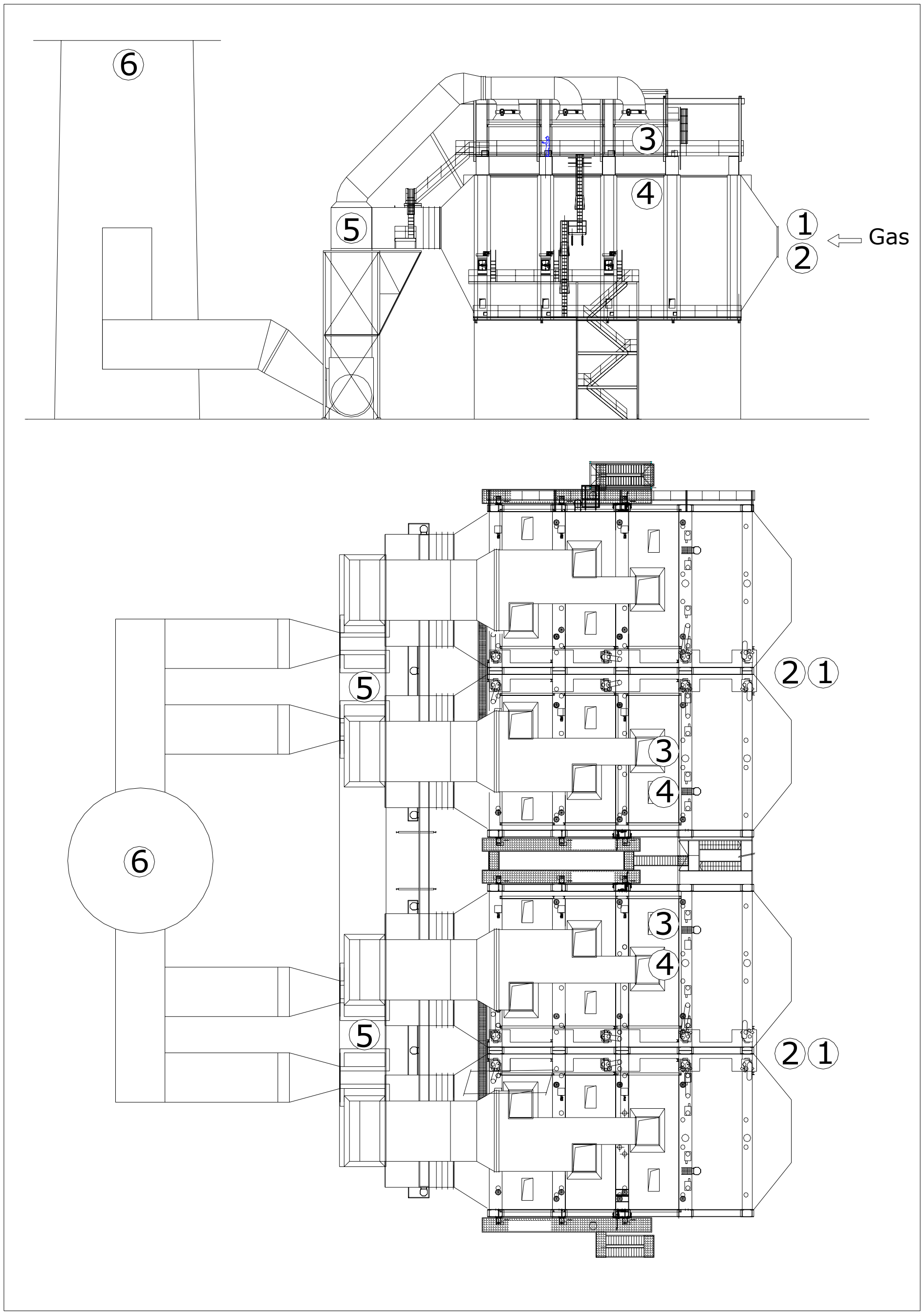
Compressed Air Flow: Continuously monitored using a Diamond II Annubar flow sensor equipped with a Honeywell 3000 Smart DP Transmitter. This ANNUBAR instrument is in the compressed air supply line after the compressors but before the desiccant dryer.

The non-instrumented data that can be found in the appendix is as follows

- Coal Analysis
- Flyash Analysis
- Coal and Alternative fuel Burned

2.2.2 Instrument Location Diagram

1 & 2: Advanced Hybrid Inlet
3 & 4: Above and Below Tubesheet
5: Advanced Hybrid Outlet
6: Plant Stack



2.2.3 Data Retrieval

Big Stone Plant's Honeywell TDC-3000 process control system monitors and controls a large number of actuators, sensors, and processes using PID controllers, programmable logic controllers, and special-purpose programs. Data gathered by the TDC-3000 is retrieved using an existing plant historian database. The dependent characteristic data presented in this report is calculated using 60-minute averages of the TDC-3000 readings, which are recorded every minute.

2.2.4 Data Reduction

Reported NO_X and SO_2 emissions have had 5% of data removed due to erroneous spikes occurring during daily calibration of CEMS instrumentation. No other assumptions or restrictions were used to transform the raw measured data into a form usable for interpretation.

3.0 Results and Discussion

3.1 General Results and Discussion

3.1.1 Chronological History of Significant Accomplishments

Quarter 1 (October 2002 – December 2002)	
System Startup	October 2002
Rapper Problems Realized	November 2002
Pulse Valve Problems Realized	November 2002
EERC Testing (99.99% particulate capture goal met)	November 2002
Inlet Field Energized	December 2002
Quarter 2 (January 2003 – March 2003)	
Soybeans burned at Big Stone as Alternative Fuels	January 2003
Derates due to high dP across the AH system begin	January 2003
Comparative Testing of Pilot unit to full-scale unit	February 2003
Plant shut down to wash boiler	February 2003
Quarter 3 (April 2003 – June 2003)	
Meeting to discuss improvement options	April 2003
Bags washed in two chambers	April/May 2003
Pitot data used for evaluation and decision	May 2003
Decision to replace filter bags	May 2003
Complete bag changeout	June 2003
Inlet field evaluated	June 2003
Plant restored to full load	June 2003
Quarter 4 (July 2003 – September 2003)	
Big Stone limited to 440 – 445 MW not due to AH	July/Sept 2003
Performance Tests	July/Sept 2003
Fluent Analysis Plan	Sept 2003
Preliminary baffle design submitted	Sept 2003
Quarter 5 (October 2003 – December 2003)	
Opacity rise attributed to initiation of bag failures	October 2003
Competitive bidding of replacement bags	November 2003
Fluent modeling results for flow baffles	November 2003
Test flow baffles installed	December 2003
Four compartments of bags replaced	December 2003

3.1.2 Discussion of Results of Significant Accomplishments

General Discussion

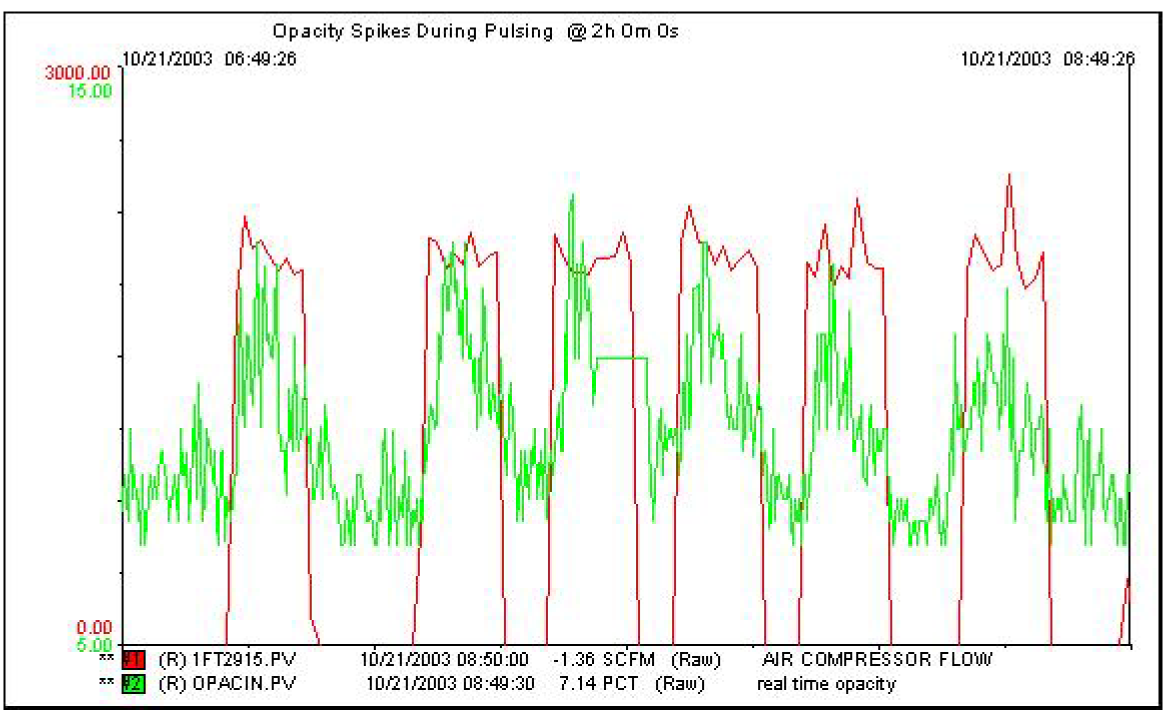
Problems have again developed with the Advanced Hybrid system. Significant bag failures have occurred in the PPS bags with the PPS scrim since installation three months prior. Indications and likely reasons for bag failure are included below. As a result, a competitive bidding effort has taken place with several different suppliers of various bag materials. This should allow us a greater flexibility of bag options, but also increase the amount of unknowns.

Other than the bag failures, performance has been maintained and even slightly improved as cooler gas temperatures into the Advanced Hybrid are realized. The cooler temperatures are due to lower ambient temperatures heading into the winter.

Some modeling results from Fluent Inc. are available and will be reviewed.

Bag Failures

In early October, it became apparent there were opacity spikes occurring during periods of pulsing. The graph below shows a two-hour time duration and the observed indications. During periods of pulsing (red), opacity (green) is increasing from around 8% to about 10-11%. These spikes contribute to an overall opacity rise, seen in Appendix B8.

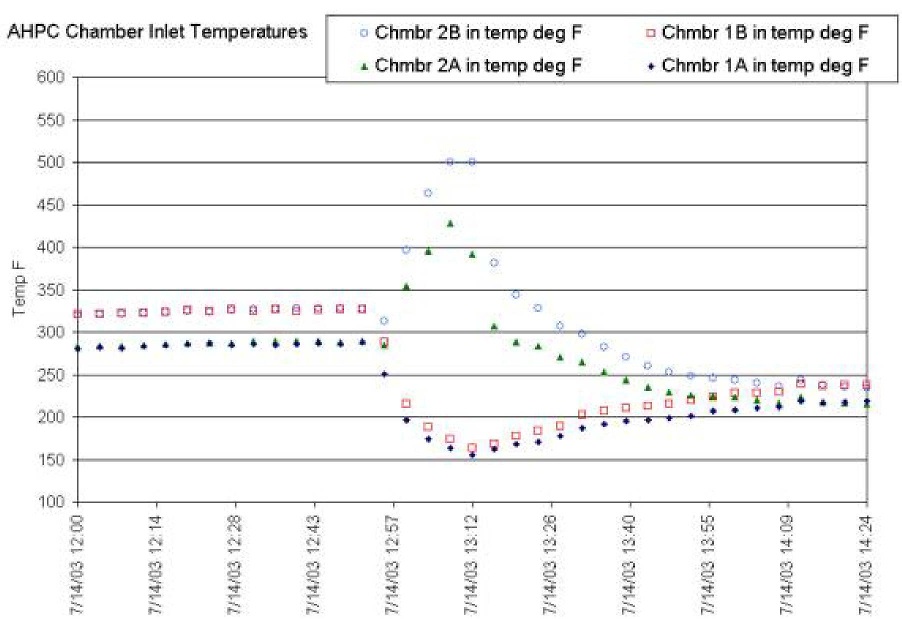


Specific Bag Failures

An exact number of failed bags is not known. The failing bags were the PPS bags with the PPS scrim. The reasons for failures appear to be the weakening of the strength of the fibers and cleaning pulsing. The temperature is likely the primary factor in weakening the bag material. The compartments of PPS bags with the most failures to the least failures are ranked in this order

1. Chamber 1B Field 3 (most failures)
2. Chamber 1B Field 4
3. Chamber 2B Field 4
4. Chamber 2A Field 4

The PPS bags in Chamber 1A appear to have few, if any, failures. The all-ptfe bags had no failures, and the PPS bags with the rastek scrim show only a few failures occurring in chamber 2B. There is an operating temperature difference between the chambers due to the regenerative style air preheater used to transfer heat from the flue gas to incoming air. As a result, 1B & 2B chambers operate approximately 20 degrees higher average temperature than 1A & 2A. This would logically explain why the compartments in chambers 1B and 2B have the most failures of PPS bags. However, the failures that occurred in Chamber 2A don't seem to follow this same pattern. A likely contributing factor to these failures was a high temperature event experienced in July 2003. During a plant trip, a failure of the air heater system caused a short-term temperature excursion. The temperatures into Chambers 2A & 2B exceeded the 375 degrees rating of the



PPS bags for about fifteen minutes.

Bag Replacement Decisions

Some bag replacement was necessary during the scheduled boiler wash outage in December. A significant operational performance improvement was made with the decision to replace the original all-PTFE bags with PPS bags in June 2003. The original style bags would not likely be considered for replacement due to high differential pressure concerns. Only PTFE membrane bags were considered allowing the fundamental goal of 99.99% particulate removal to be maintained. We considered bags of the following materials for use in the Advanced Hybrid system:

- All PTFE (new)
- All PTFE (original bag washed outside the Advanced Hybrid system)
- P-84
- Nomex
- PPS with the rastek scrim
- Fiberglass
- Superflex^{TM}

The only bags with operational history were the all-PTFE bags and the PPS bags with the rastek scrim. Both of these options seemed questionable because of either high differential pressure issues (all-PTFE), or questionable reliability strength issues (PPS). We decided to install one compartment of P-84 bags into Chamber 2B field 4, one compartment of NOMEX bags into Chamber 1B field 4, and one compartment of original all-PTFE washed bags in Chamber 2A field 3. Approximately 1000 bags were washed in the Big Stone Plant turbine bay prior to the outage. Fortunately this was accomplished, because an unexpected outage extension of 7 days occurred (unrelated to the Advanced Hybrid system). The bags in a fourth compartment Chamber 2A field 4 were also replaced with original washed all-PTFE bags. Bags in four of the twelve compartments were replaced during the December boiler wash outage. For more description of the specific type and styles, see section 2.1.2 or Appendix B23.

Fluent Modeling Effort

During the previous quarter, an effort was undertaken by Fluent Inc. to model the gas flow dynamics of the system. This was attempted to gain a better understanding of where gas flow dynamics may be adversely affecting performance, and what could be done to improve performance. The most likely improvement was the installation of flow baffles to direct gas flow from the bottom more directly into the ESP zones of the Advanced Hybrid components. Preliminary results indicated approximately 15% of the flue gas flow could be entering the area directly beneath the bag rows and bypassing the ESP zone. The significance of this is fairly strong. If the flue gas passing through the ESP portion of the Advanced Hybrid system is being cleaned at a rate of 90%, and if 15% of the flue gas is bypassing this ESP zone with 100% of the ash loading, this would result in an overall ESP efficiency of only 76.5%. This may be better understood by taking the example of a loading rate of 1 grain/acf, and working through the potential ESP efficiency calculations. First, assume a true 90% ESP efficiency rate;

$$\text{Ash loading to bags} = 1 \text{ gr./acf} * (100\% - 90\%) = 0.1 \text{ gr./acf}$$

However, if the actual case is a 15% gas bypass of untreated flue gas, the result is;

$$\text{Ash loading to bags} = 85\% * (1 \text{ gr/acf} * (100\%\text{-}90\%)) + 15\% *((1\text{gr/acf} * (100\%)) = 0.235 \text{ gr/acf}$$

This would mean a loading rate to the bags nearly 2.4 times the estimated rate of an ESP efficiency of 90%. This level of change would be needed to approach the loading rate demonstrated in the pilot unit. The full-scale unit loading rate is nearly four times the loading rate of the pilot unit.

Unfortunately, final modeling results were not available at the time baffles needed to be ordered for installation during the December boiler wash outage. Otter Tail Power Company personnel decided to purchase and install 3 sets of these baffles to allow an operational evaluation. The only reliable information in this limited format would be issues associated with installation and with operation (specifically whether or not the baffles plugged with ash during operation).

Three sets of baffles were designed by and purchased from Southern Environmental Inc. Installation was accomplished with Big Stone plant personnel. Some difficulties during installation were noted and modifications will be made if more baffles are ordered. A picture of the baffles is included in the Appendix.

A section of pitot tubes was installed across the bags with these baffles, but limited data and analysis is expected due to such a small number of baffles.

<u>Blowpipe Modifications</u>

Big Stone plant personnel modified one of the existing blowpipes so a single pulse valve pulsed 19 bags instead of 10. This was accomplished in a forward-looking manner, as there may be reasons in the future to modify the system to remove the stacked blowpipe arrangement. This arrangement has caused a definite increase in bag replacement costs when compared to a standard baghouse arrangement with no stacked blowpipes. If successful, this would lower the cost of the existing system by reducing the required headers, pulse valves, control system and pulse pipes by half.   There may also be an improvement in performance, as all the valves could be cycled through in half the time. Assuming an equal cleaning efficiency per pulse, this could result in a lower residual drag. Lastly, there is evidence that we are still over-cleaning the bags, indicated by an increased rate of bag failure on the short blow tubes as compared to the long blow tubes. A picture of this blow tube is included in the Appendix. The Big Stone Plant pitot instrumentation will be placed on the bags on this tube and some analysis may be possible.

4.0 CONCLUSIONS

The four fundamental performance parameters of the Advanced hybrid system are;

- Opacity (Appendix B8)
- Air-to-cloth ratio (Appendix B7)
- Tubesheet dP (Appendix B5)
- Compressed air flow (Appendix B22)

Opacity has increased this quarter due to the failure of the PPS bags installed in June 2003. The most likely factor contributing to the failures are temperatures nearing the operational limit of the material (375 degrees). After the failed bags were replaced during the scheduled December boiler wash, opacity returned to the historical levels of approximately 1-2%.

The A/C ratio has remained at approximately 11.5 fpm, although it dropped slightly to just under 11 fpm after the outage due to cooler gas temperatures into the Advanced Hybrid system.

Tubesheet differential pressure has declined during the period due to cooler gas temperatures into the system, as well as new bags installed during the outage.

Compressed air usage remained high during the first half of the quarter, but recovered fairly well in the weeks prior to the outage. Usage after the outage appears to be at a record low, with consistent readings less than 500 acfm.

<u>General Conclusions</u>

The failing of the PPS bags was an unfortunate development in the demonstration of this technology. More work with regards to the proper bag selection will be needed. Proper weighting of the strength resilience versus the gas flow resistance should be evaluated.

5.0 APPENDICES

APPENDIX A - COMMENTS ON ANOMALIES OF GRAPHICAL DATA

Appendix B5 & B6. The initial dP data was not historized correctly, so the first couple of days of dP history do not exist in the Plant Historian.

Appendix B19. Significant increases in Chamber Power typically indicate periods where the initial inlet field was energized, although spikes also occur during periods of reduced loading on the unit.

Appendix B17. Right hand column of units is incorrect. The ug/g unit is correct, but this is not a direct percent.

Appendix B8. Opacity Graph shows two spikes in the opacity reading that were not real (1/15/2003 & 3/1/2003). These spikes were instrumentation failures and/or calibrations.

Appendix B8. Opacity graph shows spikes around 6/10/2003. These are instrument difficulties, and not representative of actual opacity.

Appendix B15. bam, ebm, etc. are Powder River Basin mine codes

Appendix B14 & 15. The "adjustment" refers to an end of the month correction based on a comparison between visual levels and bookkeeping levels.

Appendix B21. Pulse counter graph seems to indicate no pulsing after the June 12, 2003 startup until the end of June. However, the scale is so large and the pulse cycle frequency was so insignificant, that it cannot be seen as a clear increase until the next quarter. The number of pulse cycles by June 30,2003 was 284.

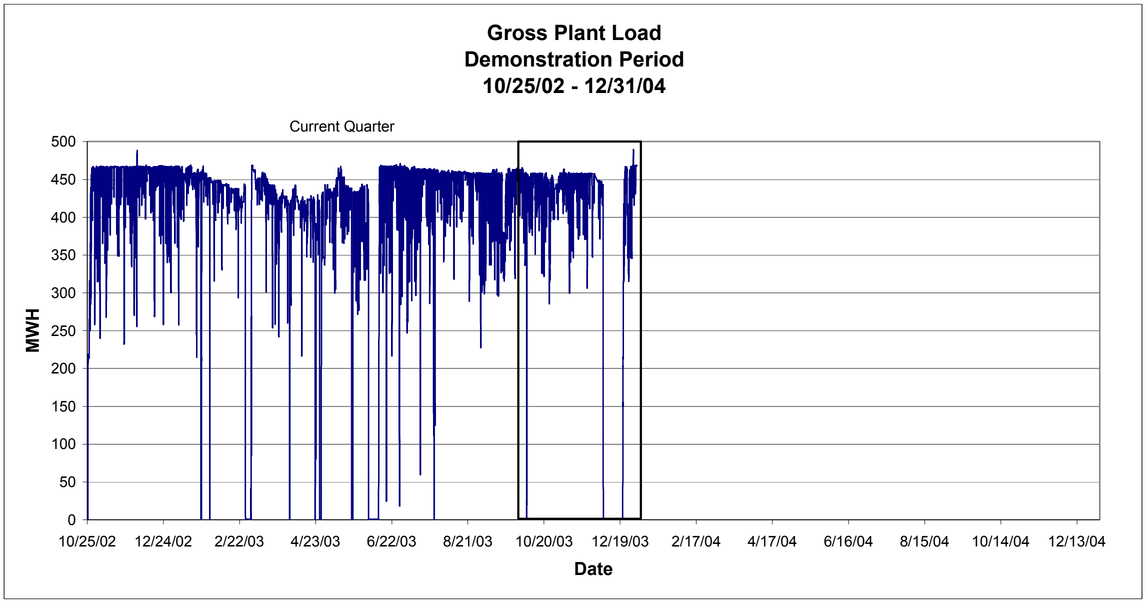
Appendix B2, B3 & B7. Low stack flow readings around 7/21/2003 are instrument problems and not real readings. As can be seen in B1, the plant was on-line and operating during the indicated period of no flow.

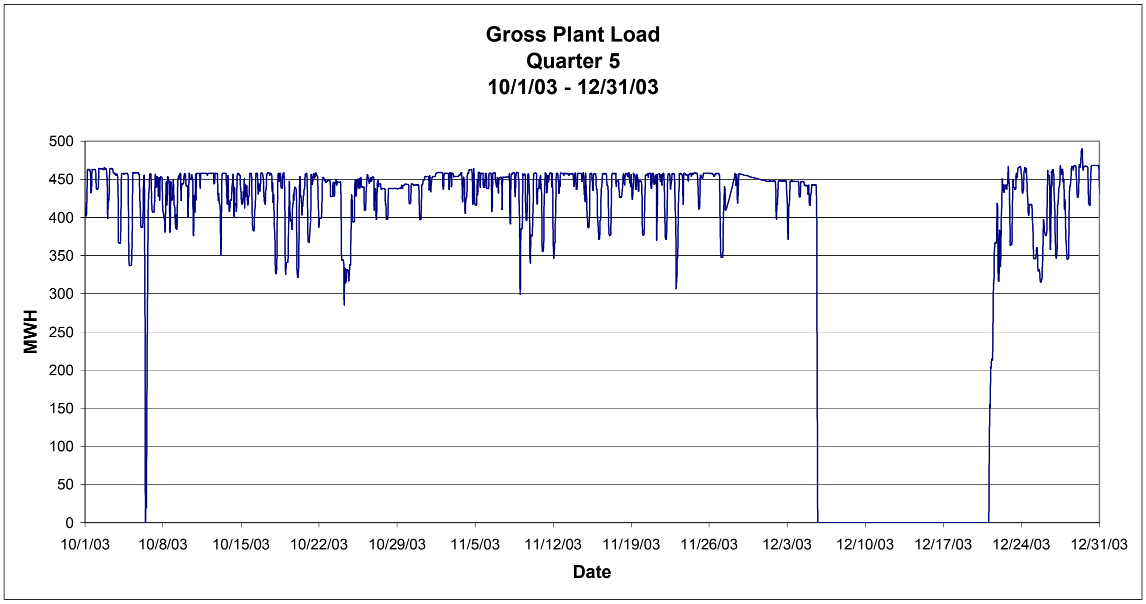
Appendix B8. Opacity spikes around 7/21/2003 and 9/23/2003 are instrument problems and not representative of actual high opacity.

Appendix B8. During the plant outage, (the period represented approximately 12/4/2003 – 12/9/2003 on the graph), the opacity is out of scale because it was removed from the plant stack and a "clear stack" calibration was performed in a clean environment. So the data from that period is not valid.

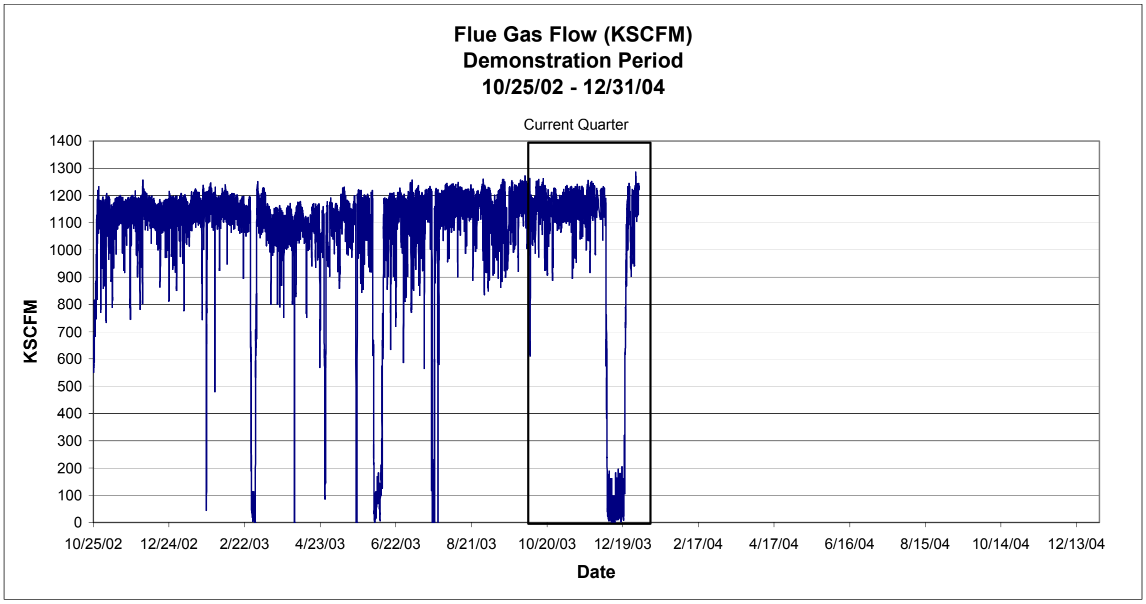
APPENDIX B – GRAPHICAL & TABULAR PERFORMANCE DATA

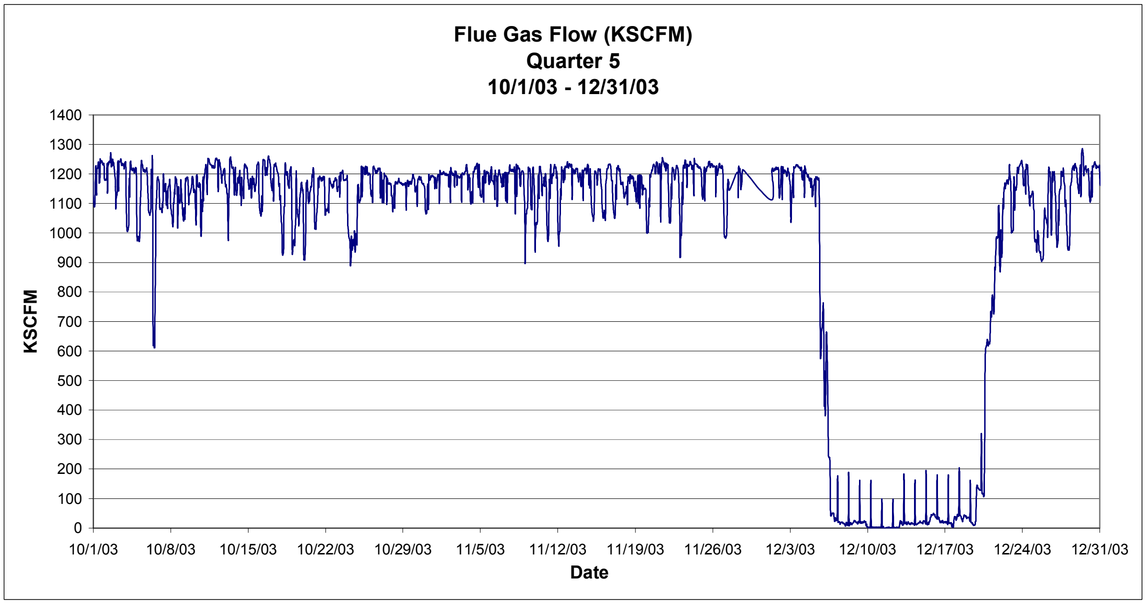
B1 Gross Plant Load



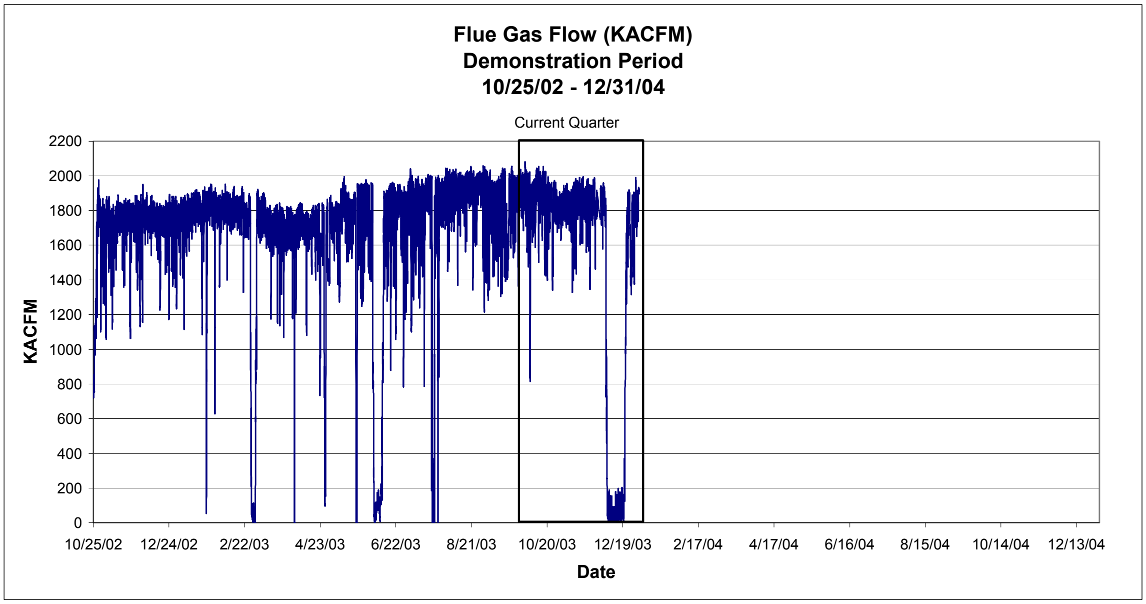


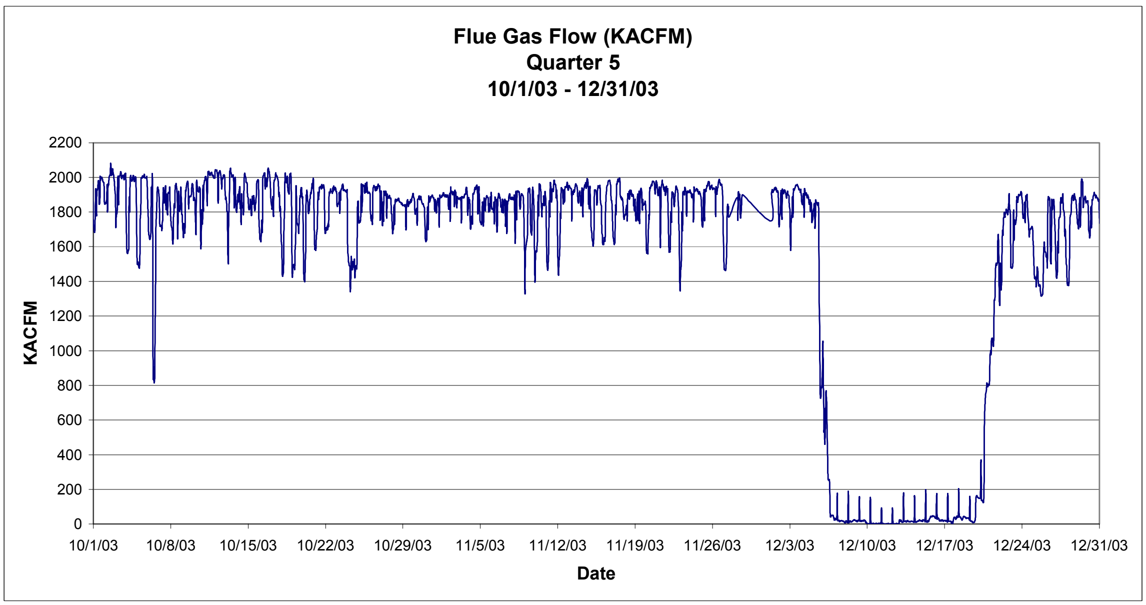
B2 Flue Gas Flow (KSCFM)



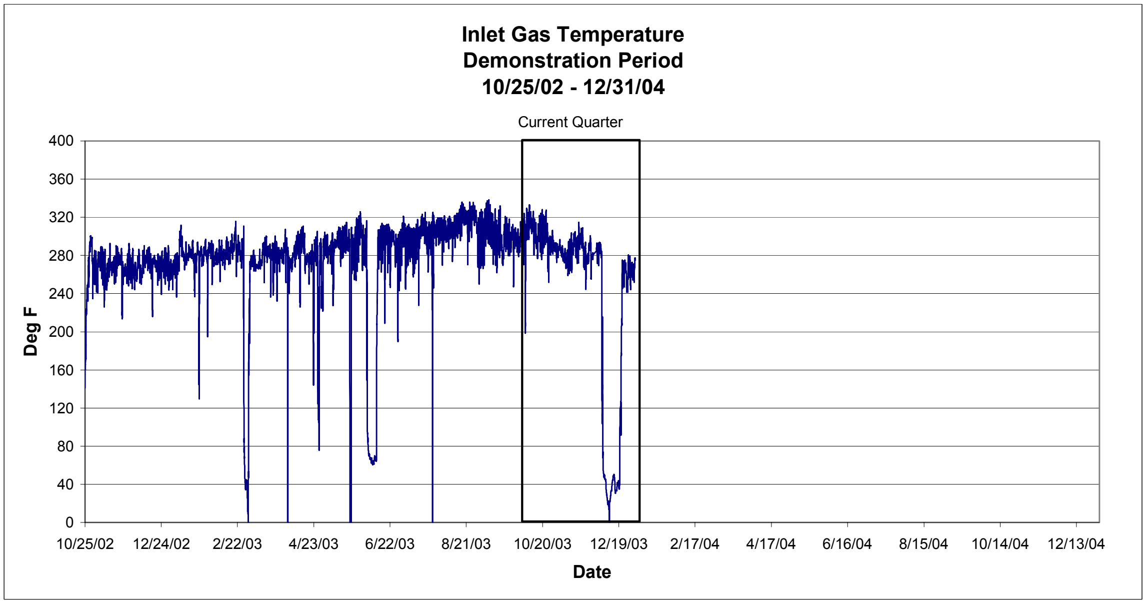


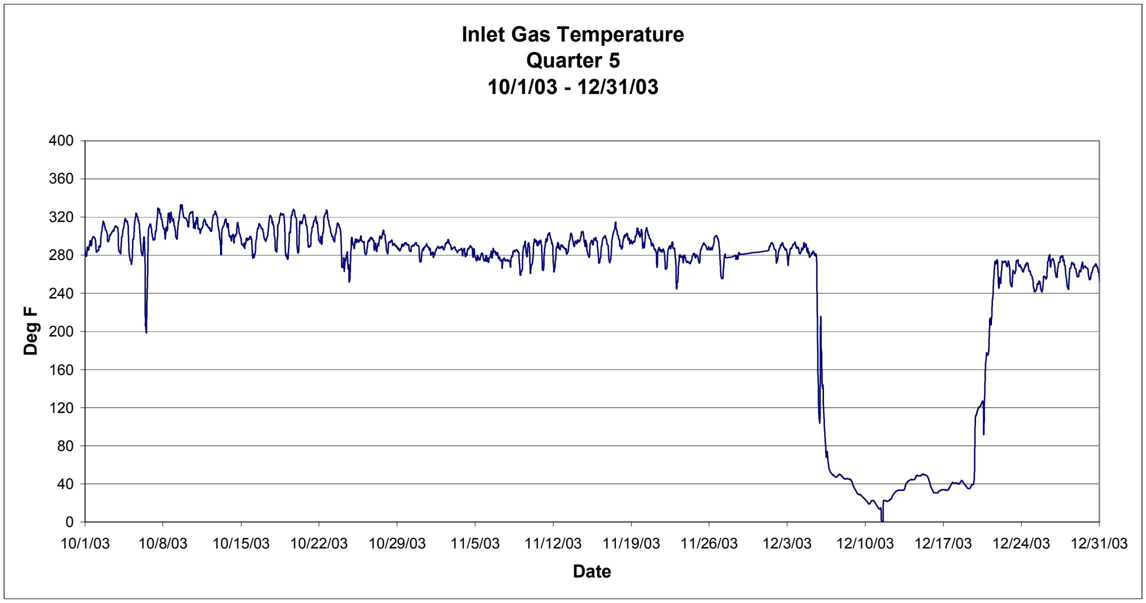
B3 Flue Gas Flow (KACFM)



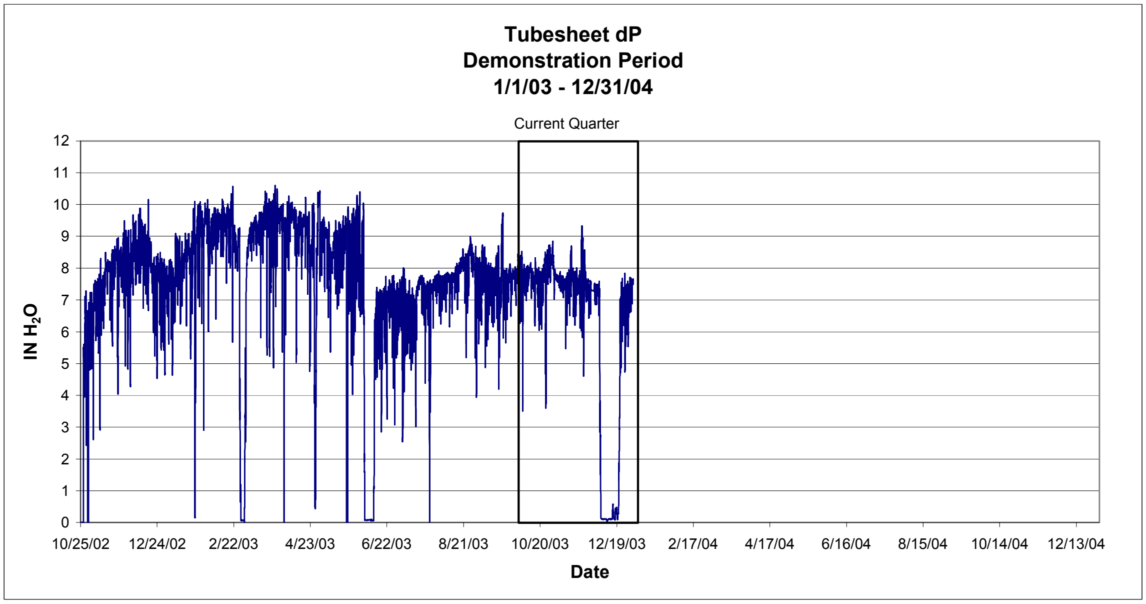


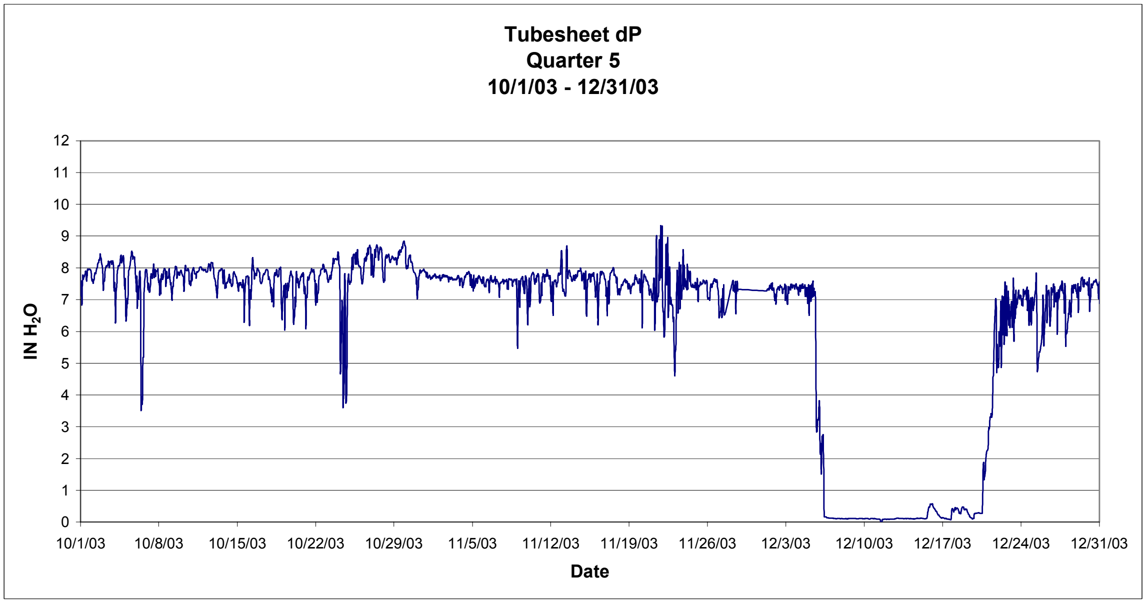
B4 Inlet Gas Temperature



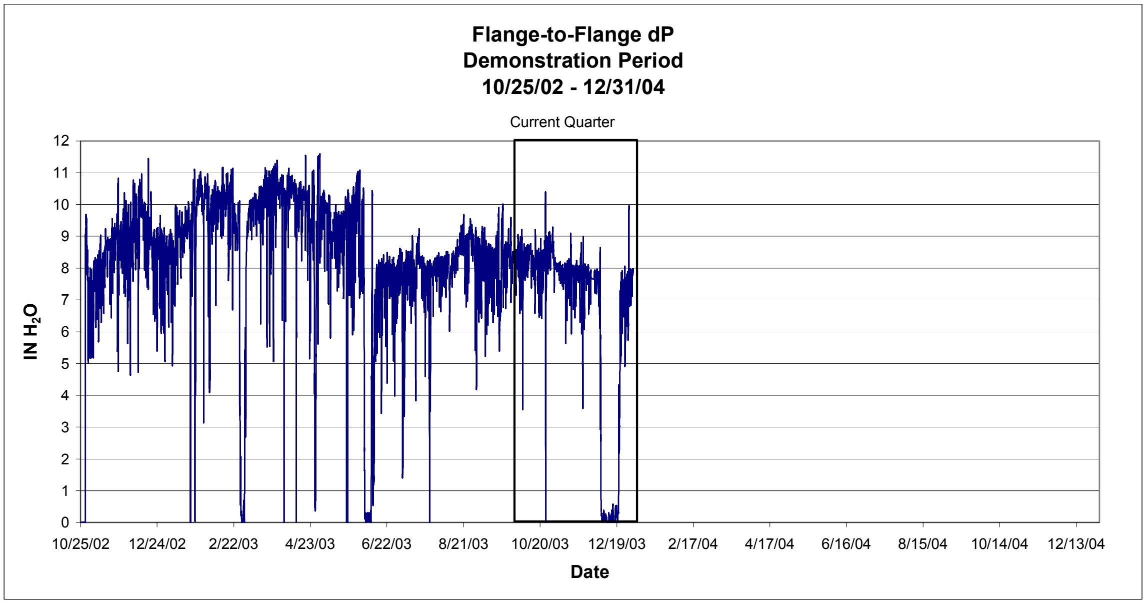


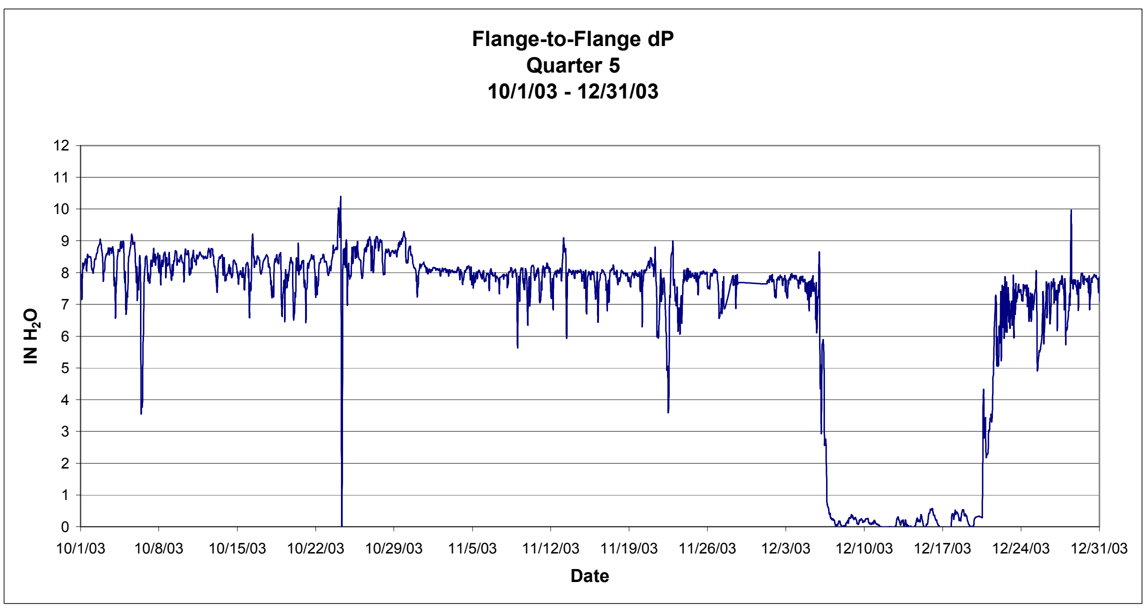
B5 Tubesheet dP



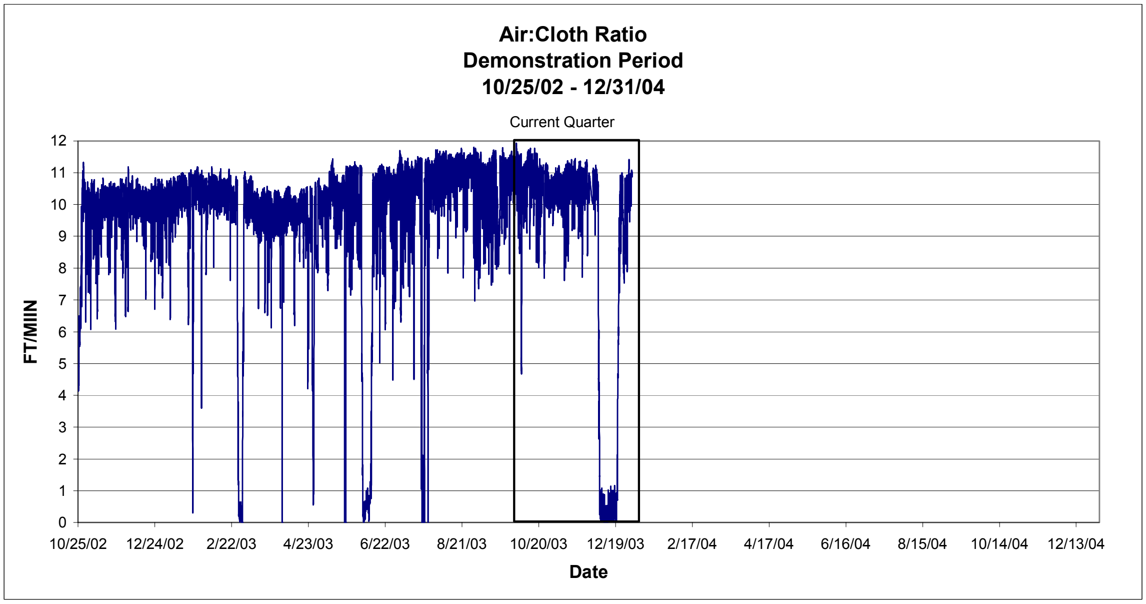


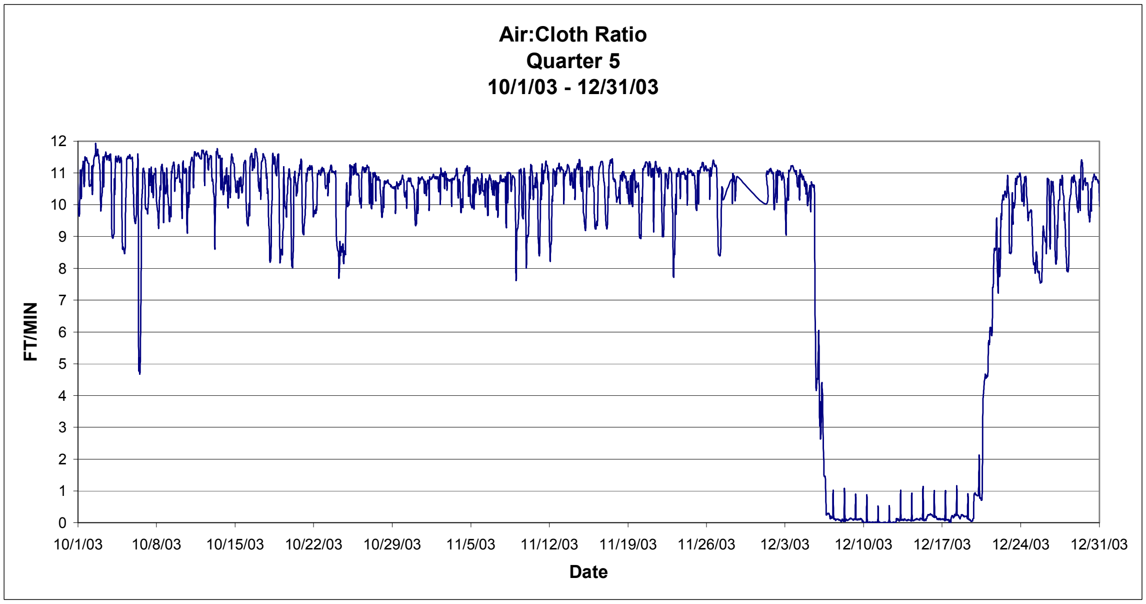
B6 Flange-to-Flange dP



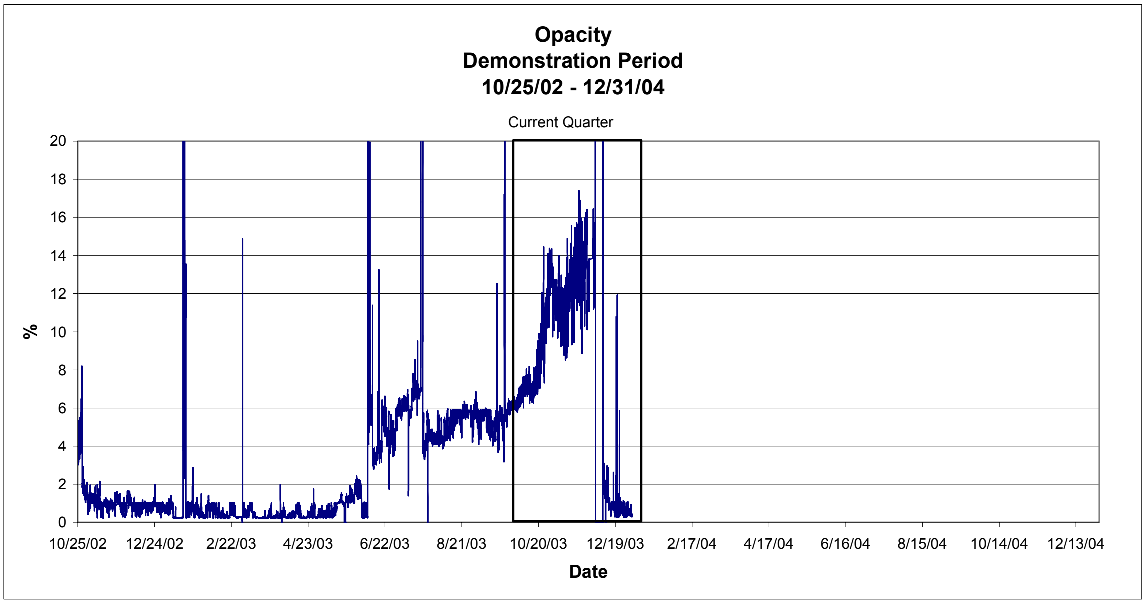


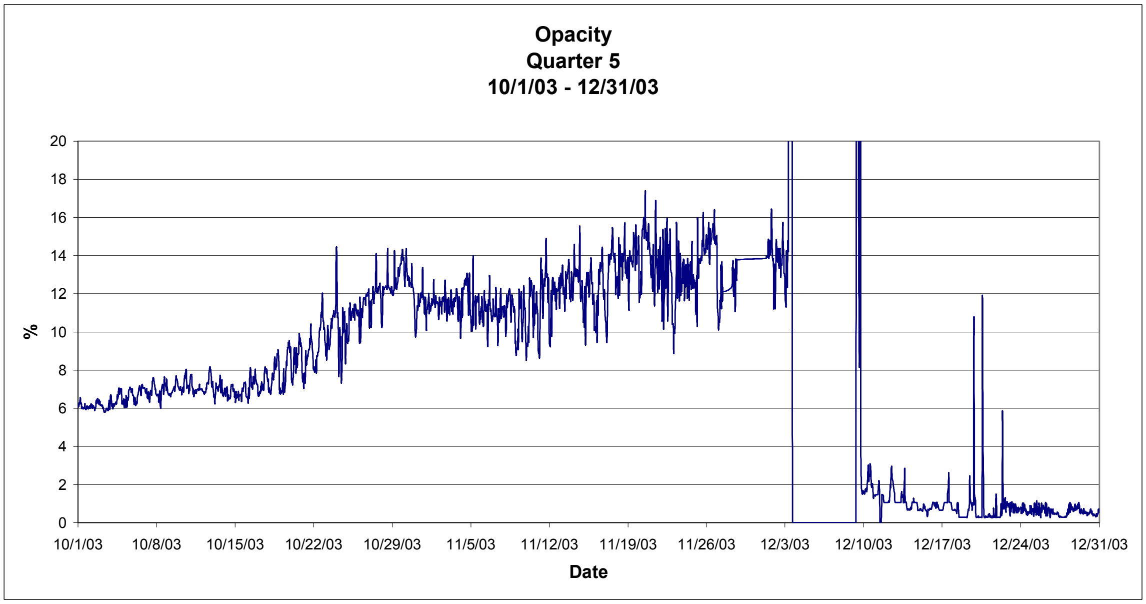
B7 Air-to-Cloth Ratio



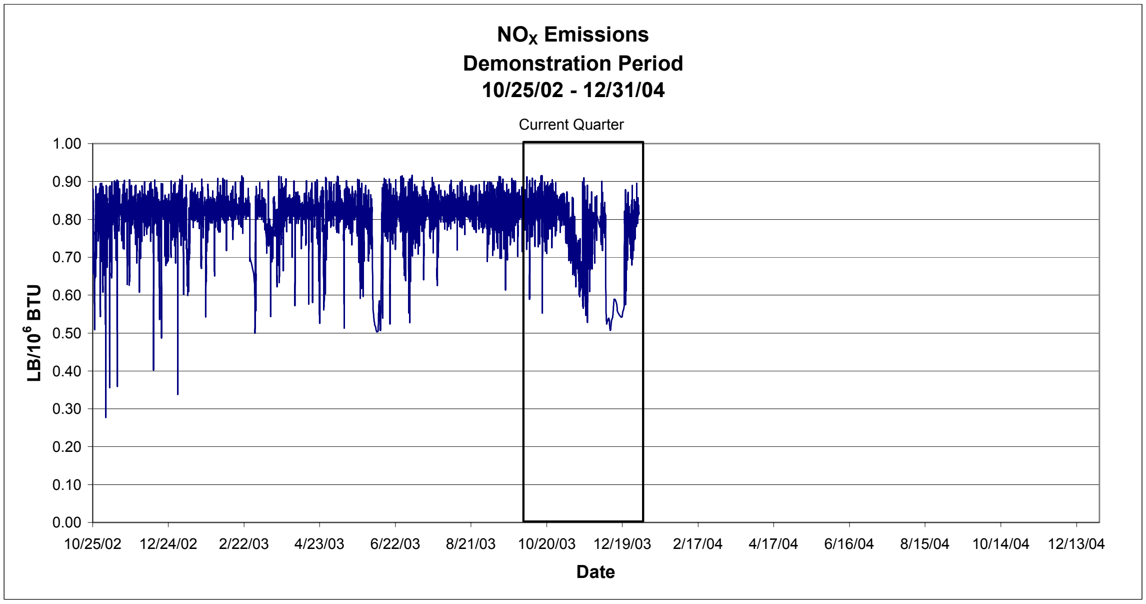


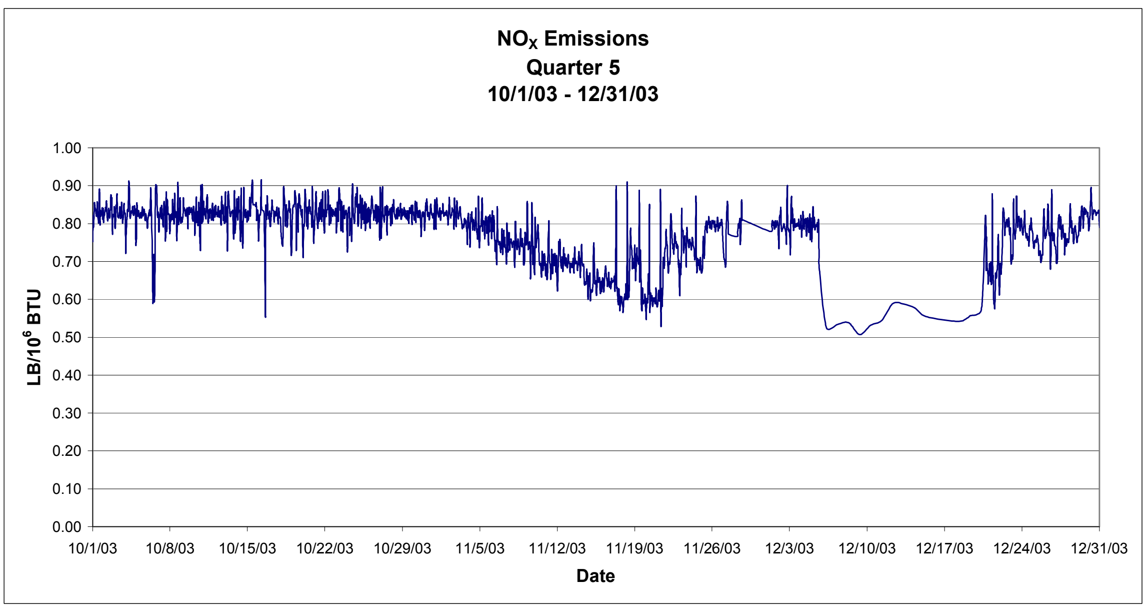
B8 Opacity


Opacity
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
%
0
2
4
6
8
10
12
14
16
18
20
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date

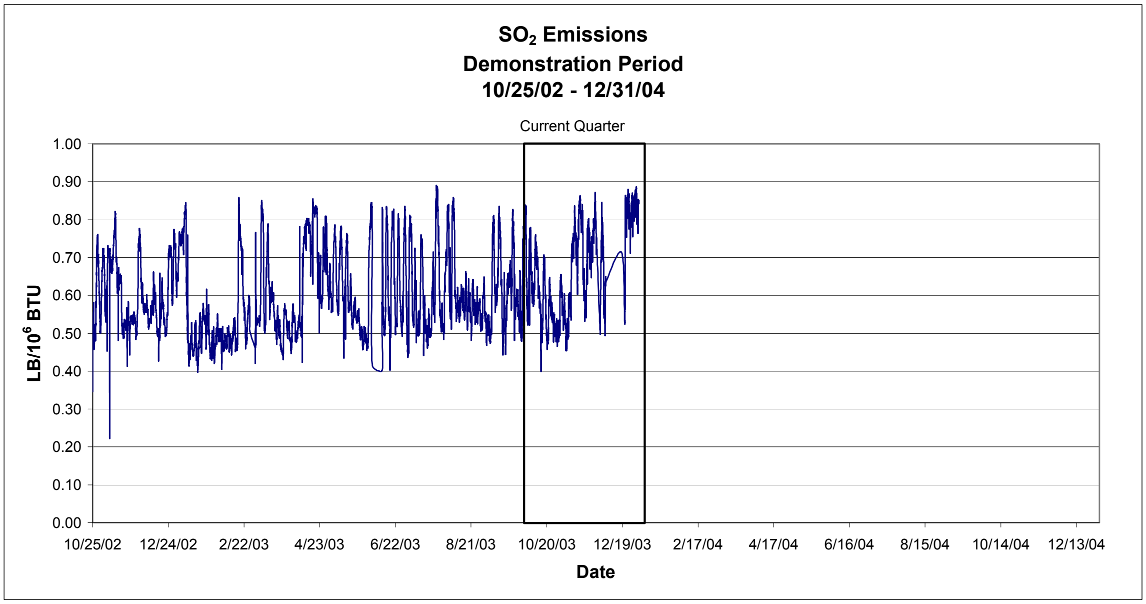

Opacity
Quarter 5
10/1/03 - 12/31/03
%
0
2
4
6
8
10
12
14
16
18
20
10/1/03
10/8/03
10/15/03
10/22/03
10/29/03
11/5/03
11/12/03
11/19/03
11/26/03
12/3/03
12/10/03
12/17/03
12/24/03
12/31/03
Date

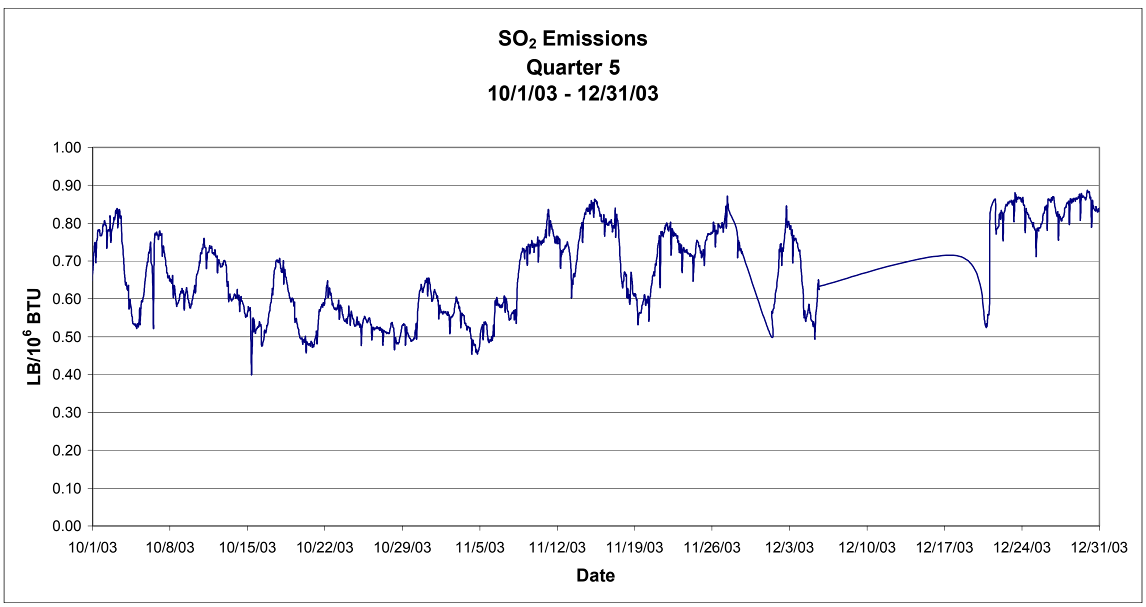
B9 NO_X Emissions



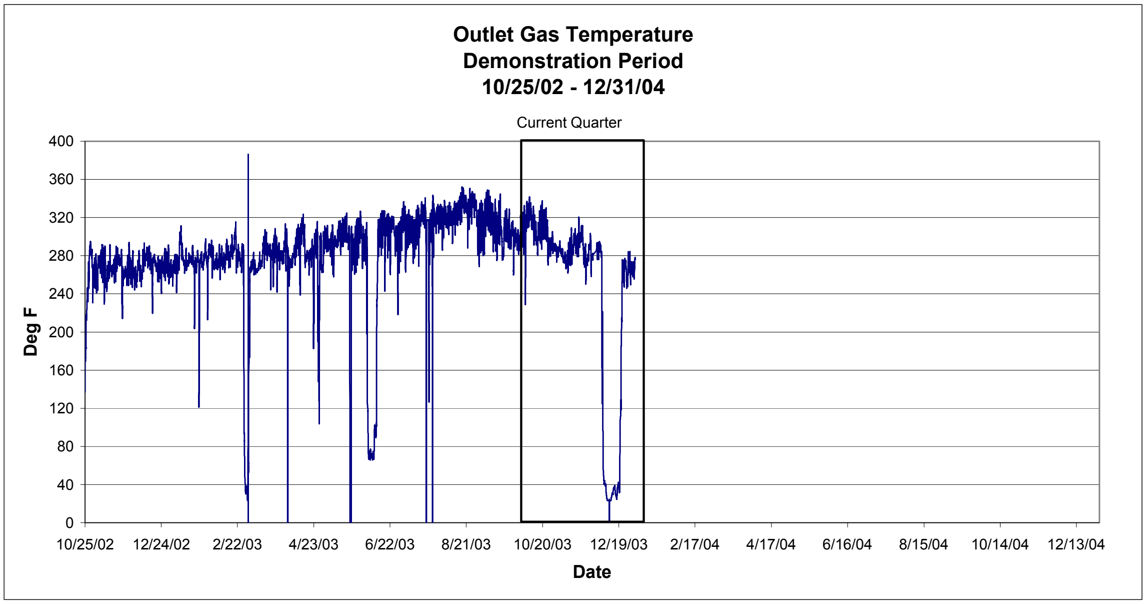


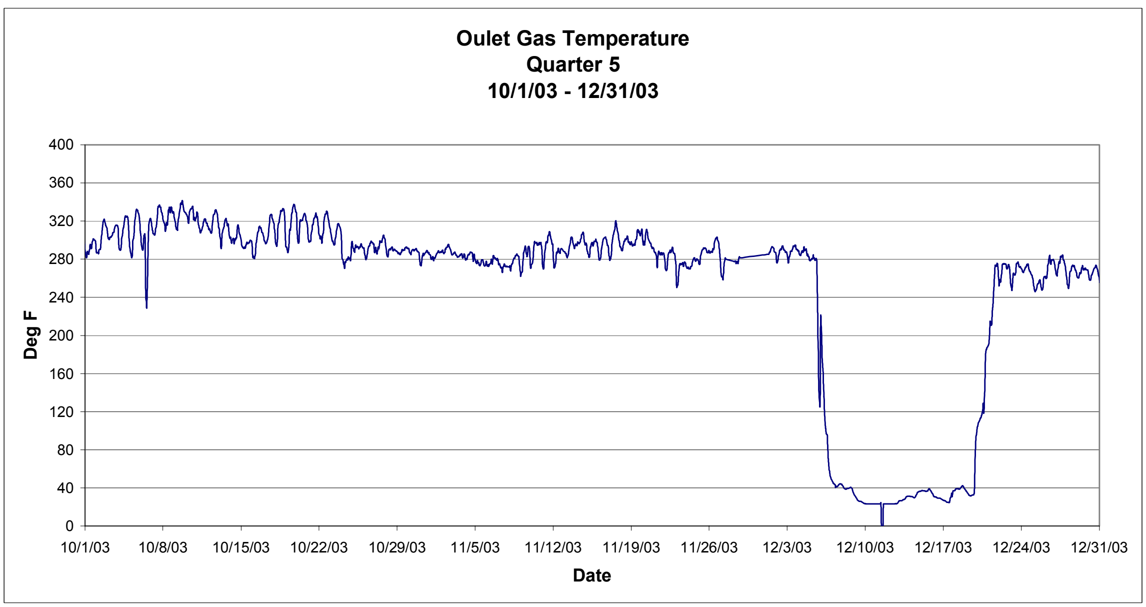
B10 SO_2 Emissions



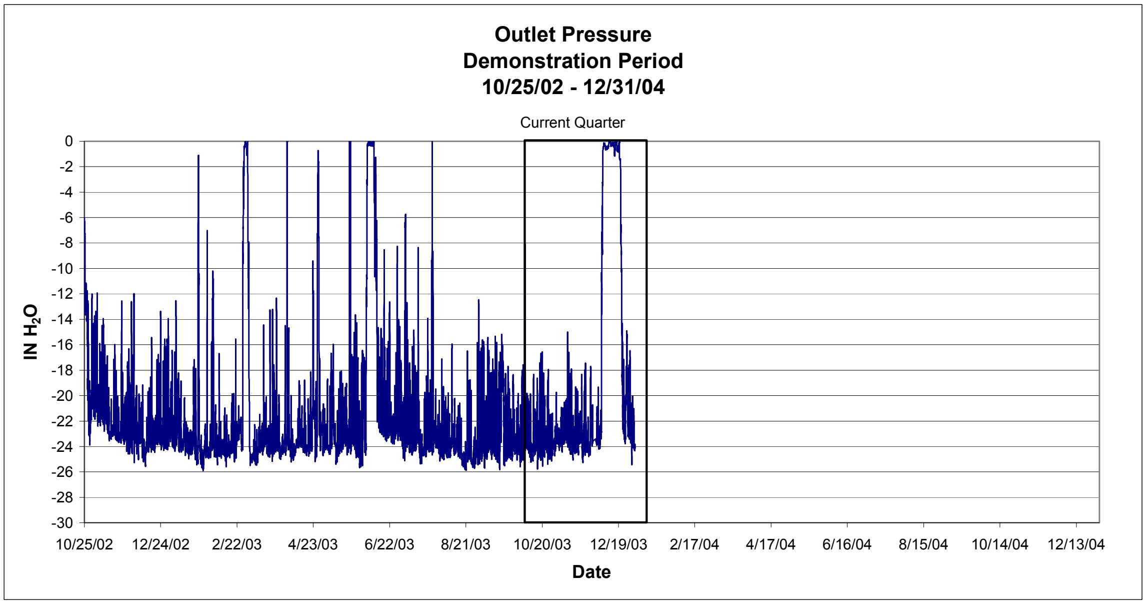


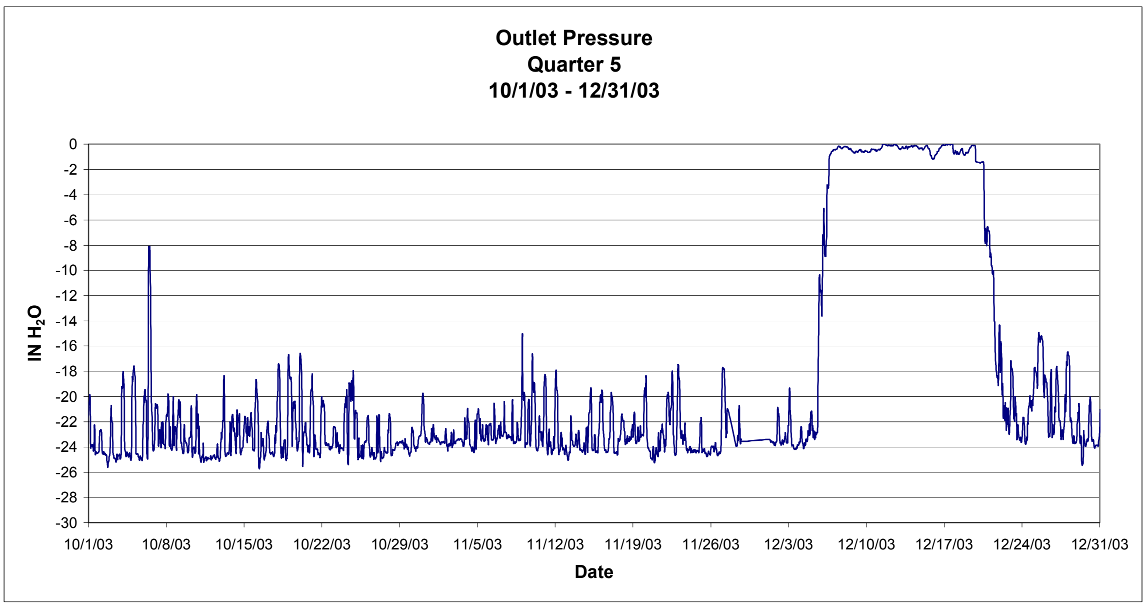
B11 Outlet Gas Temperature



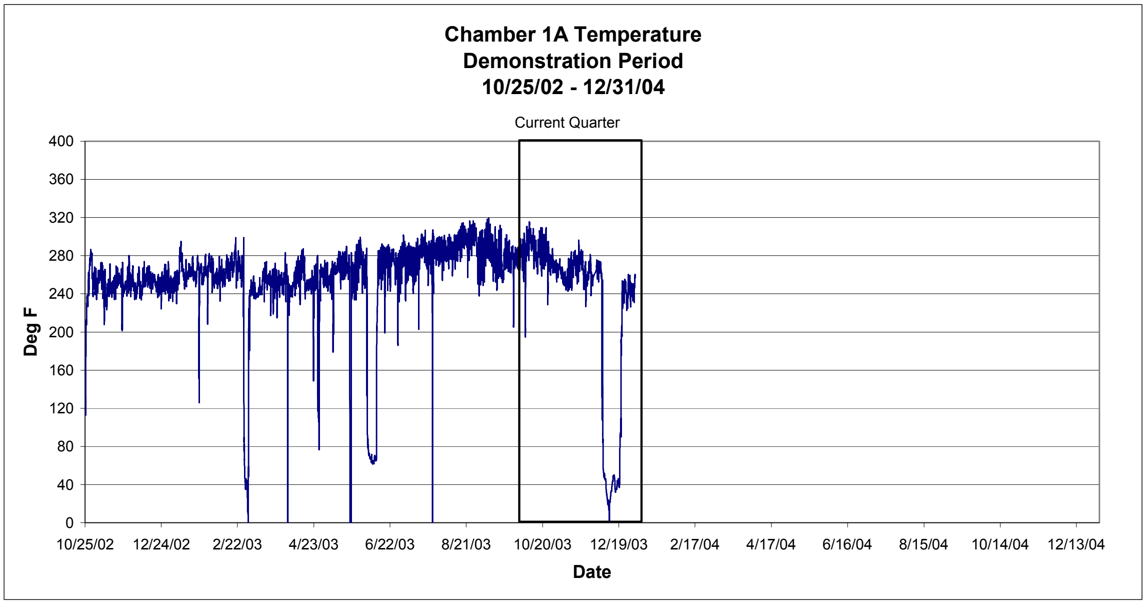


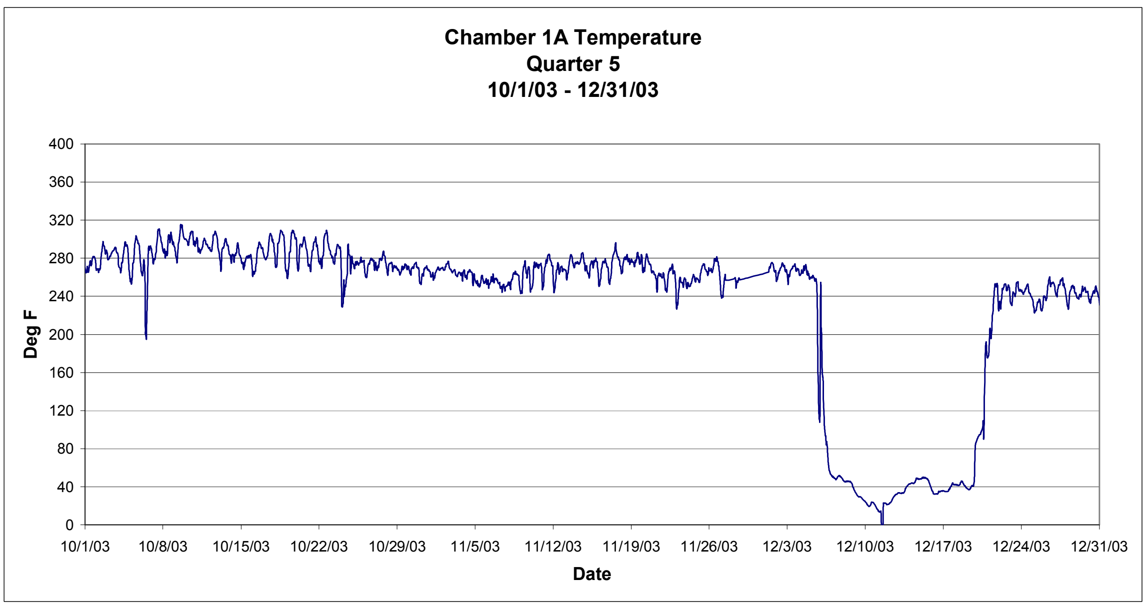
B12 Outlet Pressure

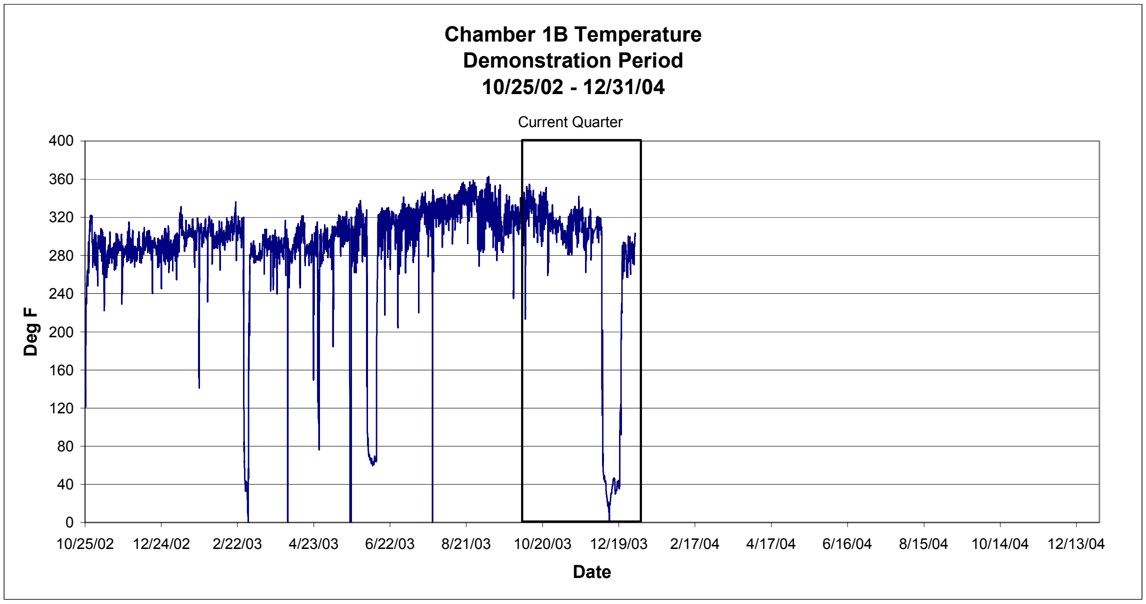


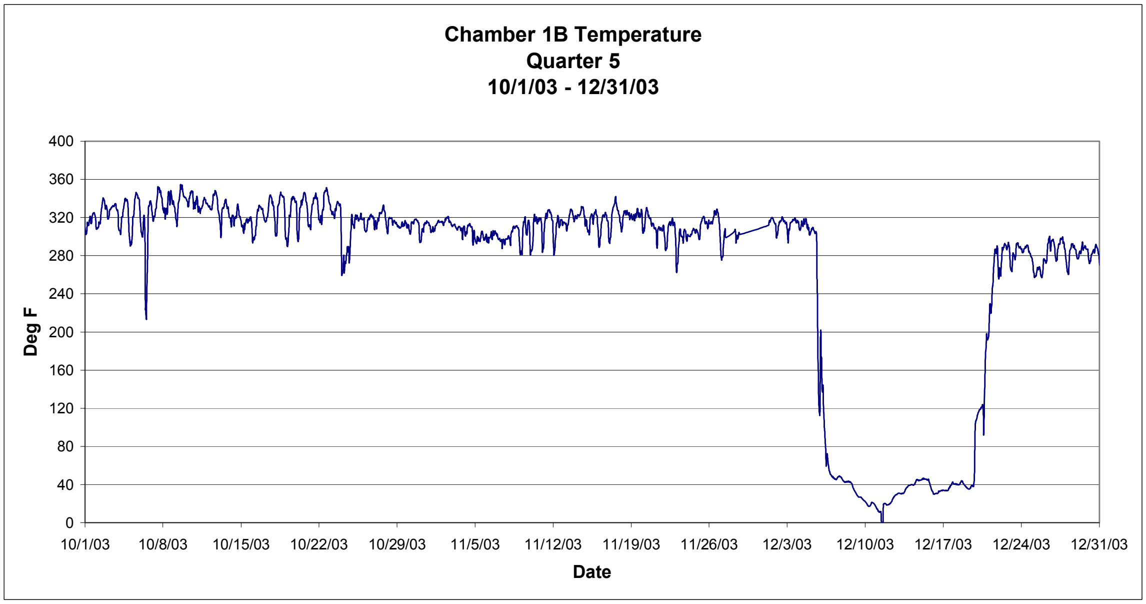


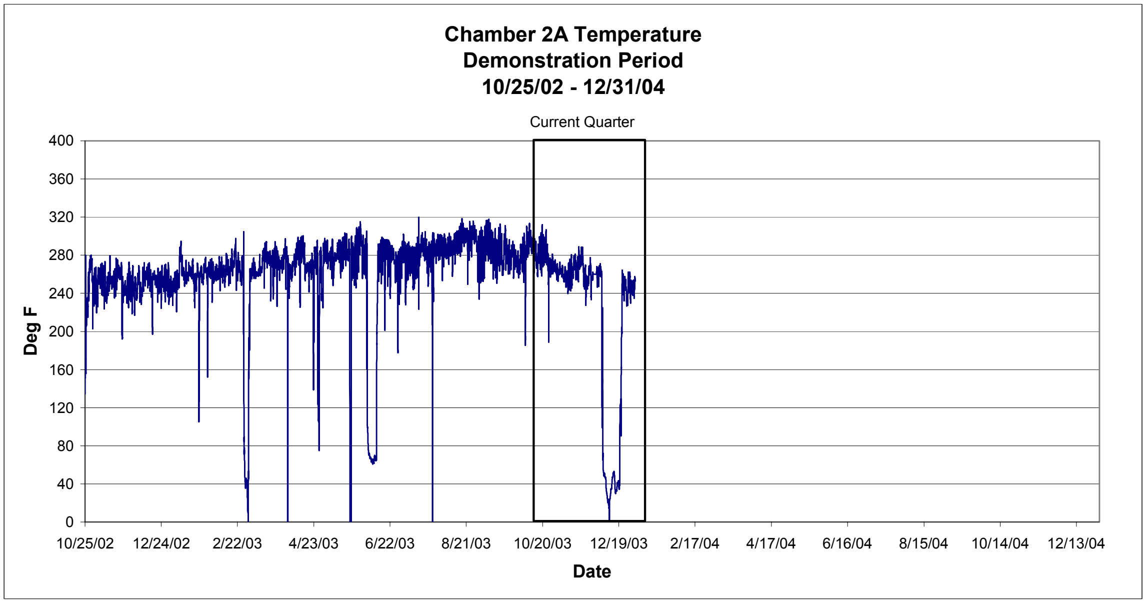
B13 Temperature per Chamber

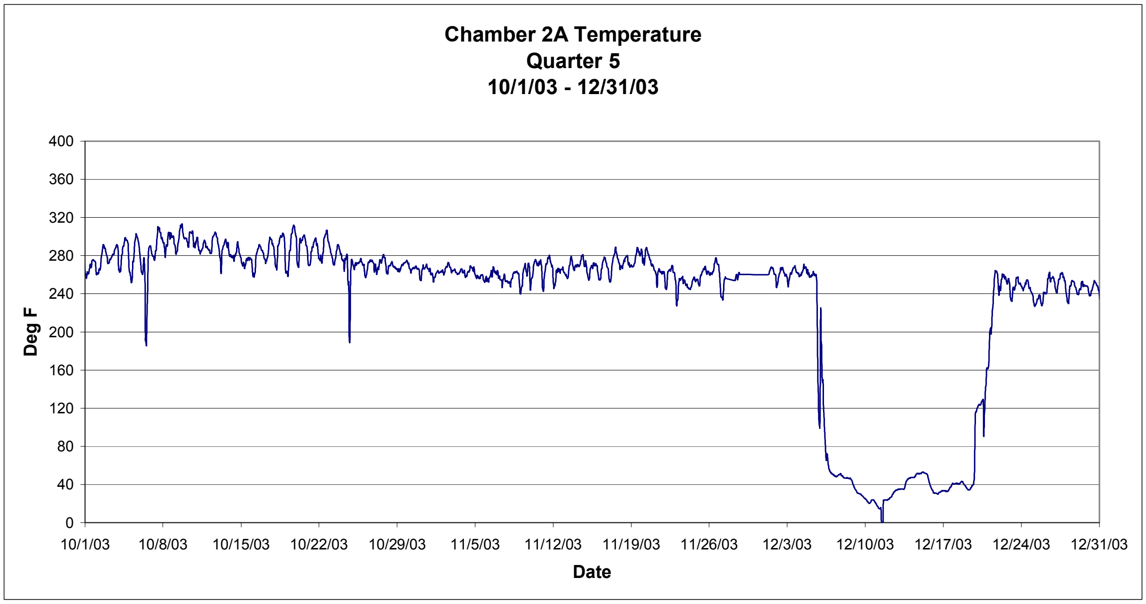


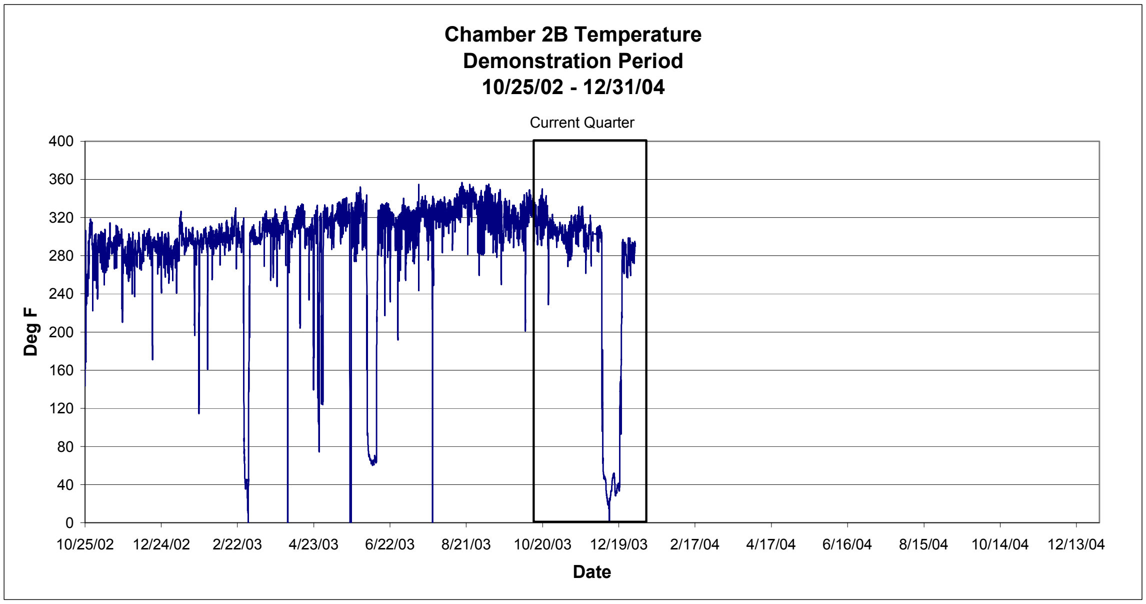


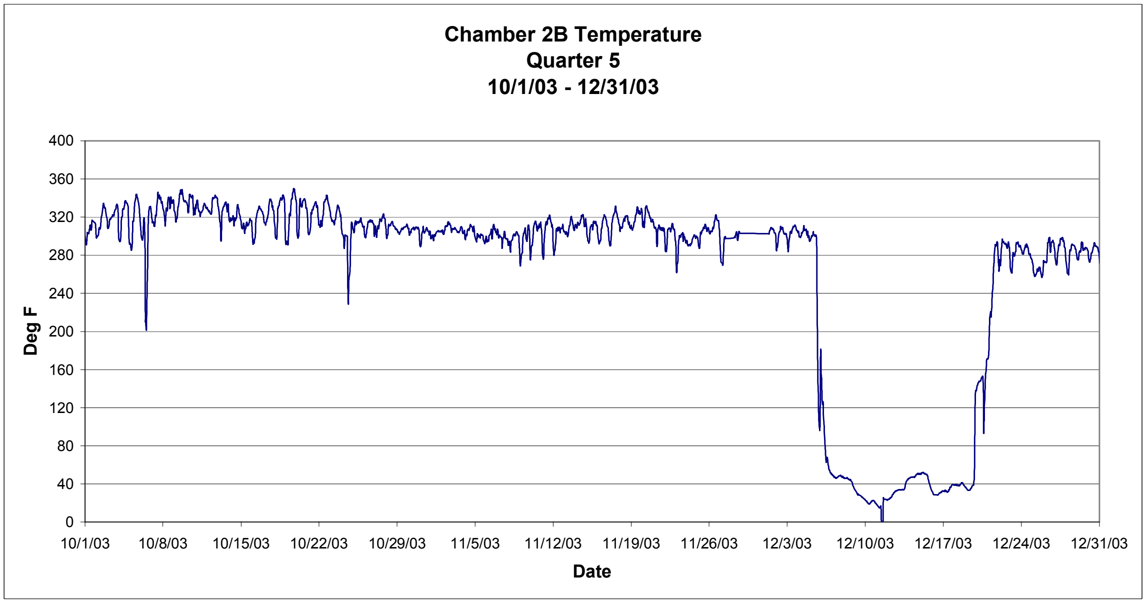

Chamber 1B Temperature
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
400
360
320
280
240
200
160
120
80
40
0
Deg F
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date


Chamber 1B Temperature
Quarter 5
10/1/03 - 12/31/03
400
360
320
280
240
200
160
120
80
40
0
Deg F
10/1/03
10/8/03
10/15/03
10/22/03
10/29/03
11/5/03
11/12/03
11/19/03
11/26/03
12/3/03
12/10/03
12/17/03
12/24/03
12/31/03
Date


Chamber 2A Temperature
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
Deg F
Date
400
360
320
280
240
200
160
120
80
40
0
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04


Chamber 2A Temperature
Quarter 5
10/1/03 - 12/31/03
Deg F
Date
400
360
320
280
240
200
160
120
80
40
0
10/1/03
10/8/03
10/15/03
10/22/03
10/29/03
11/5/03
11/12/03
11/19/03
11/26/03
12/3/03
12/10/03
12/17/03
12/24/03
12/31/03


Chamber 2B Temperature
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
Deg F
400
360
320
280
240
200
160
120
80
40
0
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date


Chamber 2B Temperature
Quarter 5
10/1/03 - 12/31/03
Deg F
400
360
320
280
240
200
160
120
80
40
0
10/1/03
10/8/03
10/15/03
10/22/03
10/29/03
11/5/03
11/12/03
11/19/03
11/26/03
12/3/03
12/10/03
12/17/03
12/24/03
12/31/03
Date

B14 Fuel Burn Record

BIG STONE PLANT
FUEL BURN RECORD
Oct-03

DATE	Coal	P. Coke	TDF	Waste Seeds	Toner	Gran. Insul.	Canvas Belting	Plastic Chips
	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)
1-Oct-03	6,319.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2-Oct-03	6,536.17	0.00	45.23	0.00	0.00	0.00	0.00	0.00
3-Oct-03	6,161.23	0.00	296.40	86.67	0.00	0.00	0.00	0.00
4-Oct-03	6,153.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-Oct-03	6,127.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-Oct-03	4,974.05	0.00	147.85	0.00	0.00	0.00	0.00	0.00
7-Oct-03	5,985.37	0.00	119.23	0.00	0.00	0.00	0.00	0.00
8-Oct-03	5,818.22	0.00	122.59	23.79	0.00	0.00	0.00	0.00
9-Oct-03	5,941.70	0.00	100.00	25.00	0.00	0.00	0.00	0.00
10-Oct-03	6,004.76	0.00	95.84	125.00	0.00	0.00	0.00	0.00
11-Oct-03	6,554.80	0.00	0.00	125.00	0.00	0.00	0.00	0.00
12-Oct-03	6,555.37	0.00	0.00	103.33	0.00	0.00	0.00	0.00
13-Oct-03	6,034.57	0.00	96.92	68.61	0.00	0.00	0.00	0.00
14-Oct-03	6,098.22	0.00	92.88	0.00	0.00	0.00	0.00	0.00
15-Oct-03	5,814.86	0.00	120.71	220.33	0.00	0.00	0.00	0.00
16-Oct-03	6,119.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17-Oct-03	6,173.77	0.00	146.93	0.00	0.00	0.00	0.00	0.00
18-Oct-03	5,794.62	0.00	144.46	98.92	0.00	0.00	0.00	0.00
19-Oct-03	5,757.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20-Oct-03	5,855.49	0.00	120.98	41.93	0.00	0.00	0.00	0.00
21-Oct-03	6,047.70	0.00	69.50	16.10	0.00	0.00	0.00	0.00
22-Oct-03	6,050.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23-Oct-03	6,053.61	0.00	73.99	0.00	0.00	0.00	0.00	0.00
24-Oct-03	4,424.76	0.00	151.22	149.32	0.00	0.00	0.00	0.00
25-Oct-03	6,050.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26-Oct-03	6,437.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27-Oct-03	5,984.16	0.00	71.57	71.57	0.00	0.00	0.00	0.00
28-Oct-03	5,872.19	0.00	95.15	49.26	0.00	0.00	0.00	0.00
29-Oct-03	6,055.15	0.00	95.25	22.40	0.00	0.00	0.00	0.00
30-Oct-03	5,880.57	0.00	118.97	117.46	0.00	0.00	0.00	0.00
31-Oct-03	5,939.92	0.00	141.81	145.87	0.00	0.00	0.00	0.00
Adjustment	6,000.00							
Total Burned	191,576.46	0.00	2,467.48	1,490.56	0.00	0.00	0.00	0.00
Total Delivered	209,506.85	0.00	2,467.48	1,490.56	0.00	0.00	0.00	0.00
HHV	8630	0	15000	7187	0	0	0	0
% Ash	4.83%	0.00%	7.04%	1.10%	0.00%	0.00%	0.00%	0.00%
Tons Ash	9,245.59	0.00	51.48	12.52	0.00	0.00	0.00	0.00

BIG STONE PLANT
FUEL BURN RECORD
Nov-03

DATE	Coal	P. Coke	TDF	Waste Seeds	Toner	Coyote Lignite	Canvas Belting	Plastic Chips
	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)
1-Nov-03	6,484.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2-Nov-03	6,474.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-Nov-03	6,412.21	0.00	25.77	46.72	0.00	0.00	0.00	0.00
4-Nov-03	6,243.01	0.00	144.47	46.62	0.00	0.00	0.00	0.00
5-Nov-03	6,174.34	0.00	50.92	122.44	0.00	0.00	0.00	0.00
6-Nov-03	6,346.40	0.00	49.08	22.32	0.00	0.00	0.00	0.00
7-Nov-03	6,248.46	0.00	71.89	146.85	0.00	0.00	0.00	0.00
8-Nov-03	6,498.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-Nov-03	6,083.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10-Nov-03	6,156.57	0.00	116.35	99.78	0.00	0.00	0.00	0.00
11-Nov-03	6,259.45	0.00	47.69	21.96	0.00	0.00	0.00	0.00
12-Nov-03	6,308.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13-Nov-03	6,683.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14-Nov-03	6,373.22	0.00	45.69	209.89	0.00	0.00	0.00	0.00
15-Nov-03	6,382.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16-Nov-03	6,384.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17-Nov-03	6,274.89	0.00	98.81	0.00	0.00	0.00	0.00	0.00
18-Nov-03	6,086.07	0.00	166.07	26.16	0.00	71.00	0.00	0.00
19-Nov-03	6,099.04	0.00	123.90	69.86	0.00	0.00	0.00	0.00
20-Nov-03	6,122.30	0.00	100.00	25.00	0.00	0.00	0.00	0.00
21-Nov-03	6,488.06	0.00	0.00	94.94	0.00	0.00	0.00	0.00
22-Nov-03	6,415.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23-Nov-03	6,336.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24-Nov-03	6,750.64	0.00	23.69	107.87	0.00	0.00	0.00	0.00
25-Nov-03	6,614.30	0.00	140.83	25.57	0.00	0.00	0.00	0.00
26-Nov-03	6,731.28	0.00	49.32	25.80	0.00	0.00	0.00	0.00
27-Nov-03	6,078.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28-Nov-03	6,769.58	0.00	22.22	0.00	0.00	0.00	0.00	0.00
29-Nov-03	6,704.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30-Nov-03	6,171.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Adjustment	3,000.00							
Total Burned	194,155.92	0.00	1,276.70	1,091.78	0.00	71.00	0.00	0.00
Total Delivered	181,751.59	0.00	1,276.70	1,091.78	0.00	71.00	0.00	0.00
HHV	8521	0	15000	7187	16932	6500		
% Ash	4.77%	0.00%	7.04%	1.10%	0.00%	0.00%		
Tons Ash	9,263.82	0.00	89.88	12.01	0.00	0.00	0.00	0.00

BIG STONE PLANT
FUEL BURN RECORD
Dec-03

DATE	Coal	P. Coke	TDF	Waste Seeds	Toner	Gran. Insul.	Canvas Belting	Plastic Chips
	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)
1-Dec-03	6,499.83	0.00	97.26	26.21	0.00	0.00	0.00	0.00
2-Dec-03	6,494.57	0.00	22.17	24.39	27.17	0.00	0.00	0.00
3-Dec-03	6,512.82	0.00	22.21	22.57	0.00	0.00	0.00	0.00
4-Dec-03	6,367.76	0.00	0.00	99.74	0.00	0.00	0.00	0.00
5-Dec-03	4,476.77	0.00	50.83	0.00	0.00	0.00	0.00	0.00
6-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19-Dec-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20-Dec-03	213.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21-Dec-03	3,794.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22-Dec-03	5,939.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23-Dec-03	6,188.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24-Dec-03	6,275.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25-Dec-03	4,964.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26-Dec-03	5,966.36	0.00	22.14	0.00	0.00	0.00	0.00	0.00
27-Dec-03	5,954.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28-Dec-03	6,021.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29-Dec-03	6,538.93	0.00	23.07	0.00	0.00	0.00	0.00	0.00
30-Dec-03	6,487.71	0.00	0.00	25.09	0.00	0.00	0.00	0.00
31-Dec-03	6,581.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Adjustment	1,000.00							
Total Burned	96,277.15	0.00	237.68	198.00	27.17	0.00	0.00	0.00
Total Delivered	124,513.74	0.00	237.68	198.00	27.17	0.00	0.00	0.00
HHV	8492	0	15000	7187	0	0	0	0
% Ash	4.86%	0.00%	7.04%	1.10%	0.00%	0.00%	0.00%	0.00%
Tons Ash	4,679.14	0.00	70.76	23.60	0.00	0.00	0.00	0.00

B15 Fuel Analysis Record

BIG STONE PLANT	COAL ANALYSIS PER TRAIN
	Oct-03

DATE	TR #	MOIS. %	% ASH AR	HHV AR	S, % AR	% ASH DRY	HHV DRY	S, % DRY	NaO %	MAF HHV	COAL TONS	TONS OK
PREV. MON.												
PREV. MON.												
1-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
2-Oct-03	bam81	29.59	4.37	8580	0.24	6.2	12186	0.34	1.56	12991	9755.200	9755.200
3-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
4-Oct-03	ebm31	30.19	4.78	8446	0.42	6.84	12098	0.6	1.9	12986	8781.275	8781.275
5-Oct-03	bam82	29.05	4.42	8654	0.31	6.23	12197	0.43	1.49	13007	9557.500	9557.500
6-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
7-Oct-03	bam83	28.99	4.54	8696	0.3	6.4	12246	0.42	1.71	13083	8852.525	8852.525
8-Oct-03	ebm32	29.8	4.84	8515	0.41	6.9	12130	0.59	1.83	13029	13087.700	13087.700
9-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
10-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
11-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
12-Oct-03	bam84	28.72	4.63	8673	0.31	6.49	12168	0.44	1.4	13013	14172.250	14172.250
13-Oct-03	bam85	29.19	4.26	8664	0.28	6.01	12236	0.39	1.52	13018	12636.750	12636.750
14-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
15-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
16-Oct-03	ebm33	30.09	4.77	8454	0.34	6.82	12093	0.49	1.72	12978	14176.000	14176.000
17-Oct-03	bam86	29.41	4.45	8620	0.25	6.3	12212	0.36	1.54	13033	14023.050	14023.050
18-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
19-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
20-Oct-03	btm001	26.87	5.43	8818	0.31	7.43	12058	0.42	1.19	0	11990.200	11990.200
21-Oct-03	btm02	26.64	5.39	8864	0.25	7.35	12083	0.34	1.17	0	11620.100	11620.100
22-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
23-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
24-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
25-Oct-03	btm03	27.18	5.25	8809	0.26	7.21	12097	0.36	1.25	0	14197.450	14197.450
26-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
27-Oct-03	btm04	26.96	5.36	8835	0.25	7.34	12096	0.34	1.08	0	13716.600	13716.600
28-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	0.000
29-Oct-03	bam87	29.17	4.71	8647	0.31	6.65	12208	0.44	1.33	13078	14149.450	6542.450
30-Oct-03	0	0	0	0	0	0	0	0	0	0	0.000	
31-Oct-03	bam88	28.61	4.57	8693	0.31	6.4	12177	0.43	1.52	13010	14104.600	
ADJ.											184820.650	163109.050
											Tons. OK	191576.460
Weighted Average		28.87	4.83	8630	0.31	6.78	12133	0.44	1.50		Burn	191576.460

Monthly Mercury Analysis

Train #	Sample #	% Moist.	Mercury ug/g dry basis	Chlor. ug/g

BIG STONE PLANT COAL ANALYSIS PER TRAIN

Nov-03

DATE	TR #	MOIS. %	% ASH AR	HHV AR	S, % AR	% ASH DRY	HHV DRY	S, % DRY	NaO %	MAF HHV	COAL TONS	TONS OK
PREV. MON	bam87	29.17	4.71	8647	0.31	6.65	12208	0.44	1.3	13078	14149.45	7607.00
PREV. MON	bam88	28.61	4.57	8693	0.31	6.4	12177	0.43	1.5	13010	14104.60	14104.60
1-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
2-Nov-03	bam89	29.21	4.24	8642	0.24	5.99	12208	0.34	1.5	12986	14255.77	14255.77
3-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
4-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
5-Nov-03	bam90	28.9	4.66	8661	0.28	6.55	12181	0.4	1.5	13035	14137.13	14137.13
6-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
7-Nov-03	ebm34	30.2	5.03	8442	0.42	7.2	12095	0.6	1.7	13033	14009.60	14009.60
8-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
9-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
10-Nov-03	ebm35	30.1	4.79	8445	0.41	6.85	12082	0.59	1.8	12970	13835.97	13835.97
11-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
12-Nov-03	ebm36	30.02	4.72	8468	0.41	6.75	12101	0.58	1.8	12977	13431.50	13431.50
13-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
14-Nov-03	ebm37	29.85	5.06	8504	0.43	7.22	12123	0.62	1.7	13066	14175.60	14175.60
15-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
16-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
17-Nov-03	bam91	29.35	4.57	8626	0.31	6.47	12210	0.44	1.5	13055	14132.80	14132.80
18-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
19-Nov-03	ebm38	30.5	4.76	8455	0.4	6.85	12165	0.58	1.9	13060	14168.75	14168.75
20-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
21-Nov-03	ebm39	30.26	4.7	8420	0.39	6.74	12073	0.56	1.9	12946	14172.00	14172.00
22-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
23-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
24-Nov-03	ebm40	30.45	4.74	8457	0.38	6.82	12159	0.55	1.8	13049	14152.15	14152.15
25-Nov-03	ebm41	29.95	4.98	8477	0.42	7.11	12101	0.6	1.8	13027	14217.10	14217.10
26-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
27-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
28-Nov-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
29-Nov-03	bam92	29.89	4.27	8584	0.26	6.09	12244	0.37	1.7	13038	12974.10	5244.85
30-Nov-03	ebm42	30.48	4.77	8454	0.43	6.86	12160	0.62	1.9	13056	14089.13	0.00
ADJ.												181644.82
											Tons. OK	194398.12
Weighted Average		29.79	4.77	8521	0.36	6.80	12136	0.51	1.68		Burn	194155.92

Monthly Mercury Analysis

Train #	Sample #	% Moist.	Mercury ug/g dry basis	Chlor. ug/g
	C2557	29.51	0.07	<0.01

BIG STONE PLANT	COAL ANALYSIS PER TRAIN
	Dec-03

DATE	TR #	MOIS %	% ASH AR	HHV AR	S, % AR	% ASH DRY	HHV DRY	S, % DRY	NaO %	MAF HHV	COAL TONS	TONS OK
PREV. MON	bam92	29.89	4.27	8584	0.26	6.09	12244	0.37	1.69	13038	12974.10	7729.25
PREV. MON	ebm42	30.48	4.77	8454	0.43	6.86	12160	0.62	1.86	13056	14089.13	14089.13
1-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
2-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
3-Dec-03	bam93	29.3	4.31	8652	0.27	6.1	12237	0.38	1.58	13032	6658.15	6658.15
4-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
5-Dec-03	ebm43	29.3	4.85	8575	0.42	6.86	12125	0.6	1.85	13018	14134.15	14134.15
6-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
7-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
8-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
9-Dec-03	ebm44	30	5.25	8419	0.43	7.5	12019	0.62	1.67	12994	11198.31	11198.31
10-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
11-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
12-Dec-03	ebm45	29.6	5.31	8463	0.44	7.55	12030	0.63	1.58	13012	0.00	
13-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
14-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
15-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
16-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
17-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
18-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
19-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
20-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
21-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
22-Dec-03	ebm46	30.4	4.87	8369	0.4	7	12025	0.57	1.8	12930	8801.65	8801.65
23-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
24-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
25-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
26-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
27-Dec-03	ebm47	29.7	4.94	8523	0.44	7.02	12120	0.63	1.89	13035	14139.83	14139.83
28-Dec-03	ebm48	29.9	4.9	8469	0.45	6.99	12087	0.64	1.83	12995	12957.55	12957.55
29-Dec-03	0	0	0	0	0	0	0	0	0	0	0.00	
30-Dec-03	ebm49	29.6	5	8524	0.42	7.11	12109	0.6	1.67	13036	14179.50	1341.83
31-Dec-03	ebm50	29.8	5.15	8470	0.43	7.34	12073	0.61	1.54	13029	12102.48	
ADJ.												91049.85
											Tons. OK	96277.15
Weighted Average		29.89	4.86	8492	0.40	6.93	12113	0.57	1.78		Burn	96277.15

Monthly Mercury Analysis

Train #	Sample #	% Moist.	Mercury ug/g dry basis	Chlor. ug/g
	04-C19	29.76	0.06	<0.01

B16 Ash Analysis Record

None recorded this quarter.

B17 Ultimate Coal Analysis

ULTIMATE ANALYSIS
AS RECEIVED

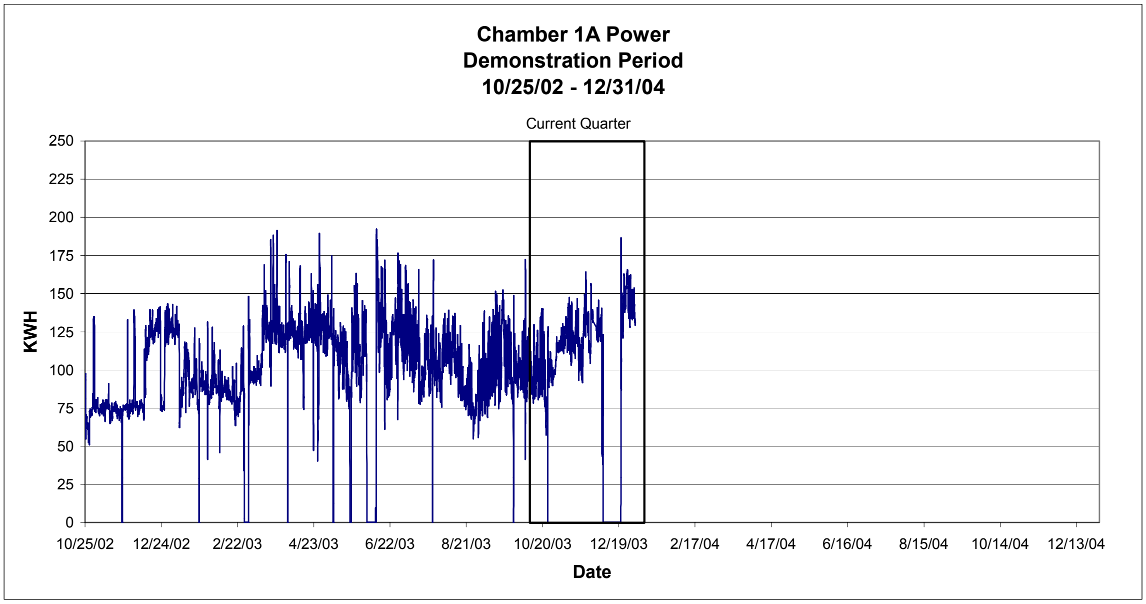
Sample Date	Moisture %	Ash %	Carbon %	Nitrogen %	Sulfur %	Hydrogen %	Oxygen %	HHV btu/lb	NaO %	Mercury ug/g Dry
05-Jan-03	30.31	4.60	48.51	0.65	0.50	3.43	12.00	8415	1.90	
06-Jan-03	29.75	4.79	48.86	0.64	0.39	3.43	12.14	8465	1.30	
07-Jan-03	29.82	4.74	48.39	0.67	0.39	3.03	12.96	8431	1.70	
08-Jan-03	28.79	4.86	49.34	0.68	0.40	3.05	12.88	8593	1.60	
12-Jan-03	28.85	4.19	50.03	0.69	0.24	3.04	12.96	8692	1.30	0.093
19-Jan-03	28.91	4.75	49.71	0.66	0.29	3.59	12.09	8696	1.40	
26-Jan-03	29.09	4.23	49.73	0.85	0.24	3.55	12.31	8624	1.30	
02-Feb-03	21.42	4.44	54.26	1.05	0.28	4.19	14.36	9477	2.00	
09-Feb-03	30.26	4.23	49.20	0.69	0.25	3.48	11.89	8487	1.40	0.103
16-Feb-03	27.91	4.37	50.12	1.08	0.28	3.79	12.45	8672	1.30	
23-Feb-03	26.60	5.10	48.81	1.36	0.31	4.14	13.68	8618	0.31	
02-Mar-03	NA	NA	NA	NA	NA	NA	NA	NA	NA	
09-Mar-03	29.99	4.48	49.46	0.63	0.26	4.21	10.97	8534	1.40	
16-Mar-03	29.23	4.53	49.32	0.66	0.26	3.74	12.26	8516	1.30	0.116
23-Mar-03	29.96	4.10	49.40	0.67	0.21	3.23	12.43	8581	1.10	
30-Mar-03	29.39	6.23	48.42	0.66	0.27	3.27	11.76	8402	1.80	
06-Apr-03	29.34	4.72	49.26	0.67	0.24	3.35	12.42	8514	1.20	
13-Apr-03	30.14	4.96	48.57	0.69	0.39	3.62	11.63	8474	1.60	0.116
20-Apr-03	30.16	4.87	48.65	0.68	0.49	3.70	11.45	8390	1.70	
27-Apr-03	30.74	4.33	48.77	0.67	0.35	3.54	11.60	8377	1.40	
04-May-03	30.57	4.81	48.95	0.66	0.30	3.59	11.12	8332	1.70	
11-May-03	29.97	4.56	50.35	0.68	0.35	3.73	10.36	8476	1.40	0.113
18-May-03	29.18	4.87	50.09	0.67	0.29	3.61	11.29	8572	1.10	
25-May-03	29.17	4.81	50.22	0.66	0.31	3.75	11.08	8557	1.40	
01-Jun-03	29.26	4.72	49.69	0.72	0.44	3.58	11.59	8501	1.80	
08-Jun-03	NA	NA	NA	NA	NA	NA	NA	NA	NA	
15-Jun-03	29.96	4.43	49.24	0.70	0.45	3.63	11.59	8476	1.70	0.013
22-Jun-03	29.52	4.42	49.74	0.65	0.32	3.42	11.93	8564	1.40	
29-Jun-03	30.43	4.74	48.83	0.71	0.36	3.40	11.53	8404	1.70	
06-Jul-03	29.10	4.56	50.03	0.67	0.30	3.42	11.92	8539	1.00	
13-Jul-03	30.39	4.90	48.72	0.67	0.42	3.10	11.80	8415	1.30	0.105
20-Jul-03	29.36	4.28	50.07	0.69	0.31	3.51	11.78	8663	1.20	
27-Jul-03	28.14	5.06	49.96	0.68	0.60	3.70	11.86	8633	0.90	
03-Aug-03	29.70	4.61	49.24	0.70	0.40	3.83	11.52	8474	1.40	
10-Aug-03	28.75	4.28	50.44	0.74	0.29	4.06	11.44	8663	1.10	0.081
17-Aug-03	29.04	5.44	49.38	0.76	0.33	3.88	11.17	8415	1.30	
24-Aug-03	28.98	4.84	49.89	0.65	0.29	3.54	11.81	8584	1.20	
31-Aug-03	28.92	4.85	49.86	0.69	0.27	3.51	11.90	8500	0.80	
07-Sep-03	29.69	4.23	50.77	0.70	0.27	3.69	10.65	8656	1.40	
14-Sep-03	29.35	4.52	49.83	0.68	0.32	3.28	12.02	8489	1.40	0.084
21-Sep-03	30.82	4.88	48.81	0.72	0.26	3.56	11.35	8275	1.10	
28-Sep-03	29.26	4.74	50.11	0.75	0.35	3.65	11.14	8590	1.10	
05-Oct-03	29.17	4.26	50.42	0.68	0.23	3.35	11.89	8561	1.60	
12-Oct-03	NA	NA	NA	NA	NA	NA	NA	NA	NA	
19-Oct-03	NA	NA	NA	NA	NA	NA	NA	NA	NA	
26-Oct-03	27.13	5.07	51.78	0.67	0.28	3.30	11.77	8847	1.10	0.069
02-Nov-03	28.99	4.46	50.15	0.71	0.35	3.58	11.76	8636	1.10	
09-Nov-03	29.51	4.26	49.18	0.69	0.28	3.51	12.57	8545	1.20	0.071
16-Nov-03	29.93	4.86	47.98	0.71	0.43	3.64	12.45	8431	1.30	
23-Nov-03	30.26	4.75	47.73	0.66	0.44	3.42	12.74	8489	1.40	
30-Nov-03	30.33	4.35	48.75	0.71	0.36	3.36	12.14	8444	1.40	
07-Dec-03	NA	NA	NA	NA	NA	NA	NA	NA	NA	
14-Dec-03	NA	NA	NA	NA	NA	NA	NA	NA	NA	
21-Dec-03	NA	NA	NA	NA	NA	NA	NA	NA	NA	
28-Dec-03	29.76	5.08	49.07	0.70	0.42	3.47	11.50	8557	1.30	0.057

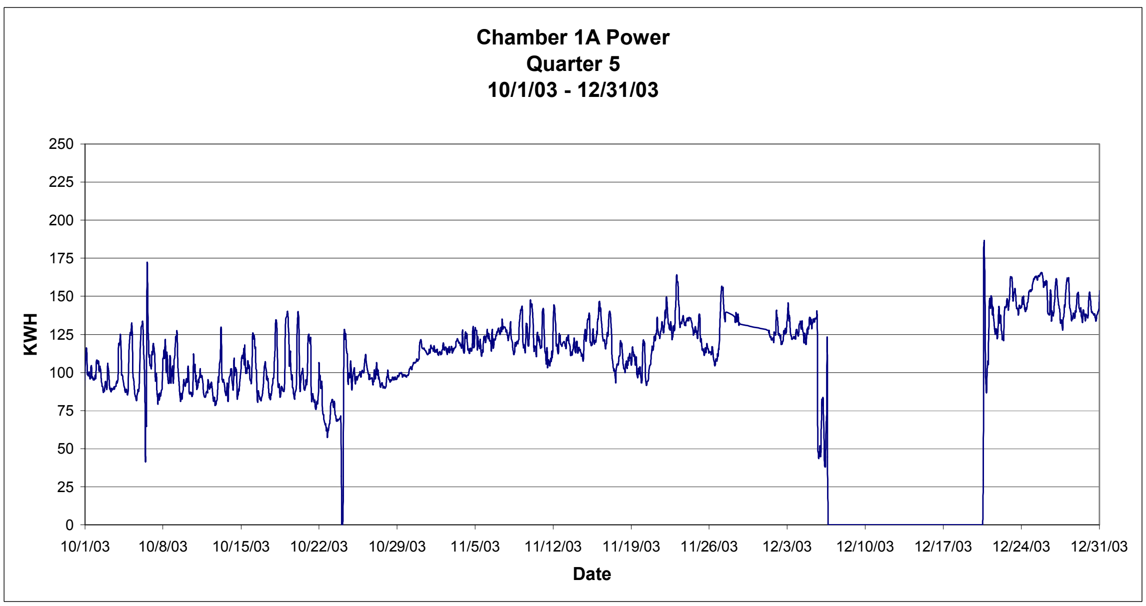
B18 Photographs

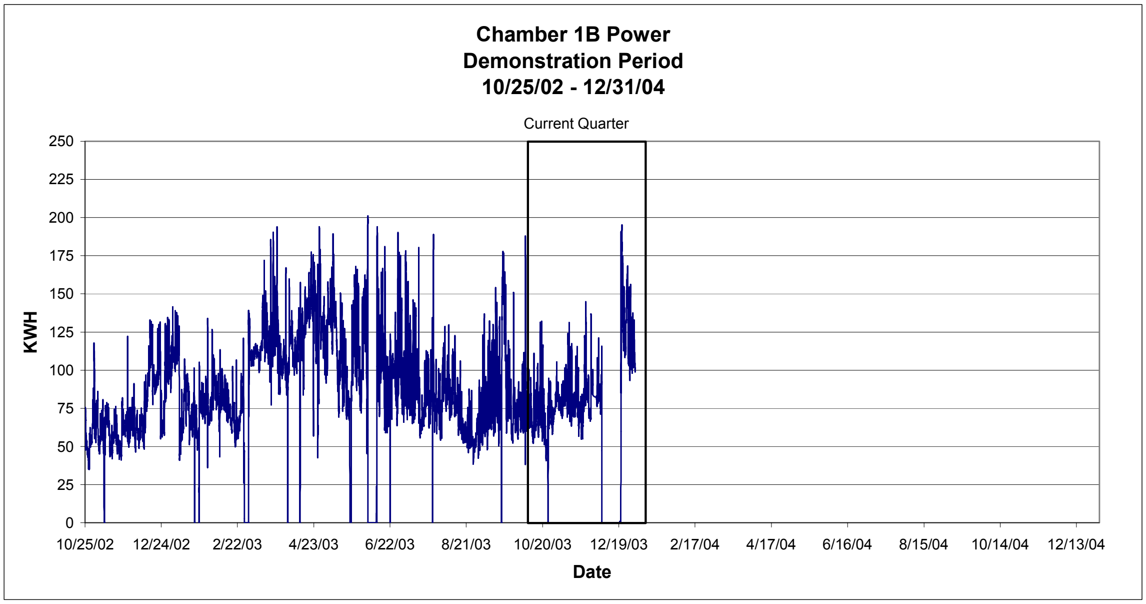
Bag wash of original bags in Big Stone turbine bay

Baffles laying on Advanced Hybrid walkway prior to installation

B19 ESP Power by Chamber






Chamber 1B Power
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
KWH
250
225
200
175
150
125
100
75
50
25
0
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
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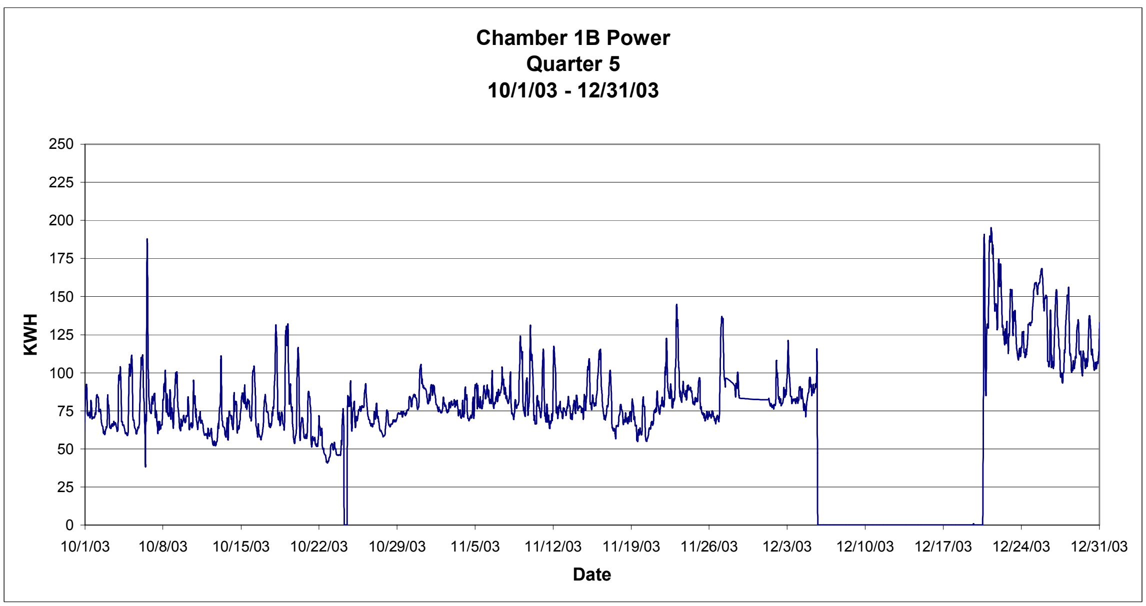
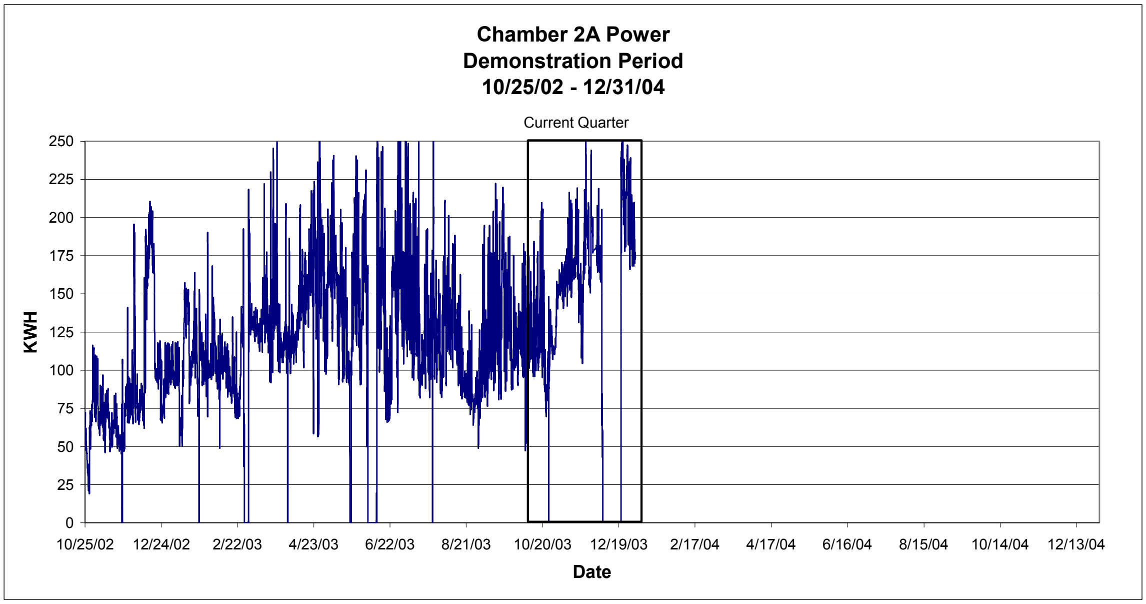
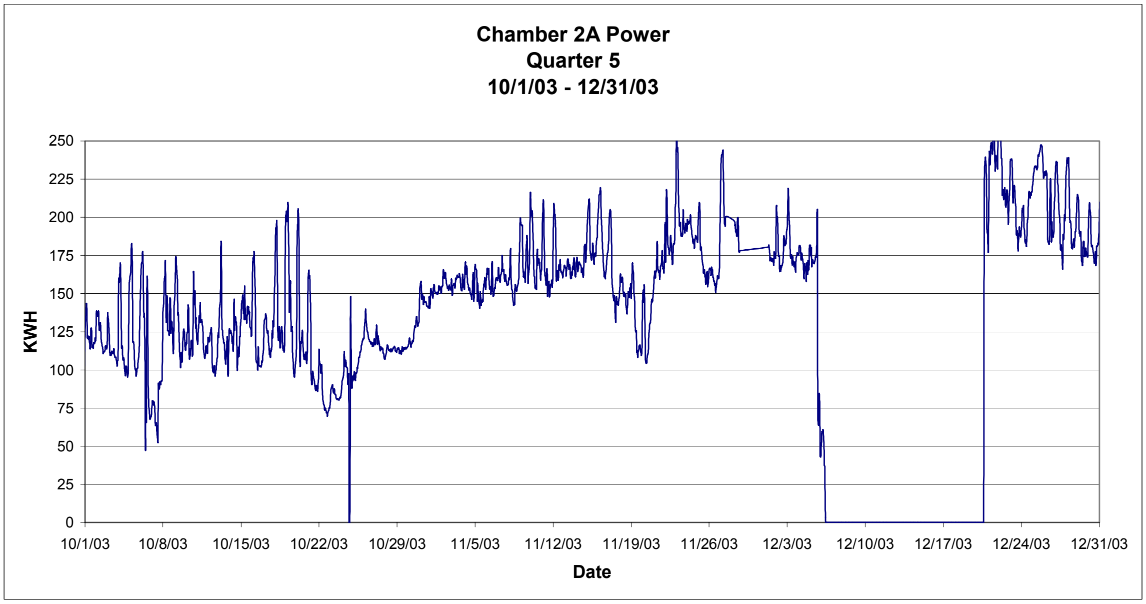
10/14/04
12/13/04
Date

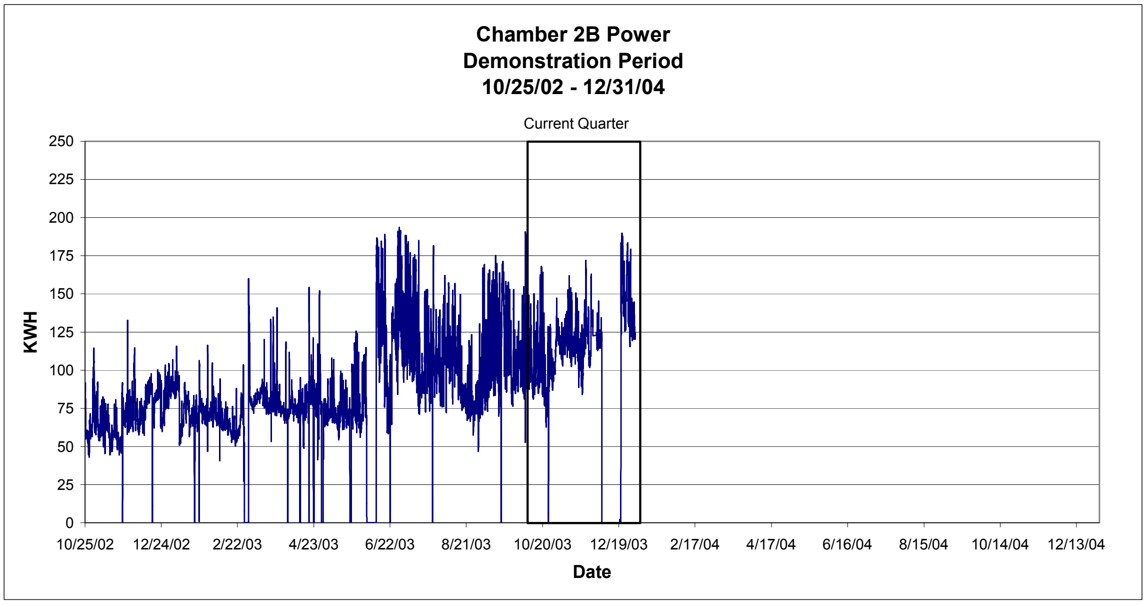

Chamber 1B Power
Quarter 5
10/1/03 - 12/31/03
KWH
250
225
200
175
150
125
100
75
50
25
0
10/1/03
10/8/03
10/15/03
10/22/03
10/29/03
11/5/03
11/12/03
11/19/03
11/26/03
12/3/03
12/10/03
12/17/03
12/24/03
12/31/03
Date

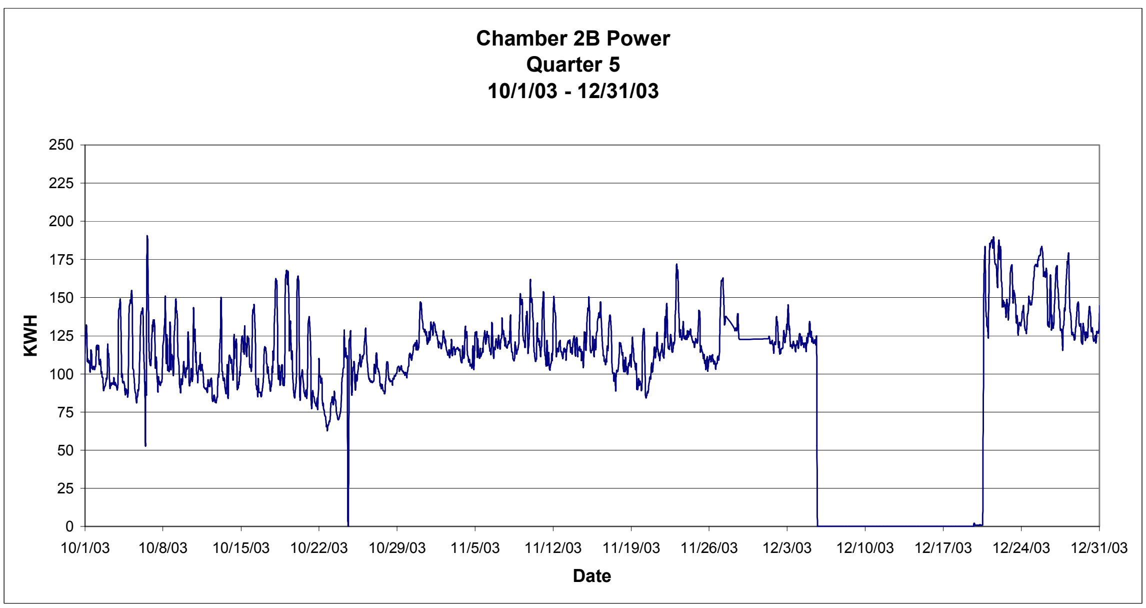


Chamber 2A Power
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
KWH
250
225
200
175
150
125
100
75
50
25
0
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date



Chamber 2A Power
Quarter 5
10/1/03 - 12/31/03
KWH
250
225
200
175
150
125
100
75
50
25
0
10/1/03
10/8/03
10/15/03
10/22/03
10/29/03
11/5/03
11/12/03
11/19/03
11/26/03
12/3/03
12/10/03
12/17/03
12/24/03
12/31/03
Date


Chamber 2B Power
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
KWH
250
225
200
175
150
125
100
75
50
25
0
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date


Chamber 2B Power
Quarter 5
10/1/03 - 12/31/03
KWH
250
225
200
175
150
125
100
75
50
25
0
10/1/03
10/8/03
10/15/03
10/22/03
10/29/03
11/5/03
11/12/03
11/19/03
11/26/03
12/3/03
12/10/03
12/17/03
12/24/03
12/31/03
Date

B20 ESP Tabular Data

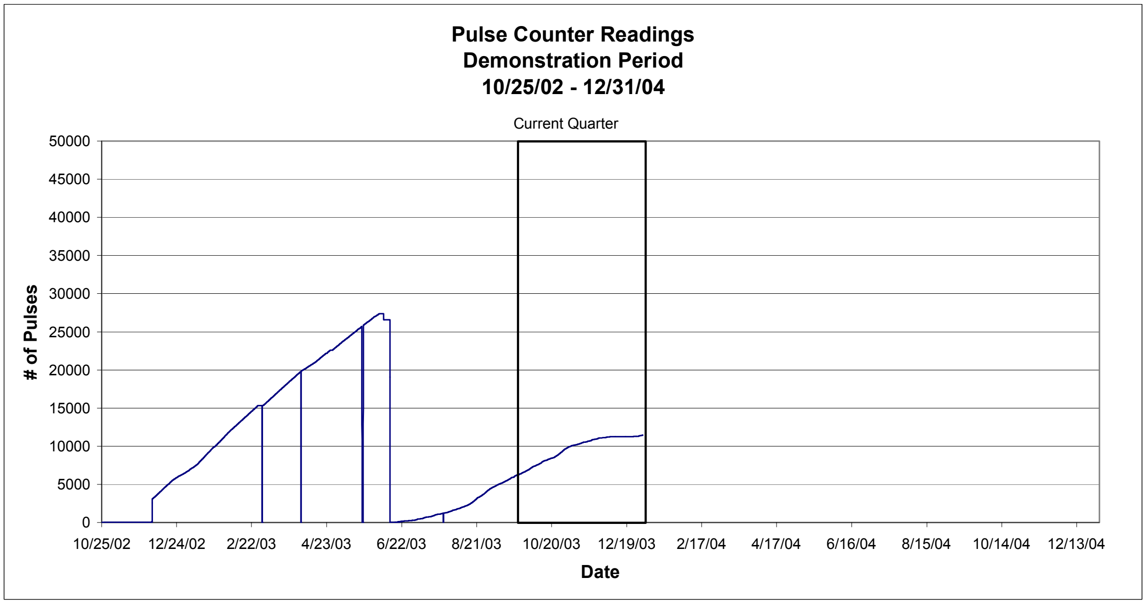
Transformer/Rectifier Performance Readings

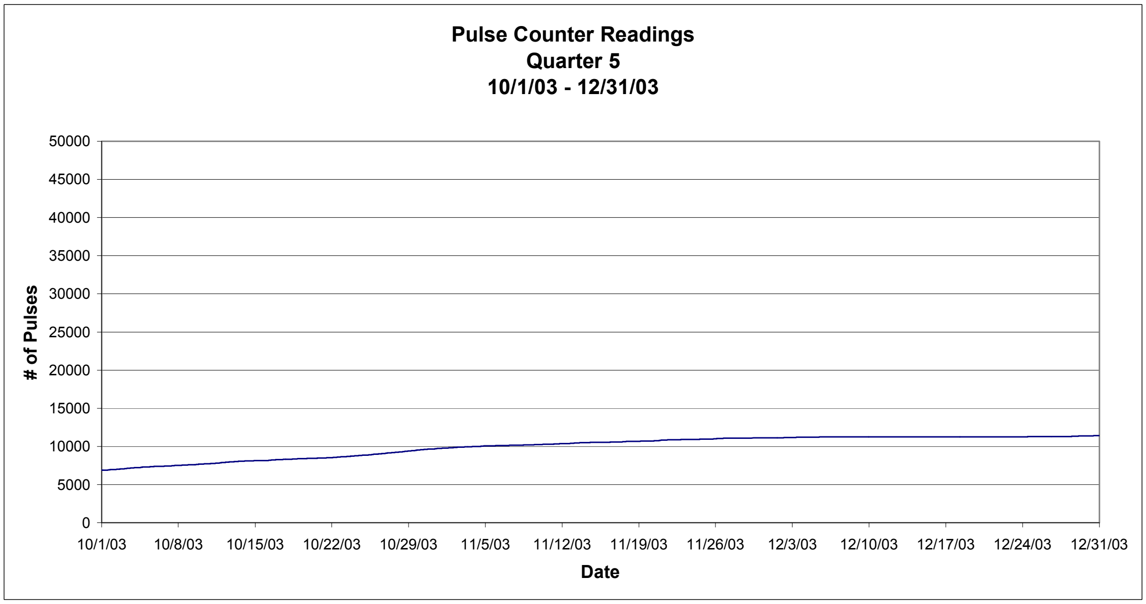
15-Oct-03	* Limiting factors highlighted											
Chamber	Field 1			Field 2			Field 3			Field 4		
	mA	kV	spm	mA	kV	spm	mA	kV	spm	mA	kV	spm
1A	80	62.8	81	408	46.1	19	771	48.9	19	832	53.8	19
1B	123	55.9	99	330	48.6	19	534	47.5	19	598	48.6	19
2A	345	63.9	43	607	53.5	19	593	52.3	19	787	51	19
2B	273	60.5	98	457	50.2	19	743	49.5	19	688	48.7	19

15-Nov-03	* Limiting factors highlighted											
Chamber	Field 1			Field 2			Field 3			Field 4		
	mA	kV	spm	mA	kV	spm	mA	kV	spm	mA	kV	spm
1A	113	64.6	24	538	46.1	19	927	49	16	970	52.7	8
1B	223	58.5	99	387	48.4	19	576	47.4	19	702	49.2	19
2A	485	64.1	42	753	49.1	19	750	49.7	18	962	48.8	9
2B	379	63.7	55	566	49.7	19	882	49.8	18	764	48.4	19

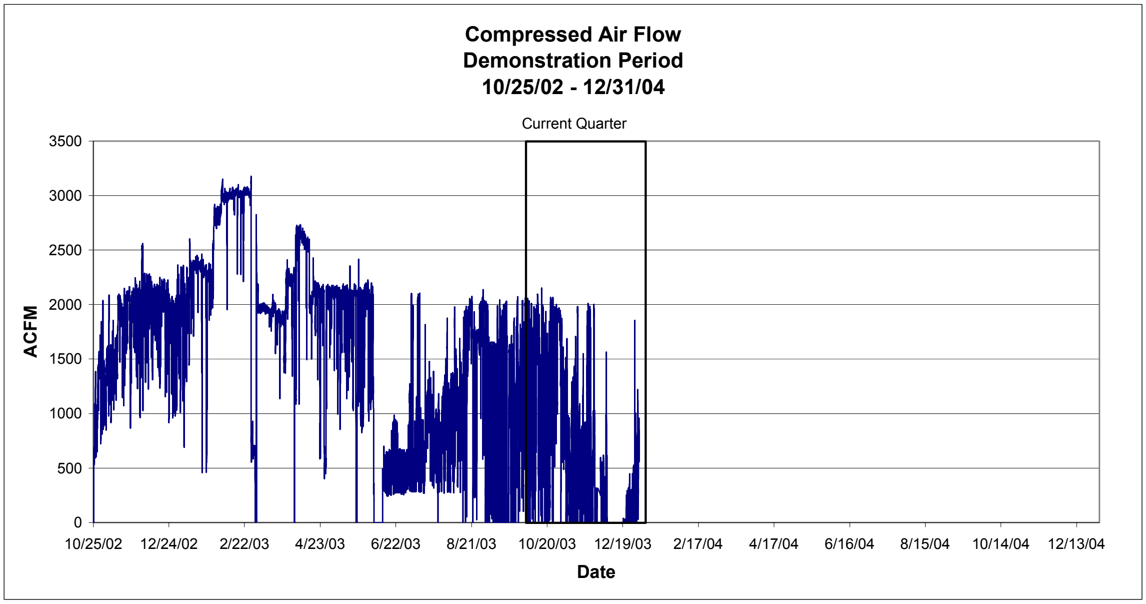
4-Dec-03	* Limiting factors highlighted											
Chamber	Field 1			Field 2			Field 3			Field 4		
	mA	kV	spm	mA	kV	spm	mA	kV	spm	mA	kV	spm
1A	133	64.4	33	566	48	19	942	50.7	15	971	54.8	8
1B	215	60.2	99	435	50.5	19	627	49.2	18	718	50.7	19
2A	427	65	3	791	54	19	786	54.5	19	977	52	8
2B	301	64.2	29	567	51	18	903	51.6	18	688	44.7	18

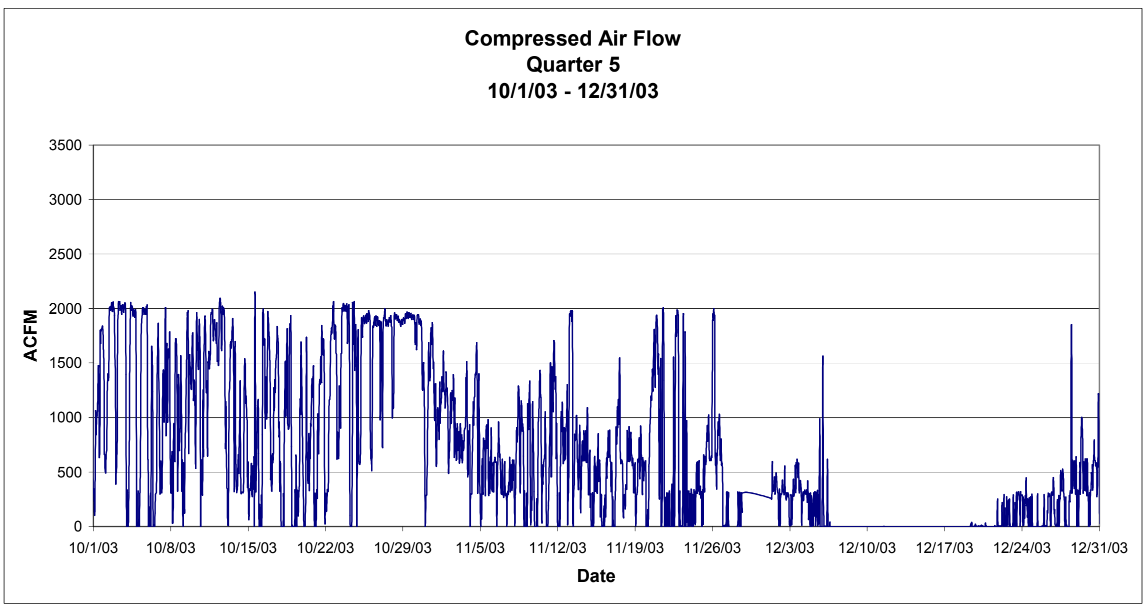
B21 Pulse Counter Readings





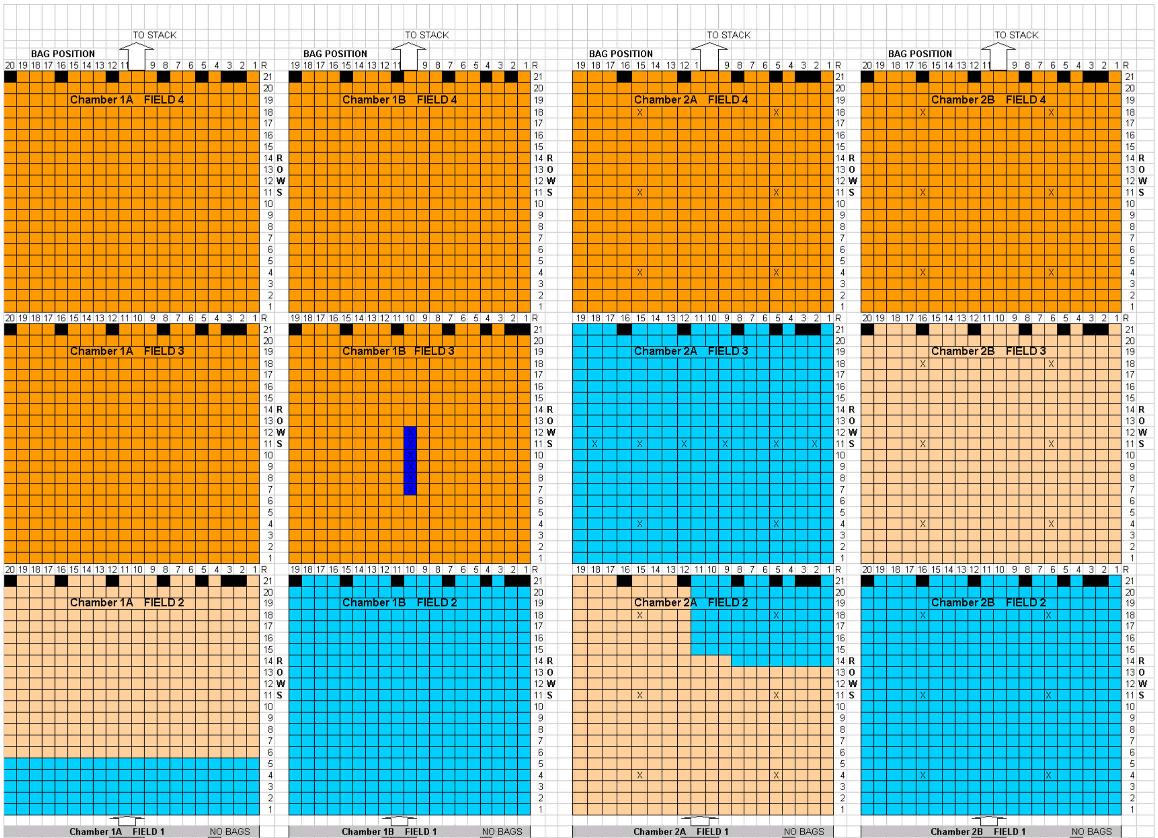
B22 Compressed Air Flow





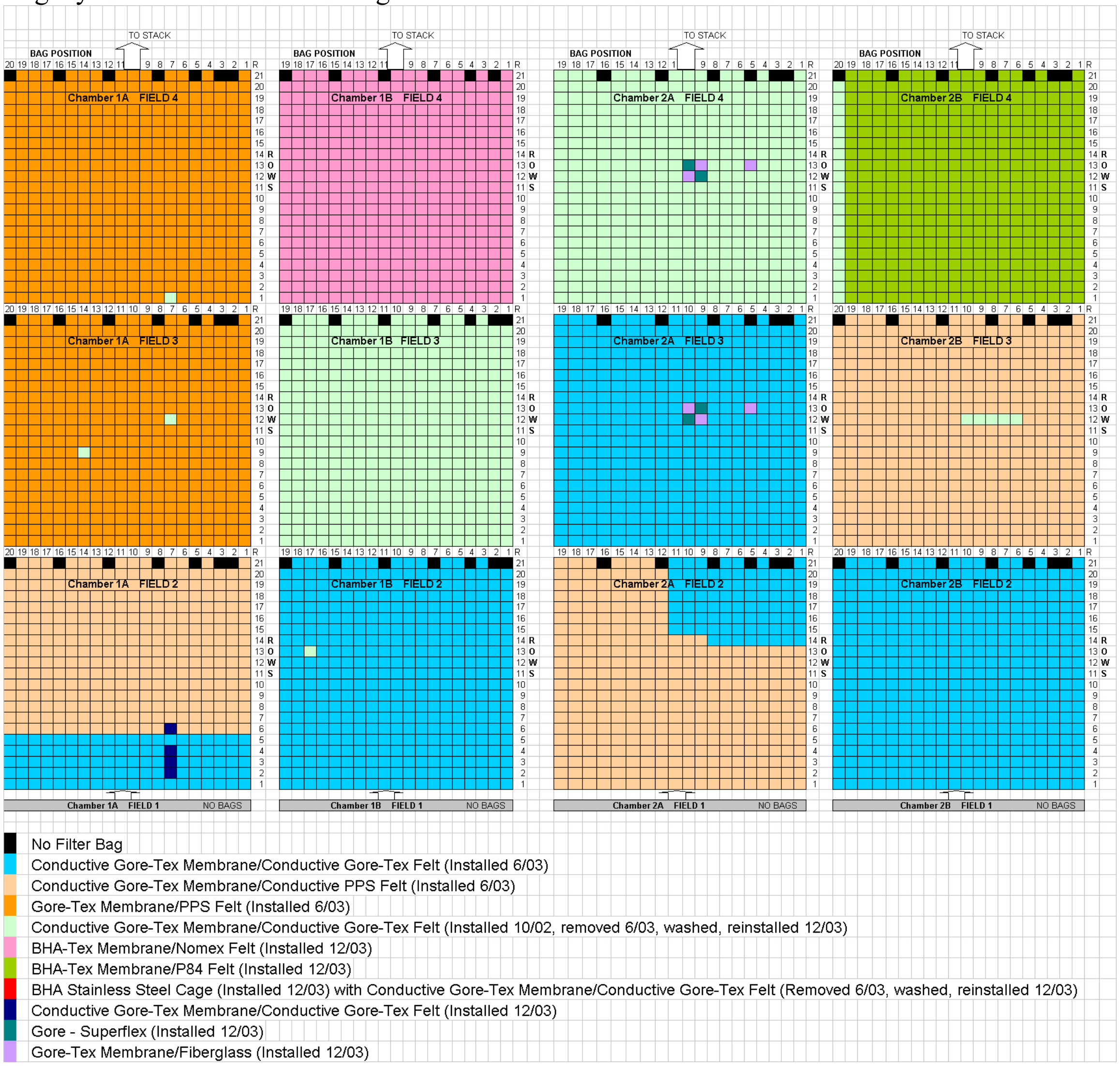
B23 Bag Layout Diagram

Bag layout prior to boiler wash outage in December



- No Filter Bag
- Conductive Gore-Tex Membrane/Conductive Gore-Tex Felt (Installed 6/03)
- Conductive Gore-Tex Membrane/Conductive PPS Felt (Installed 6/03)
- Gore-Tex Membrane/PPS Felt (Installed 6/03)
- Test Bags (Installed 6/03)
- X Pitot Tube Location

Bag layout after boiler wash outage in December.



B25 W.L. Gore Report on Bag Analysis

Creative Technologies Worldwide

Full scale *Advanced Hybrid*™ Filter Big Stone Demonstration Operation Site Filter Bag Analysis

Date: September 4, 2003
Prepared By: Dwight Davis and Rich Gebert

Background:

Plant Location: Otter Tail Power Company, Big Stone City, South Dakota
Filter Bag Type: GORE-NO STAT® filter bags (GORE-TEX® membrane conductive/GORE-TEX® felt)
Bag Diameter: 6.0 inch
Length: 7 meter
Air/Cloth: 10 to 12 fpm
Dust Type: Fly Ash from Coal-Fired Boiler
Coal Type: Eagle Butte, Belle Ayr Mine; Western Sub-bituminous

GORE-NO STAT® filter bags were installed and pre-coated prior to the October 25, 2002 start-up of the full scale *Advanced Hybrid*™ Filter at Otter Tail Power Company's Big Stone Plant located in Big Stone City, SD. The unit remained in operation until the Big Stone Plant shutdown for a boiler wash on February 26, 2003. Operation resumed on March 2, 2003, with five conductive GORE-TEX® membrane on conductive polyphenylene sulfide (PPS) felt filter bags installed in Compartment 12. The PPS bags replaced the original filter bags in cross row 21, positions 1,4,6,7 & 10 (see bag locator chart in the appendix). During the February boiler wash 40 pitot tubes were also installed in compartments 7,8,9,10,11,and 12 for measuring air flow from individual filter bags. On April 26th and May 8th, chambers 2B and 1A respectively, filter bags were washed in place by Big Stone plant personnel while the Big Stone Plant operated at reduced load. The second boiler wash with a bag change out occurred on June 2, 2003.

As part of the Power Plant Improvement Initiative Big Stone Demonstration site DOE funding program, filter bags were removed for lab analysis when compartments or the entire Advanced Hybrid™ Filter were taken off line. Filter bag/s were removed November 9th after 2 weeks of operation, February 28th after 18 weeks of operation, April 12th after the PPS bags experienced 6 weeks of operation, and June 2nd after the PPS bags experienced 3 months of operation.

Filter Bag Evaluation:

A total of seven filter bags were removed over the eight month time period by W.L. Gore and Associates personnel for evaluation purposes. Various tests including; air permeability, felt strength, residual dust cake particle size and elemental analysis, along with visual observations including membrane microscopic examination were undertaken.

Air Permeability Analysis

The air permeability analysis of the filter bag media was performed in the lab using the Frazierometer. Permeability is the volumetric flow rate of air, measured in cubic feet per minute (cfm) through a square foot of filter media at a pressure differential of 0.5 inches water gauge (w.g.). The unit of measure is cfm/ft2 @ 0.5"w.g. and is called the Frazier Number (Fn). Samples of the *Advanced Hybrid®* filter bag media were cut from the top, middle, and bottom bag locations. The sample size was five inches in the vertical bag length direction along the entire circumference of the bag. Typically three measurements per bag sample were taken. An average value is then calculated from the nine measurements per bag. . Each sample is tested for permeability in the condition it was received from the field and again in the identical location after lightly brushing the dust cake. See Table 1:

Otter Tail Power Company							
Big Stone Power Plant Improvement Initiative Demonstration Site							
Filter Bag analysis summary chart - All Frazier #'s are reported as cfm/ft2@ 0.5 in.w.g. driving force							
Date installed	**Date removed**	**installed time**	**Laminate backing**	**As rec'd (Fn)**	**After light brushing (Fn)**	**Flat width ave.(cm)**	**Mullen Burst (psi)**
10/25/2002	11/9/2002	2 wks.	GORE-TEX felt	2.1	4.2		
10/25/2002	3/1/2003	18	GORE-TEX felt	2	4.6		701
10/25/2002	3/1/2003	18	GORE-TEX felt	1.5	4.3		724
3/1/2003	4/12/2003	6	PPS felt	1.4	6.6	24.9	323
3/1/2003	6/2/2003	13	PPS felt	1.8	5.5	24.9	372
3/1/2003	6/2/2003	13	PPS felt	1.7	5	24.9	374
10/25/2002	6/4/2003	32	GORE-TEX felt			24.6	742

Table 1. Test Results Summary Chart

All the filter bags when removed contained a thin layer of dust similar to typical coal fired boiler fabric filter particulate collector applications. This residual filter cake and filter bag media air permeability measurement is shown in the " as received Frazier numbers" column. As the filter bags seasoned, whether the bags consisted of the conductive GORE-TEX felt or conductive PPS felt backing, the differences in the overall permeability of the two types of filter bags narrowed. After light brushing, all the filter bag perms returned to near new levels. It should be noted that when brushing the bags removed March 1st, extra effort was required to remove all the dust off the surface of the bag.

Felt Strength

Mullen burst tests were run on a portion of samples taken for the air permeability measurements. The test consists of applying pressure in the reverse direction of airflow on a three inch diameter filter bag sample, continuously increasing the pressure until the sample is ruptured. The physical strength of new GORE-TEX® felt backed filter bags averaged 650 psi while the PPS felt filter bags averaged 344 psi. As shown with the Mullen Burst test results, both types of filter bags' physical strength has not been weakened due to chemical or thermal attack of the flue gas environment inside the *Advanced Hybrid*™ Filter to date.

Visual and Microscope Analysis

As noted earlier, all the filter bags contained a thin layer of dust cake on the membrane surface, typical of most coal -fired boiler applications. The primary dust cake was easily brushed off the November sampled filter bag and the PPS bags removed in April and June, but required more effort on the bags removed in February. The filter bags were examined for membrane damage from electrostatic discharge or sparking using a microscope - no damage was observed. However, by the February inspection inside the *Advanced Hybrid*™ Filter chambers, a portion of the filter bags exhibited wear in two general areas. One located at the center of the bottom disk of the bag, and the second area where the bag occasionally comes into contact with the bottom bag guide rails. The design of the filter bag took into account the expected wear at the bag guide rails incorporating a double layer of material in the bottom cuff.

Samples were taken from two of the filter bags for SEMS and an EDS analysis of the dust layer from the two filter bags removed in February. The results can be found in the APPENDIX. The SEMS indicate the residual flyash dust cake particle size falls in the range of 0.5 to 10 microns. Results from the EDS analyses indicate Potassium's presence in the flyash along with the other expected elements.

A single wrinkle formed on each of the PPS bags indicates some stretching occurred during the operation of the Advanced Hybrid™ Filter. The flat width measurements of these bags reaffirmed the visual observation showing the bags circumference increased roughly 0.9 cm.

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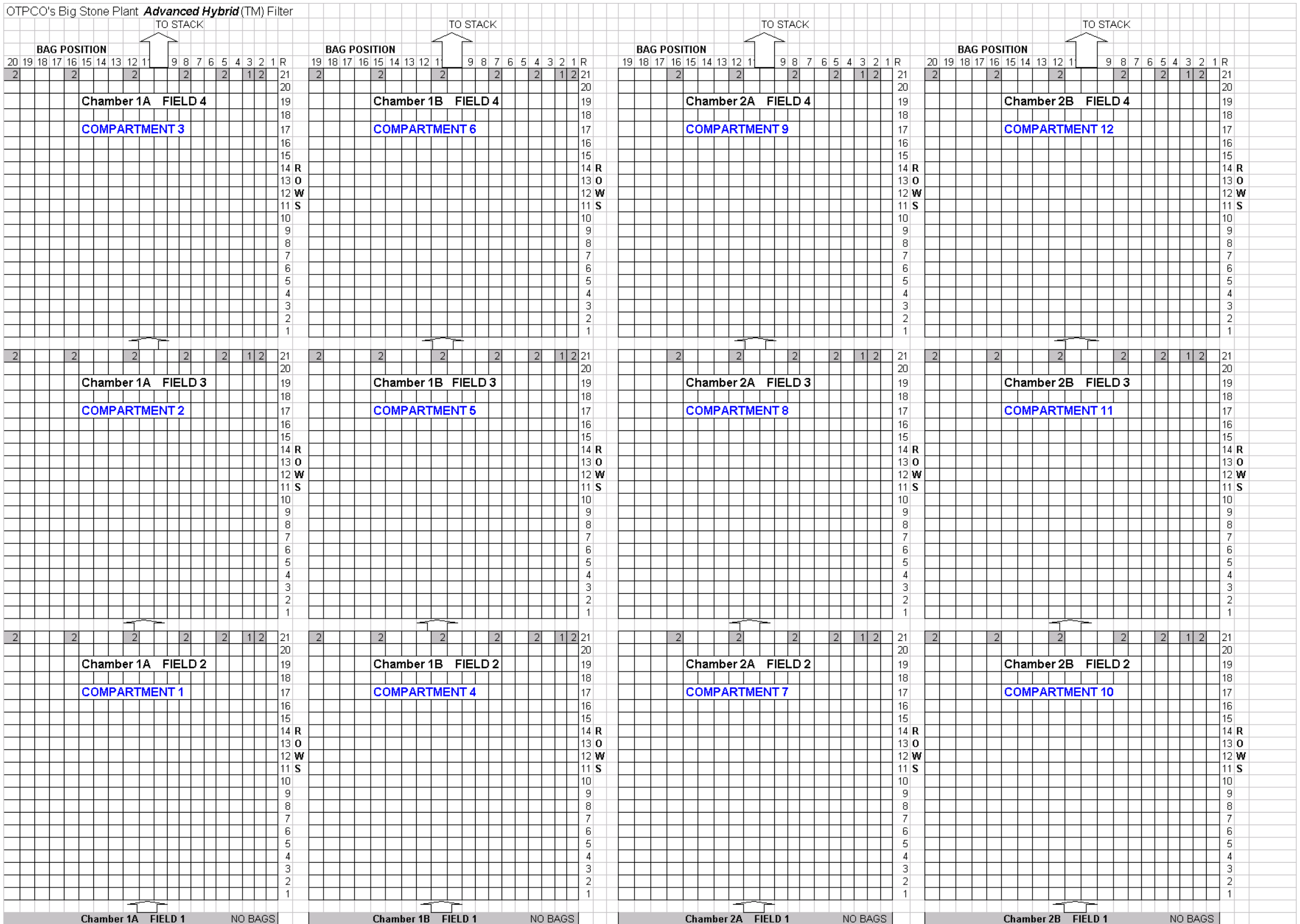
Conclusions:

- Visual analysis of filter bags revealed excellent membrane integrity.
- Laboratory analysis of the filter bags revealed no membrane damage caused by electrostatic discharge or sparking.
- After 32 weeks of service the GORE-NO STAT® filter bags exhibited no loss in physical strength and the permeability looked good.
- After 13 weeks of service the PPS backed GORE-TEX® membrane filter bags also showed no loss in strength and retained their permeability.
- Future PPS bag manufacturing will incorporate a design change to reduce/eliminate the bag circumference growth.

APPENDIX
Bag Locator Chart



Number Designations

1	6/1/2002	Bags eliminated due to Rapper Pinwheel Assembly in the way
2	10/12/2002	Bags eliminated due to Rapper Shaft bearing supports in the way

Oct. 25, 2002 rev

SEMS Photo

Surface comparison of 777013-Dust Cake and 777023-Dust Cake:

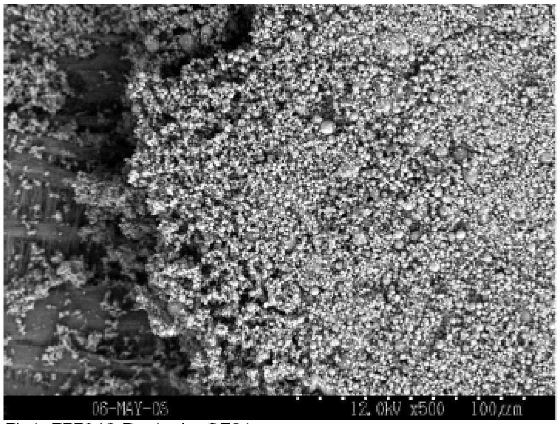


Fig1: 777013-Dustcake-SF01

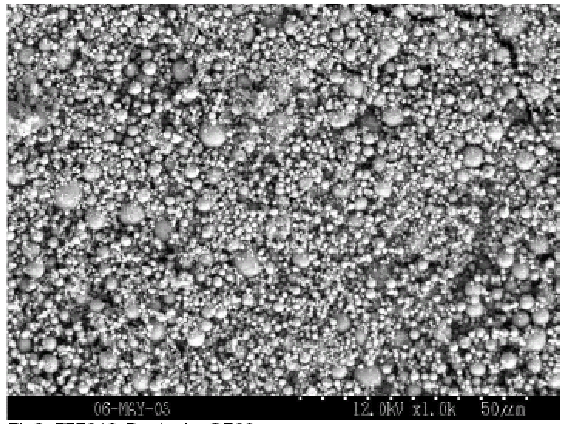


Fig2: 777013-Dustcake-SF02

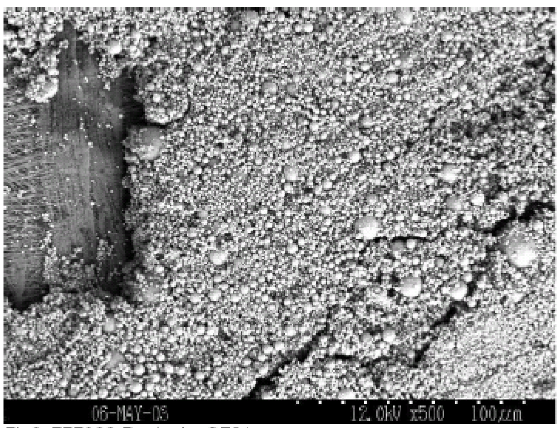


Fig3: 777023-Dustcake-SF01

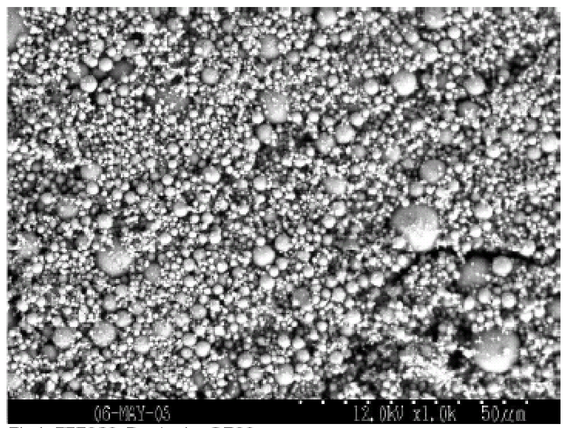


Fig4: 777023-Dustcake-SF02

Elemental comparison of 777013-Dust Cake and 777023-Dust Cake:

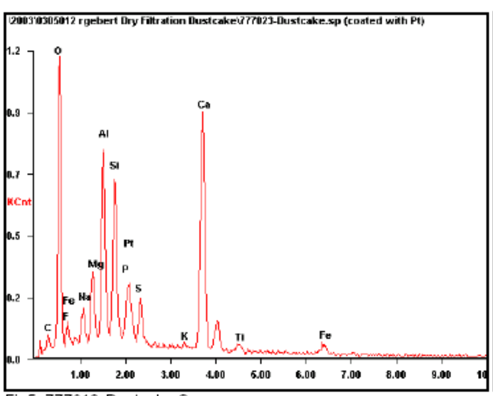


Fig5: 777013-Dustcake-Spc

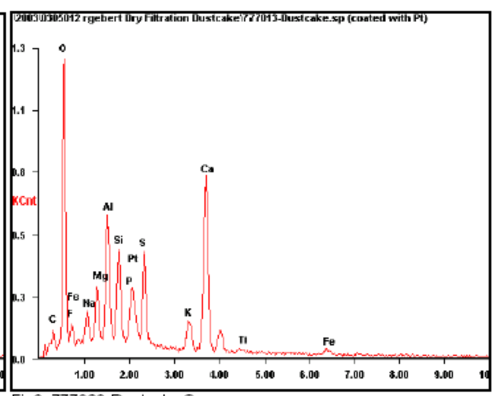


Fig6: 777023-Dustcake-Spc

EDS results

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