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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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.

During this quarter of operation, significant problems have developed that are a serious cause of concern. The differential pressure across the bags in the system is causing the plant to limit the output and steps need to be taken to improve performance.

Through testing, it has been determined that the ESP portion of the advanced hybrid has significantly

different performance than the pilot unit ESP performance reported by the EERC. Ash is being deposited on the bags at a rate of 3-5 times faster than comparable conditions in the pilot unit.

The same testing has shown that the residual drag across the bags in the system is as much as 50% higher than the results in the pilot unit. It is difficult to discern how much of this might be caused by low ESP efficiency, and how much might be a function of the bags themselves or the ash cake on the bags.

A data gathering and analysis effort is building to help improve performance. A new tool to the project has been introduced. Individual bag pitot tubes have been placed into service and the hope is that information from these instruments will aid in understanding the current performance status and potential improvements.

Particulate capture of the system remains high as is evidenced by current opacity monitor readings. No stack tests were performed in this quarter.

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^{TM}". 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^{TM}" 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.

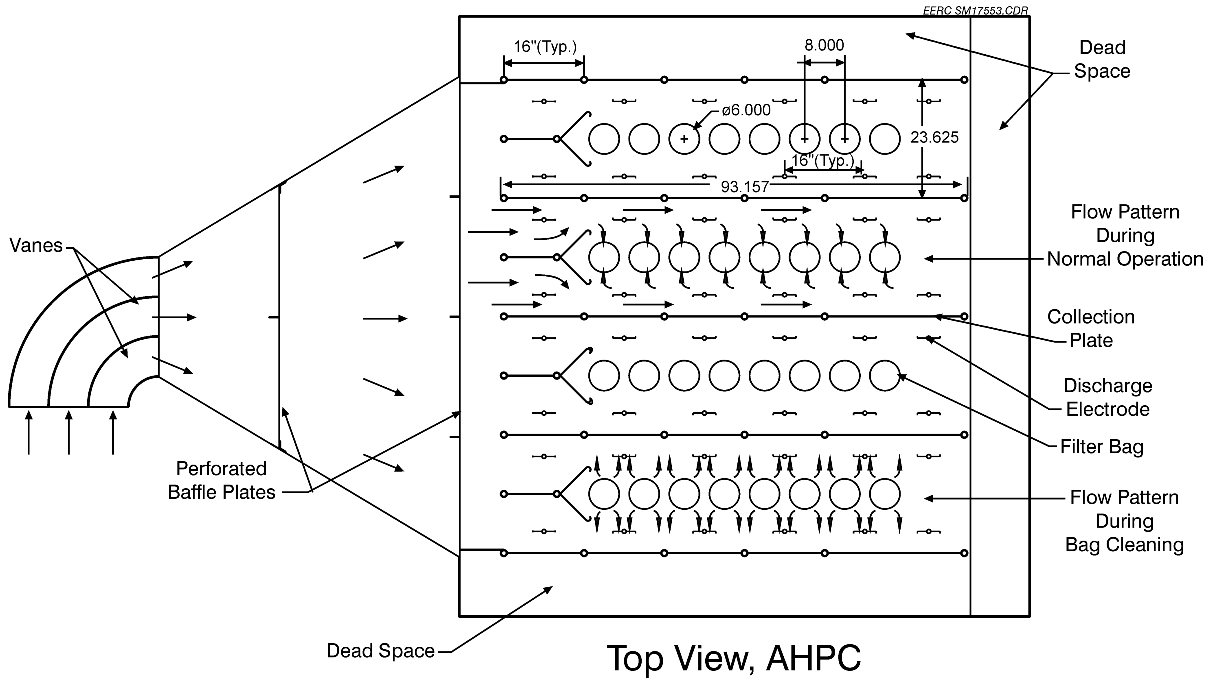


Figure 1. Top view of the old configuration for the 9000-acfm *Advanced Hybrid*™ filter at Big Stone.

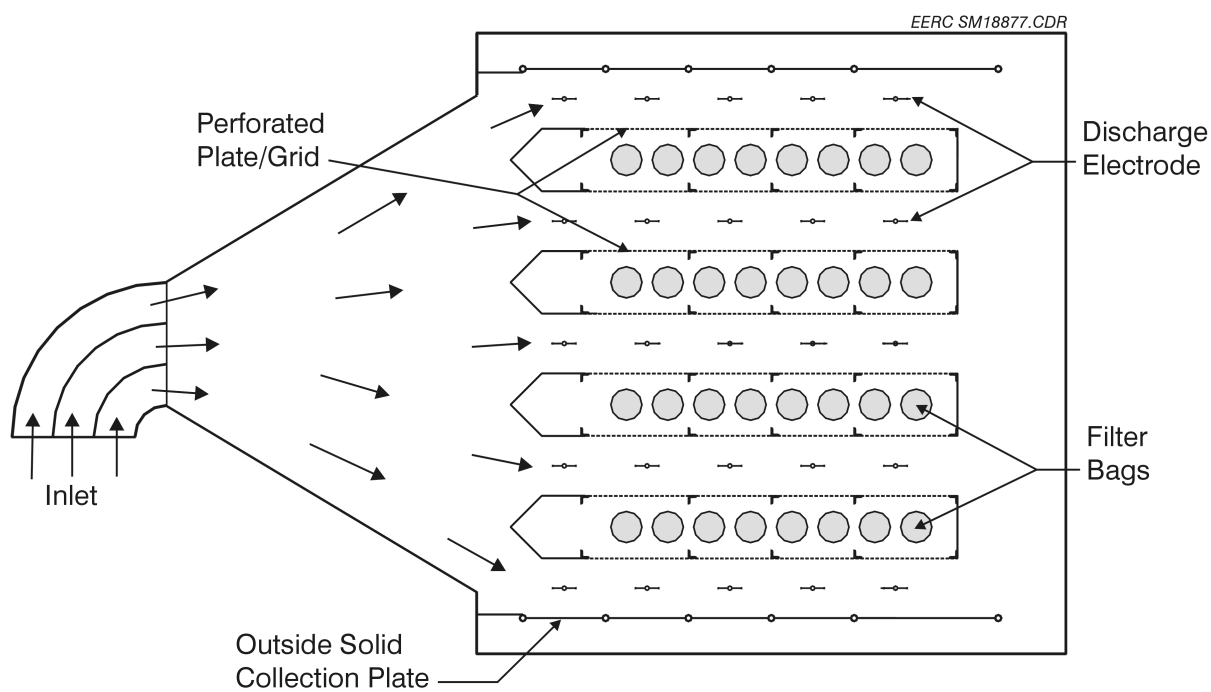


Figure 2. Top view of the perforated plate configuration for the 9000-acfm *Advanced Hybrid*™ filter.

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

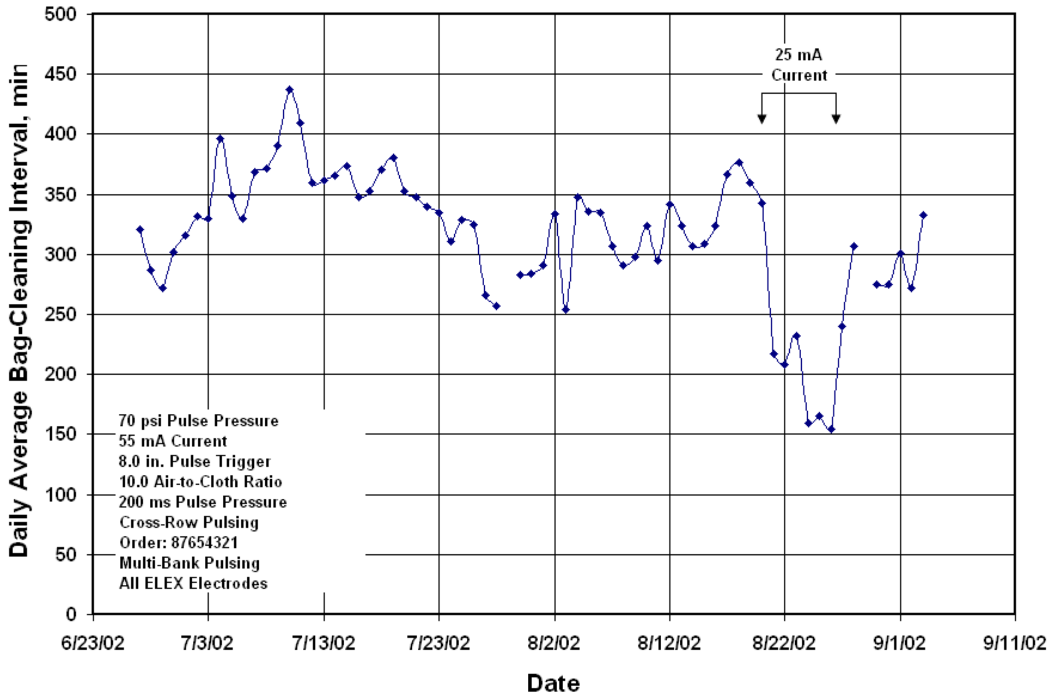


Figure 3. Daily average bag-cleaning interval for summer 2002 tests with the 9000-acfm *Advanced Hybrid*™ filter.

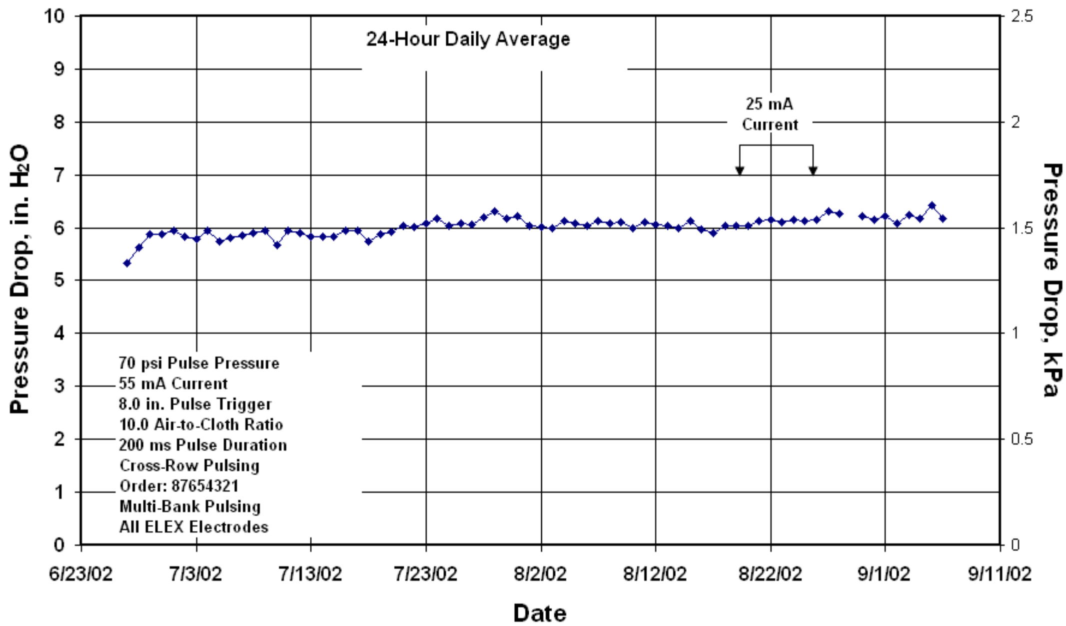


Figure 4. Daily average pressure drop for summer 2002 tests with the 9000-acfm *Advanced Hybrid*™ filter.

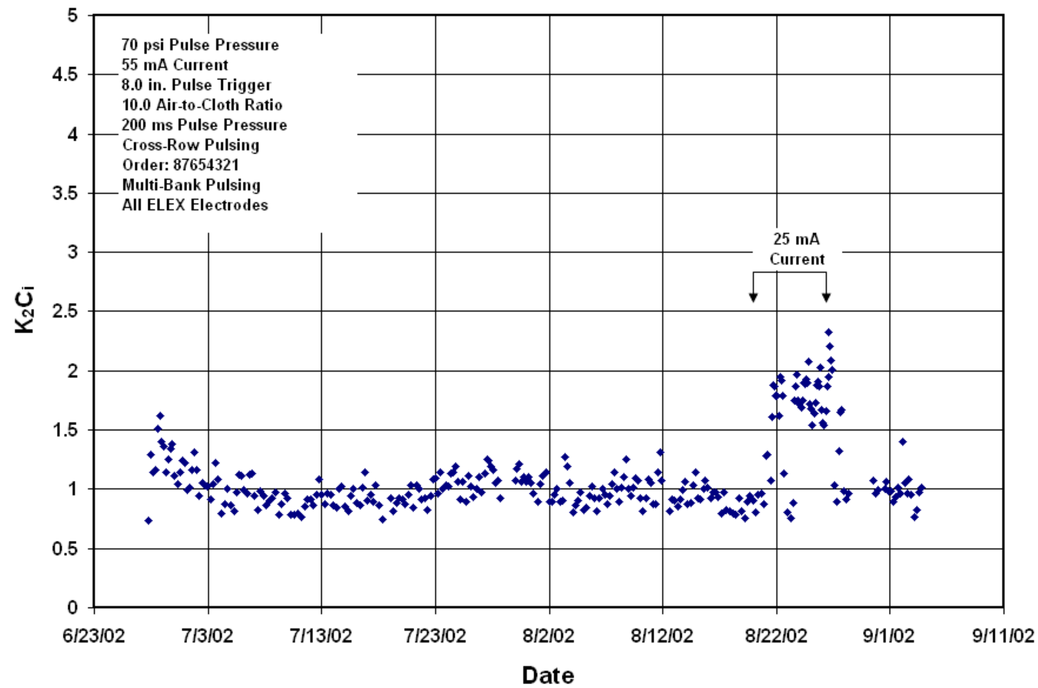


Figure 5. K_2C_i for summer 2002 tests with the 9000-acfm *Advanced Hybrid*™ filter.

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.

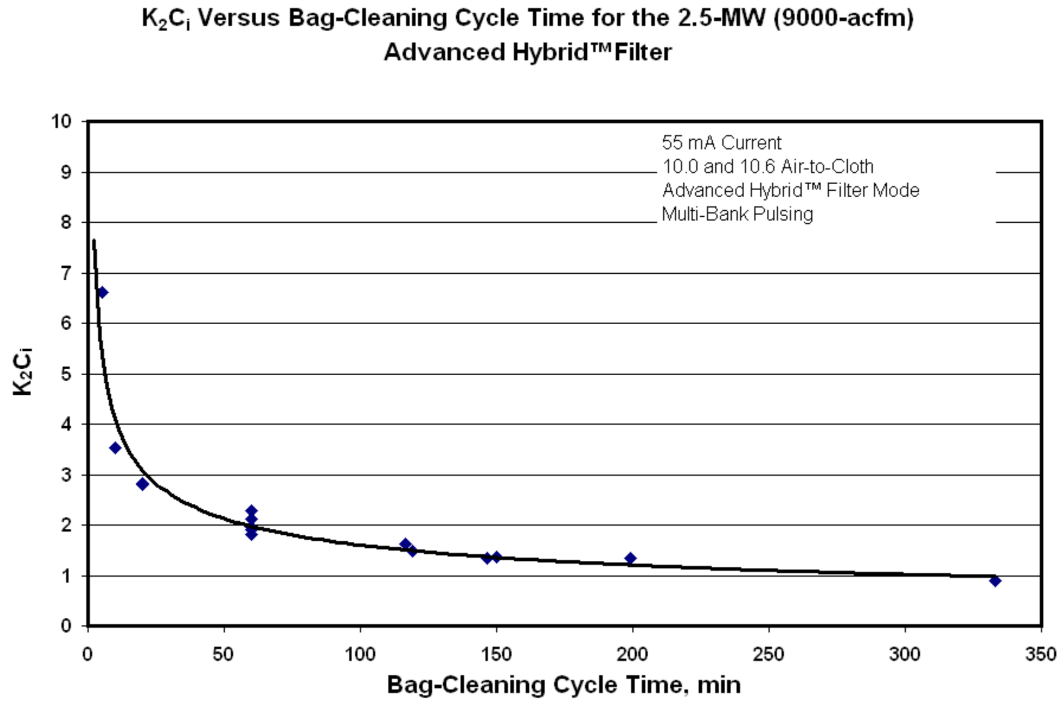


Figure 6. Effect of pulse interval on K_2C_i for 9000-acfm pilot *Advanced Hybrid*™ filter.

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).

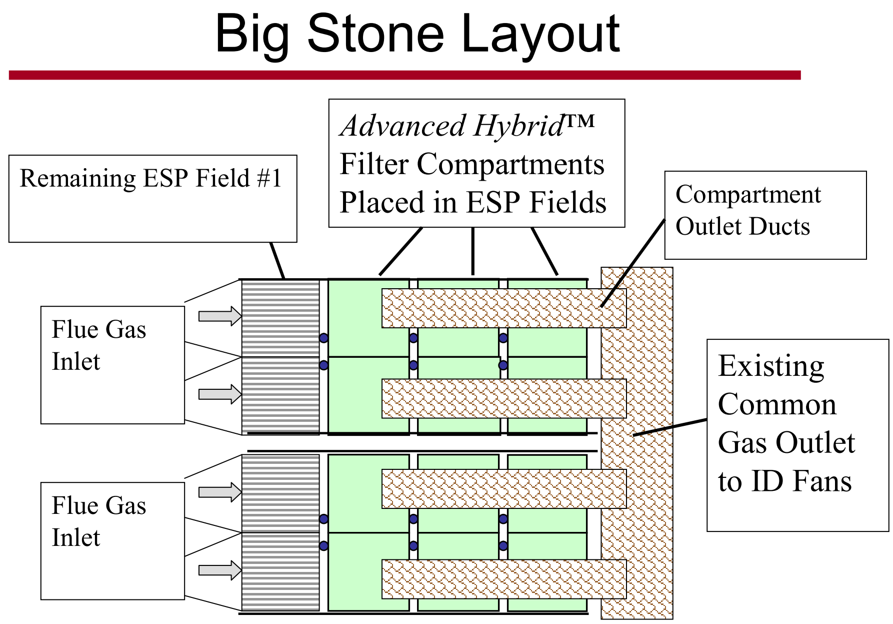


Figure 7. Top view of the *Advanced Hybrid*™ filter full-scale retrofit configuration at Big Stone.

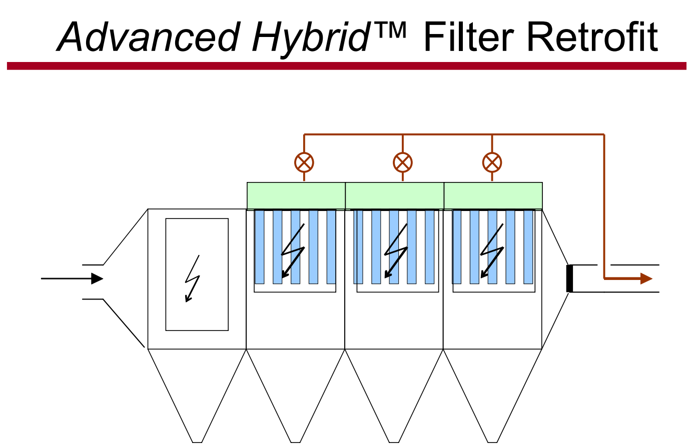


Figure 8. Side view of the *Advanced Hybrid*™ filter full-scale retrofit configuration at Big Stone.

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	4833	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	Unchanged
Pulse Pressure	80 psi	Unchanged
Cleaning Mode	DP control	Unchanged
TR Rating of AH Field	1500 ma, 55 kV	Unchanged
TR Rating of Inlet ESP Field	2000 ma, 55 kV	Unchanged
<u>Inlet ESP Field Data</u>		
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 ESP 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

Compartment	Number of Bags	Bag Type
Chamber 1A Field 2	**413**	**GORE-TEX™ Felt/GORE-TEX™ Membrane**
Chamber 1A Field 3	**413**	**GORE-TEX™ Felt/GORE-TEX™ Membrane**
Chamber 1A Field 4	**413**	**GORE-TEX™ Felt/GORE-TEX™ Membrane**
Chamber 1B Field 2	**392**	**GORE-TEX™ Felt/GORE-TEX™ Membrane**
Chamber 1B Field 3	**392**	**GORE-TEX™ Felt/GORE-TEX™ Membrane**
Chamber 1B Field 4	**393**	**GORE-TEX™ Felt/GORE-TEX™ Membrane**
Chamber 2A Field 2	**393**	**GORE-TEX™ Felt/GORE-TEX™ Membrane**
Chamber 2A Field 3	**393**	**GORE-TEX™ Felt/GORE-TEX™ Membrane**
Chamber 2A Field 4	**393**	**GORE-TEX™ Felt/GORE-TEX™ Membrane**
Chamber 2B Field 2	**413**	**GORE-TEX™ Felt/GORE-TEX™ Membrane**
Chamber 2B Field 3	**413**	**GORE-TEX™ Felt/GORE-TEX™ Membrane**
Chamber 2B Field 4	**413**	**GORE-TEX™ Felt/GORE-TEX™ 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^{o}F and 29.92 in HG as standard conditions. The flow is converted to kacfm using the following equation:

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

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.

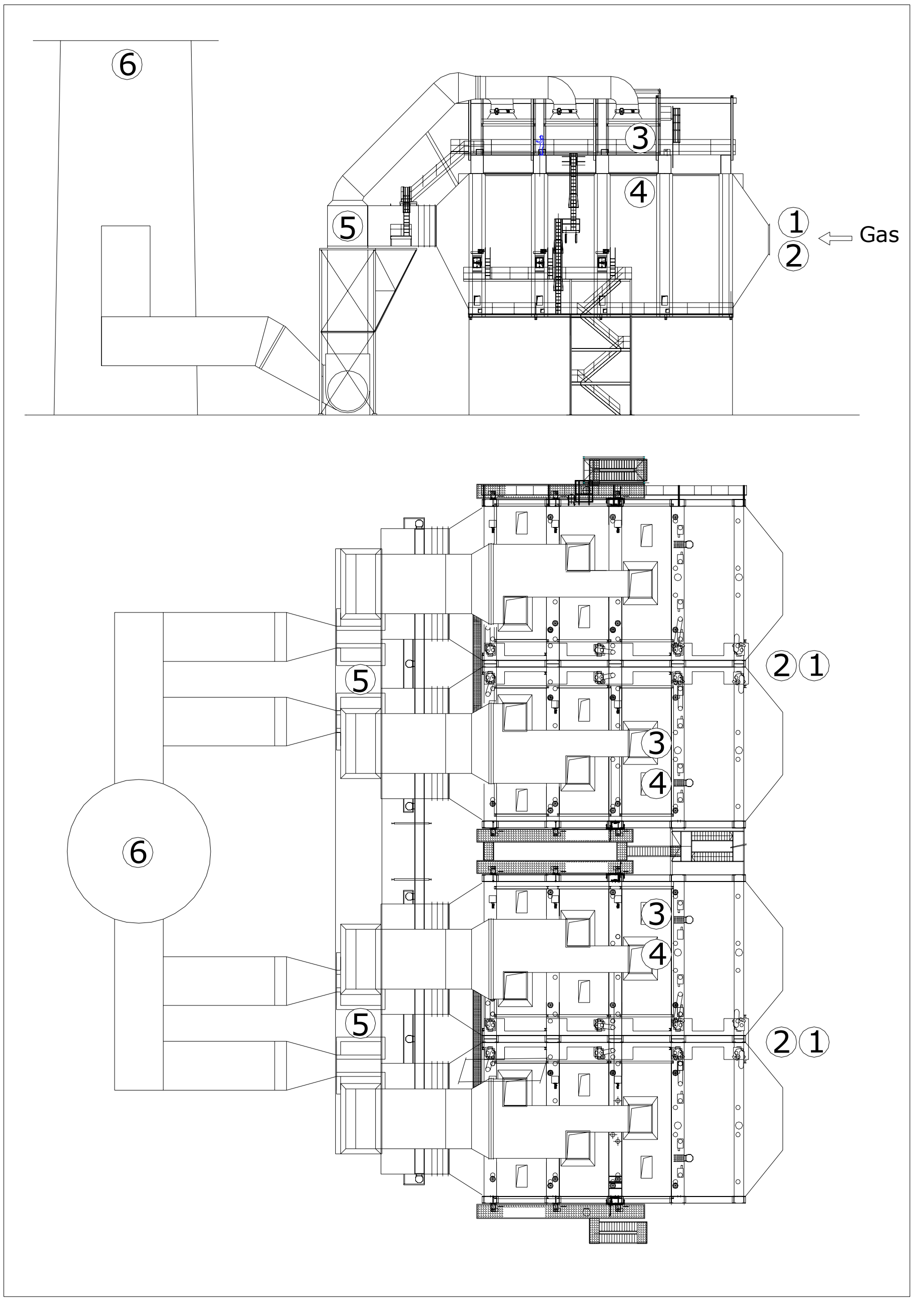
Compressed Air Flow: Continuously monitored using a Diamond II Annubar flow sensor equipped with a Honeywell 3000 Smart DP Transmitter. This ANNUBAR instrument is in the compressed air supply line after the compressors but before the desiccant dryer.

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
Meeting to discuss improvement options	March 2003

3.1.2 Discussion of Results of Significant Accomplishments

The system to date has experienced significant operational problems. The focus is the high differential pressure across the bags. Some of the mechanical issues have been resolved, but the primary performance concerns appear to be design and/or process related. Very significant derates of power plant output have occurred as a result of ID fan limitations, caused by the high differential pressure across the bags of the Advanced Hybrid systems. The factors that appear to be contributing to this are described below.

The first regular full-load plant derate due to the high differential pressure across the Advanced Hybrid system occurred on January 8, 2003. Since that date, the plant has experienced derates as high as 55 MW. This is a significant detriment to the plant and the company's portfolio of available energy. As a result, an aggressive stance to improve AHPC performance has been taken. The performance of the system still boils down to two factors, mechanical reliability and process performance.

Mechanical Issues

Two issues remain with the mechanical operation of the system, plate rapper alignment and compressed air supply pressure to the headers of the pulse valves.

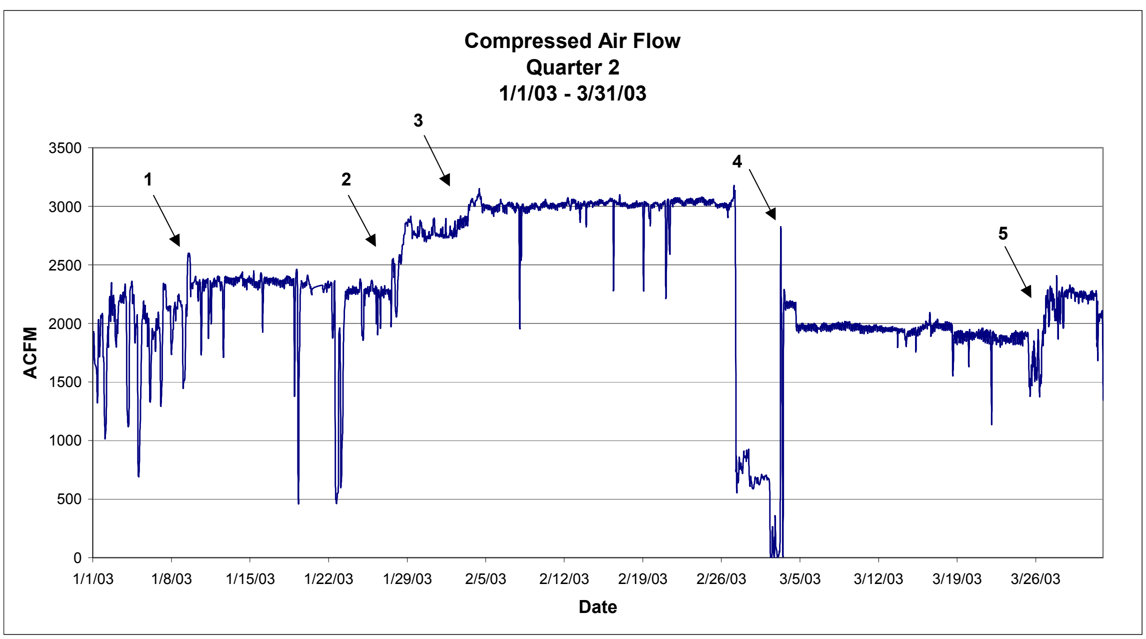
Two of the plate rappers remain a problem with regards to internal clearances and binding of the rapper shafts while in operation. A derate was taken on January 19th to inspect the system, evaluate the cause, and develop possible solutions. The problem with the rapper shafts binding due to internal obstructions as the system heats up is related to two problems. First, the rapper shafts being too small for the retaining collars at the wall. The second issue is, the opposite expansion of the rapper shafts and walkways due to opposite fixed points. This problem is described in the first quarterly report from the period of October 2002 – December 2002. Several pictures can be found in Appendix B18. The most likely fix is the replacement of the section of the rapper shafts extending through the fixed bearing so the retaining equipment can prevent the shaft from sliding laterally. This would most likely occur during the outage in June, 2003.

The other likely fix is to modify the existing equipment binding due to thermal expansion differences. There are five collars per rapper shaft that have clearance issues. The collar bolting is the problem. The collars, bolts, and visual evidence of the damage that occurs are shown in the pictures in Appendix B18 titled "Missing Roller" and "Damaged Bolt & Nut". Modifications to this system will take place during the scheduled wash outage in June. Other damage that occurred can be seen in the pictures titled "Anvil - Front View" and "Anvil – Angle View". Since there is poor hot alignment, a portion of the hammers are not striking the anvils squarely, damaging the anvils.

The other mechanical concern is the flow limitation from the pressure regulators in the compressed air system. As the system was installed, there were six regulators installed as described in the following table (location diagram of chambers and fields is included in multiple areas in the appendix). The AHPC system is capable of faster, more aggressive pulsing, but the regulators are limiting how much

Regulator #	Size	Compartment Supply
1	1.5”	Chamber 1A, Fields 2, 3, & 4
2	1.5”	Chamber 1B, Fields 3 & 4
3	1.5”	Chamber 2A, Fields 3 & 4
4	1.5”	Chamber 2B, Fields 2, 3, & 4
5	1.0”	Chamber 1B, Field 2
6	1.0”	Chamber 2A, Field 2

compressed air flow they allow through. During periods of off-line cleaning, we need to be able to pulse through all of the valves as quickly as possible to bring the off-line compartment back on-line. The following description of the efforts to resolve this issue can best be broken down by describing the “Compressed Air Flow” graph in Appendix B22.



Period 1. During this period, we removed regulators 2 and 3 from service and allowed full plant air system pressure to reach the headers, approximately 100 psig. Just prior to this date, the plant began derating due

to high differential across the bags. A slight increase in compressed air usage is seen on the graph. This made only slight improvements to lower the differential pressure (Appendix B5).

Period 2. We changed regulators 1 and 4 to 2" regulators and set the pulse cleaning cycle pause time to 0.1 seconds. We have been limited to 0.4 seconds of pause time between pulses due to the time required to refill the headers. A noticeable step change from 2250 acfm to 2800 acfm is seen on the trend. We were greatly exceeding the desiccant dryer capacity at this time, as this is rated for approximately 2000 acfm.

Period 3. We removed regulators 1 and 4 from service. This is the highest period of compressed air usage and we had great difficulty maintaining the compressed air system pressure in the plant.

Period 4. The plant was off-line to wash the steam heat transfer surfaces of the boiler. During this outage, we noticed the bags experiencing the highest pulse pressures were forming small concentric wear areas approximately 1 inch in diameter at the very bottom of the bags. This was likely due to the aggressive pulse energy and a poor bag-to-cage fit causing the bag to flex and rebound into the bottom of the cage. At that time we were exceeding the rating of the dessicant dryer. The plant compressed air system was not capable of supplying that continuous volume of compressed air. We put all regulators back in service and increased the pause time to 0.4 seconds.

Period 5. Twelve individual regulators were installed (one per compartment) and the cycle pause time was decreased from 0.4 seconds to 0.3 seconds. This has been the normal state since that time. Graphical data indicates constant pulsing with the pause time at 0.4 seconds results in compressed air usage of approximately 1900 acfm, and a pause time of 0.3 seconds results in a compressed air usage of approximately 2250 acfm.

With all twelve compartments having a dedicated pressure regulator, we have resolved the problem of not maintaining the pressure in the header during pulsing. After regulator installation, the headers have been maintaining a pulse pressure of approximately 80 psig.

System Performance

A great deal of effort has been put forth to both establish where we are at with the existing performance, and what can be done to improve performance. The very high differential pressure is significantly different than the previously reported results of the Pilot Unit operation. The first step in evaluating the performance was to attempt baseline testing with the pilot unit in place. The pilot unit was started up on

February 3, and testing took place on February 8. There were two parameters, K2Ci and Residual Drag, which needed to be evaluated to compare performance of the two units. A short explanation of these terms and how they are calculated follows.

K2Ci

K2Ci a measure of the loading rate of dust to the filter bags. The measurement was completed by stopping the bag pulsing and measuring the rate of the rise in differential pressure. A slower rate of differential pressure rise would mean that the ESP portion of the Advanced Hybrid was taking out more dust prior to it reaching the bags. A faster differential pressure rise would mean that the ESP portion is not removing as much dust prior to it reaching the filter bags. Various tests were completed the night of February 8. A trend of the differential pressure of both the full-scale unit and the pilot unit is included below. A description of the individual tests follows.

Residual Drag

Residual Drag is the minimum resistance possible after pulse cleaning, or the resistance of the system with just the bags and whatever dust cake cannot be removed from the bags from pulsing. It is calculated by taking the differential pressure immediately after cleaning and dividing by the air-to-cloth ratio. The units for this measurement are INH2O/ft/min. Although the test was not set up to measure the residual drag of the pilot plant, previously reported results are in the 0.5 – 0.6 range.

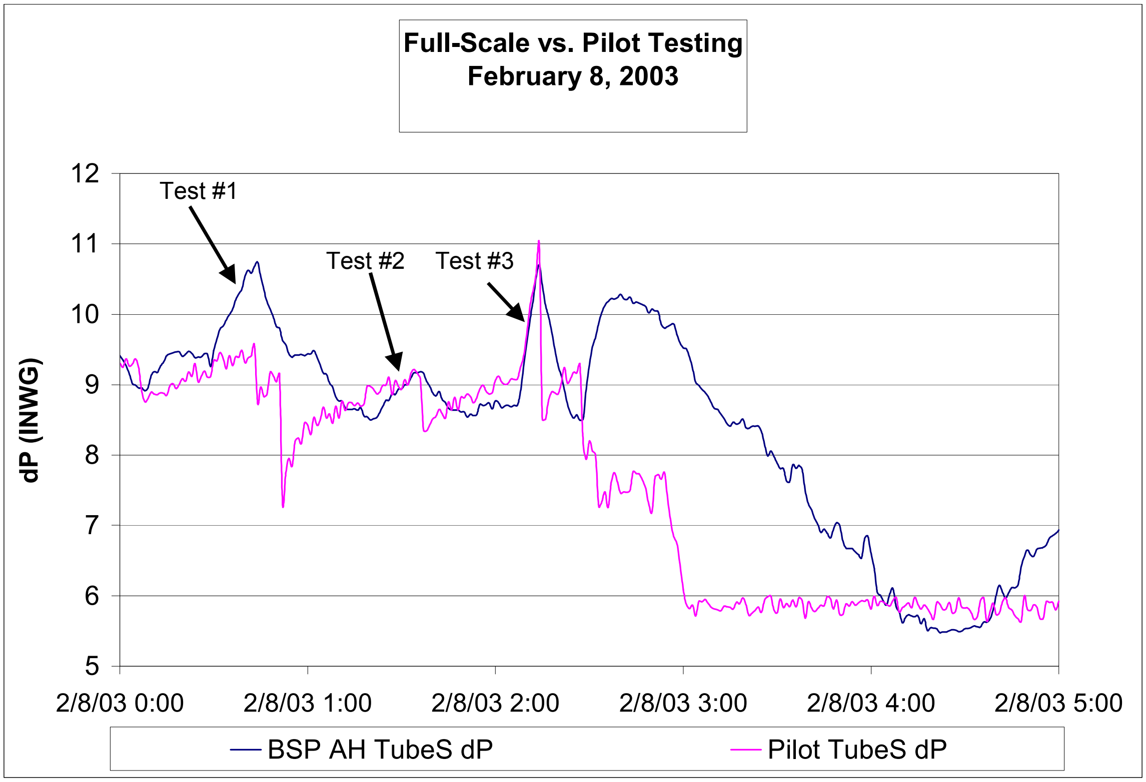
ESP Efficiency

For our test, ESP efficiency was calculated by a rule of thumb method. The loading rate with no ESP section in service was taken as the 0% ESP efficiency state. A 100% efficient ESP would have a 0 loading rate. Therefore, if the K2Ci value was found to be 5.0, and the no ESP loading rate was found to be 19.0, the efficiency value was calculated by the following equation;

$$\text{ESP Efficiency} = (19.0 - 5.0) / 19.0 * 100 = 73.7\%$$

This is an unconventional method of calculating ESP efficiency but works well for our comparison testing.

Test #1. The TRs to only the Advanced Hybrid fields were energized. Both the full-scale system and the pilot unit were operating at 10.4 fpm according to flow instrumentation. The pulsing of the full-scale system was halted until the differential pressure reached unacceptable levels. Then the pulse system was started, but the rate of differential pressure increase was measured, and the differential pressure after one cycle of cleaning was measured.



Test #2. The first test was repeated with all of the TRs, including the full-scale inlet field, energized.

Test#3. The same test was repeated with all of the TRs for both the pilot unit and the full-scale unit shut off. This test should be a good comparison of the overall ash loading rate to the bags without any electrostatic cleaning of the flue gas.

The following table is the summary of the test results.

	Air-to-cloth Ratio	K2Ci		ESP Efficiency		Residual Drag
		Full-Scale	Pilot	Full-Scale	Pilot	Full-Scale
Test #1	10.4	5.17	0.91	72.5 %	95.4 %	0.91
Test #2	10.4	3.02	1.5	83.9 %	92.5 %	0.83
Test #3	10.4	19.94	18.77	0 %	0 %	NA

Very significant conclusions can be made by analyzing the results of this testing. The loading rate of ash to the bags is 3 – 5 times higher in the full-scale unit when compared to the pilot unit. This means that the amount of dust that is being removed by the ESP portion of the systems is significantly different.

The residual drag is significantly higher in the full-scale unit as noticed during the first few days of startup (see Quarter 1 report).

Running the inlet field of the full-scale system reduces the ash loading to the bags by about 40% ((5.17-3.02)/5.17*100). Improving the ESP portion of the system also has a significant effect by reducing the residual drag. By doing nothing more than improving the overall collection of the ESP sections (inlet field and Advanced Hybrid fields) from 72.5% to 83.9%, the residual drag has been reduced from 9.1 to 8.3, approximately 9%

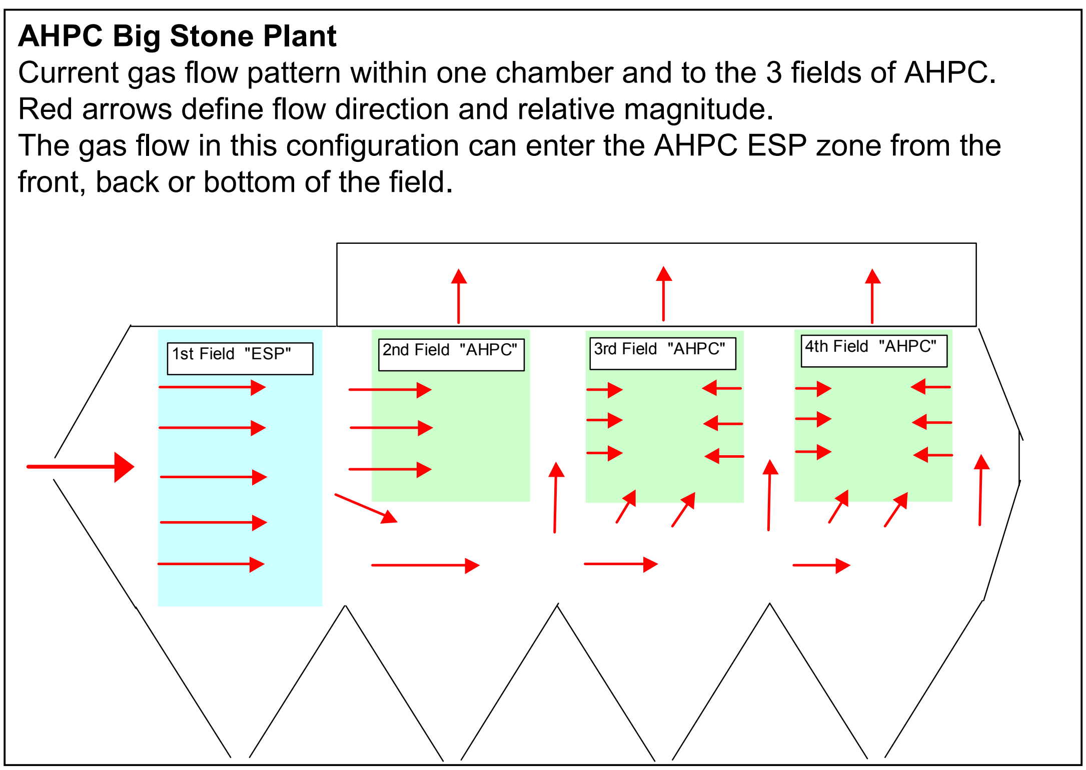
The comparison results from Test 3 show a very good correlation to the full-scale unit and the pilot unit. This tells us that the inlet dust loading to both systems is about equal.

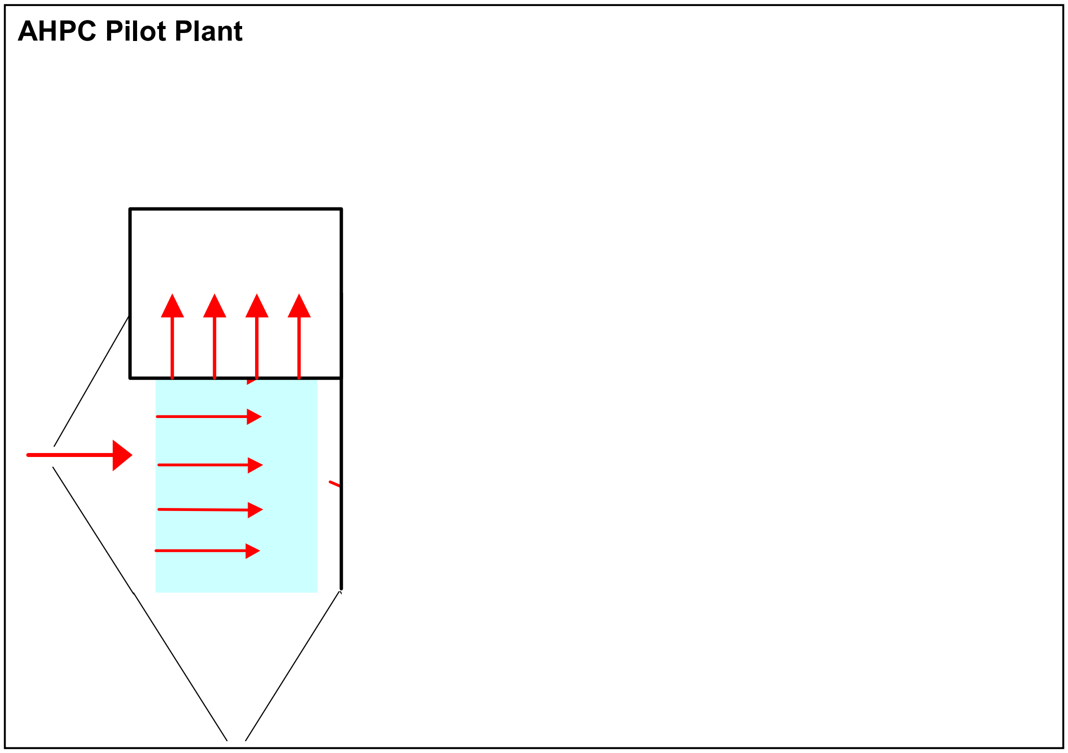
Possible Reasons for Performance Differences

Trying to formulate a plan for improving the performance of the system involves putting together several hypothesis as to why the performance may be different than expected, how it can be verified, and what can realistically be done to improve the system.

Possible explanations for the ESP efficiency difference have been a flow distribution difference as the pilot unit is a side entry system and the full-scale unit is more of a combination of 1/3 side entry and 2/3 bottom entry. Some flue gas may also be bypassing the ESP section if there is a significant portion of the flue gas that is coming up from the area below the bags.

A better description of the flow differences can be found in the following diagrams. The diagrams represent the flow as modeled by ELEX AG at the beginning of the project. Some of the flow is vertical as represented by the red arrows. However, the pilot unit flow is more represented by the flow only in the first field. After entering this field in the pilot, the gas flow is upwards and into the clean gas plenum. There are no "back fields" of Advanced Hybrid components in the Pilot unit.





At this time, no reasonable improvements to the Advanced Hybrid ESP portion could be ascertained. The only suggested improvements are power off rapping or the potential for flow baffles that would require significant money and mechanical changes to the system.

Possible explanations to the residual drag issue are more resistance due to bag material or manufacture, cleaning system deficiencies, or ash characteristics limiting removal during pulsing.

We investigated the effect of the burning of soybeans in the Big Stone Plant as an alternative fuel. During the first two months of the year, approximately 15,000 tons of soybeans (5% of the total fuel) were burned, with the obvious effect of fouling the steam tube surfaces inside the boiler furnace. This might have had some effect on increasing the residual drag of the system by depositing ash on the bags that cannot be easily removed. The EERC analyzed the residual ash cake taken from a bag in service and found a high percentage of potassium. An analysis of soybeans and corn (which is also an alternative fuel fired at the Big Stone Plant) is included in Appendix B24. We should have documented the residual drag of the system at the end of December and the residual drag of the system after the soybeans were burned. This would have given us more information as to how much of the residual drag difference between the pilot unit and the full-scale unit was due to combustion of higher potassium fuels. The EERC determined it is likely the flyash from the soybeans was a factor in the increase of the residual drag. The e-mail from Stan Miller from the EERC is included in Appendix B25.

Performance Improvement Plan

A great deal of effort was put into assembling a performance improvement plan. There were two tactics taken as a part of this effort; a short-term plan designed to help the plant get back to full-load capability, and a long-term plan to bring the Advanced Hybrid system performance up to expected levels.

Short-term Improvement Plan

- Testing the off-line cleaning system
- Testing power off rapping
- Improvements to the ESP Inlet Field
- Washing the filter bags
- Pitot tube data gathering

Off-line Cleaning

The intention of the off-line cleaning system was to close the outlet damper of one of the twelve compartments of the system and pulse that chamber while no gas flow is passing through the bags. In theory, this would allow a better cleaning of the bags, reducing the residual drag and the differential pressure of the system. Once the issues with the compressed air regulators were resolved, this technique was attempted several times. Although there were times when there appeared to be a slight improvement in differential pressure, the results were miniscule at best and this path was not further pursued. The existing cleaning system was removing the ash at the same rate in either cleaning mode. The trend below shows that the average dP before and after a round of off-line cleaning is at relatively the same level. Another difficulty in this arrangement is that simply closing the outlet damper to a single compartment raised the dP by 1.0 – 1.5 INH2O and this could cause the existing condition of limited fan capability to worsen and result in an ID fan stall.

Power Off Rapping

Power off rapping was also tried to improve the overall field strength of the ESP system. In almost all cases the field strength was increased, but the overall effect on differential pressure was minimal or non-existent. The existing system did not have a true power off rapping system installed, so the test of the system was done manually by shutting off the power to the TR to a certain field, and manually commanding the plate and electrode rappers to run. Since little to no benefit was seen with regards to power off rapping it was not adopted as a performance improvement strategy.

Improvements to the ESP Inlet Field

The performance of the inlet ESP field seemed to vary considerably from chamber to chamber. Since the original ESP equipment was over 25 years old and difficult to maintain improvements to plate spacing or rapping could be made to bring the ash removal abilities of the inlet field to the maximum. Although improving this section of the system does not improve the Advanced Hybrid system, it was determined that the field would be analyzed by technicians from ELEX AG and modifications made to try to improve the overall performance.

Washing the Filter Bags

W.L. Gore personnel recommended washing the existing bags to remove the residual dust cake that could not be removed by pulsing. This seemed like an attractive option as the concern over the potassium rich flyash from the soybeans burned in the Big Stone Boiler could be eliminated. However, there was an even larger concern that water would be in direct contact with the flyash in the Advanced Hybrid box. This material is much like concrete dust and if some of the dust were to get wet and not be removed, this could cause major issues inside the system. More investigation was needed to make this decision.

Pitot Tube Data Gathering

One of the corner stones to decision making was the effort by W.L. Gore and Associates to install a substantial number of pitot tubes directly over an individual bag. This should allow better specific information with regards to potential improvement options. The effort to complete this task was significant, and the decisions that were made with regards to bag washing and bag replacement were in large part based on this tool. A brief description of this effort is needed to understand the measurement history.

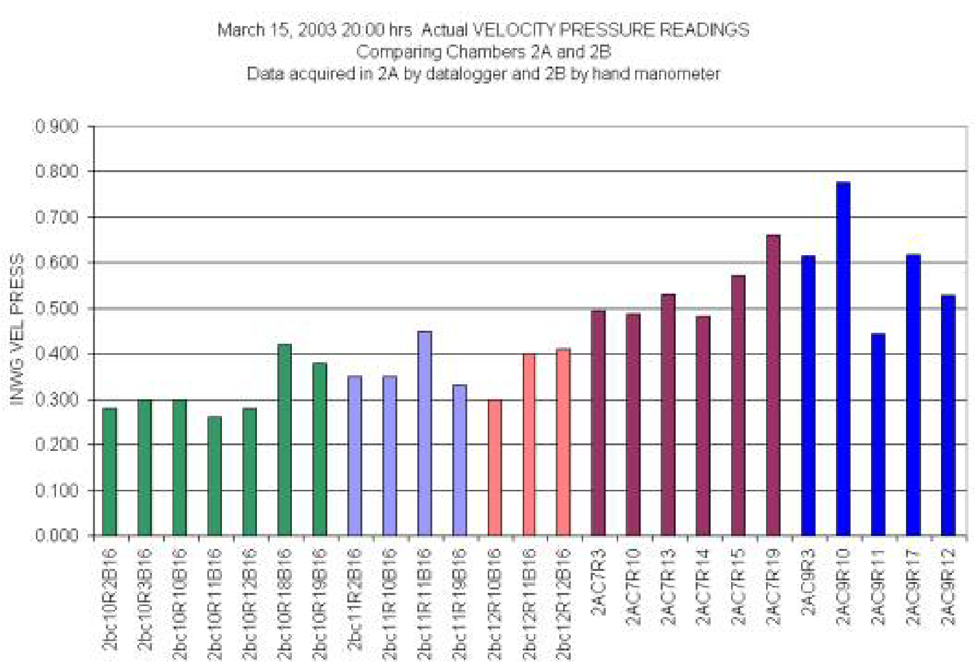
Pitot Tube Measurements

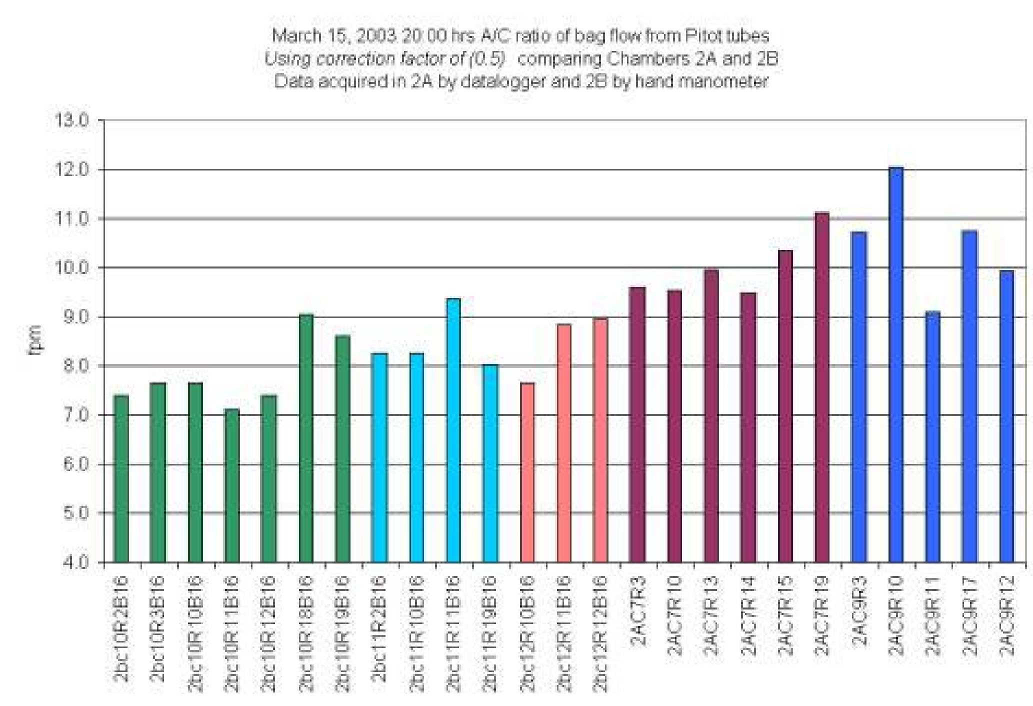
Pitot tube measurements were used successfully on the Pilot unit and reported to the NETL by the EERC. The best description of the Pitot tube effort is the pictures included in Appendix B26. These are photographs depicting the installation of the pitot tubes as they were clamped on to the pulse pipes and extended into the bags. Also included in Appendix B27 is a document from Rich Gebert of W.L. Gore and Associates with more specific design and details of the pitot tubes. The placement of the Pitot tubes can be found on a specific bag layout chart in Appendix B28. These pitots were installed during the boiler wash outage from February 26 through March 2. Low pressure transmitters (Appendix B29) were set up near these compartment locations to record the velocity and static pressure data. There were a limited number of transmitters available for velocity pressure readings, so the connection lines to the transmitters have to be moved frequently to show multiple compartment data.

Data from Pitot Tube Measurements

By the end of the quarter, only limited data was available for analysis. The following graphs are some examples of the data that was retrieved and reported by W.L. Gore and Associates personnel. There are three different types of information that could be garnered from the data; velocity pressure, air-to-cloth ratio, and filter bag drag. (These are represented in the first three graphs below). The fourth graph represents an example of the actual data as it is read from the PLC recording the data from the instruments. No substantial conclusions could be made as to the overall performance of the system by the end of the quarter. The limited data seemed to indicate there were fairly significant flow differences between compartments and between bag locations within compartments. However, the team did feel this was going to be a valuable tool and would aid in the evaluation of the following two aspects in the next quarter;

- Flow differences before and after a bag wash
- Flow differences between bag materials





March 15, 2003 20:00 hrs A/C ratio of bag flow from Pitot tubes
Using correction factor of (0.5) comparing Chambers 2A and 2B
Data acquired in 2A by datalogger and 2B by hand manometer
fpm
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
2bc10R2B16
2bc10R3B16
2bc10R10B16
2bc10R11B16
2bc10R12B16
2bc10R18B16
2bc10R19B16
2bc11R2B16
2bc11R10B16
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2bc12R10B16
2bc12R11B16
2bc12R12B16
2AC7R3
2AC7R10
2AC7R13
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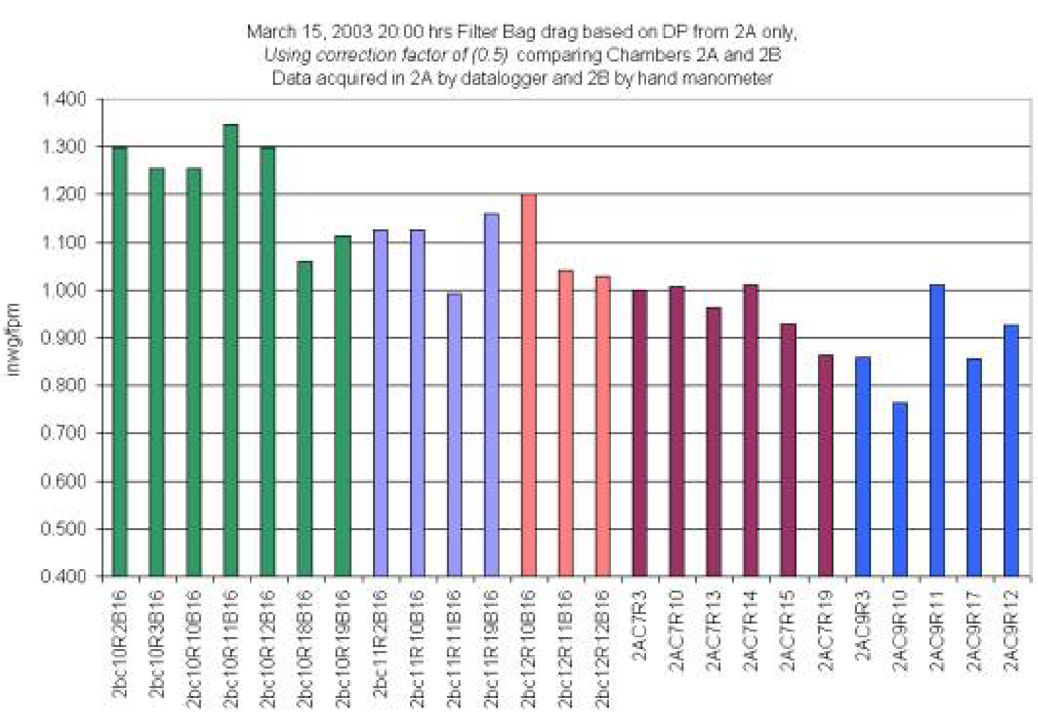
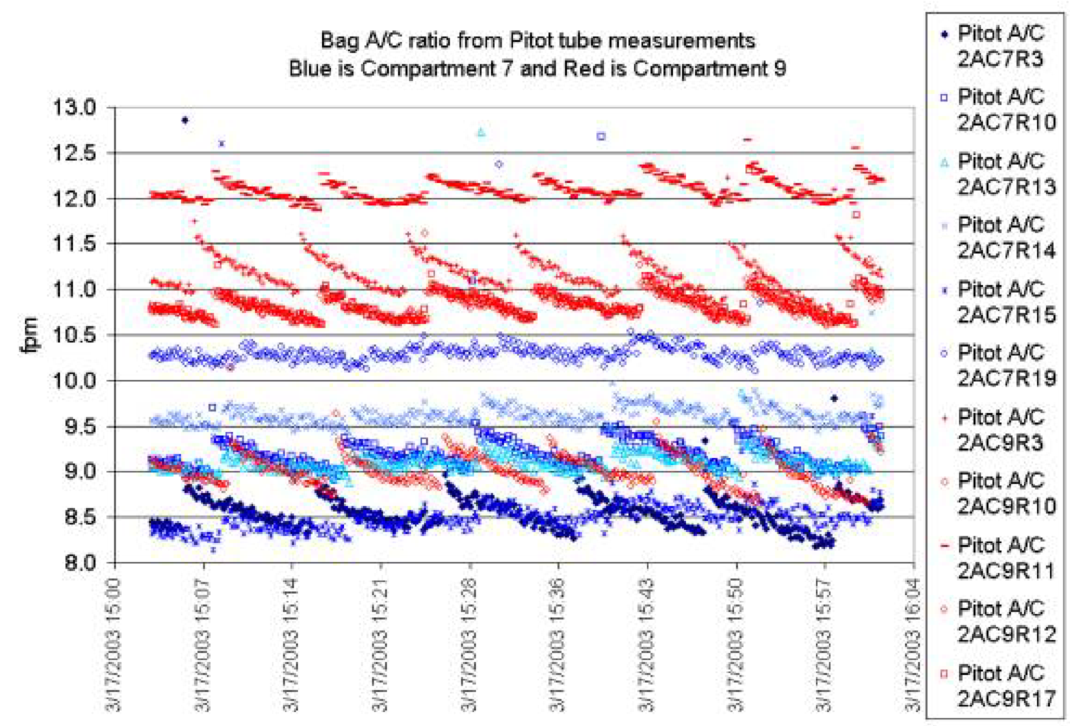
2AC9R17
2AC9R12



March 15, 2003 20:00 hrs Filter Bag drag based on DP from 2A only,
Using correction factor of (0.5) comparing Chambers 2A and 2B
Data acquired in 2A by datalogger and 2B by hand manometer
inwg/fpm
1.400
1.300
1.200
1.100
1.000
0.900
0.800
0.700
0.600
0.500
0.400
2bc10R2B16
2bc10R3B16
2bc10R10B16
2bc10R11B16
2bc10R12B16
2bc10R18B16
2bc10R19B16
2bc11R2B16
2bc11R10B16
2bc11R11B16
2bc11R19B16
2bc12R10B16
2bc12R11B16
2bc12R12B16
2AC7R3
2AC7R10
2AC7R13
2AC7R14
2AC7R15
2AC7R19
2AC9R3
2AC9R10
2AC9R11
2AC9R17
2AC9R12


Bag A/C ratio from Pitot tube measurements
Blue is Compartment 7 and Red is Compartment 9
fpm
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
3/17/2003 15:00
3/17/2003 15:07
3/17/2003 15:14
3/17/2003 15:21
3/17/2003 15:28
3/17/2003 15:36
3/17/2003 15:43
3/17/2003 15:50
3/17/2003 15:57
3/17/2003 16:04
Pitot A/C 2AC7R3
Pitot A/C 2AC7R10
Pitot A/C 2AC7R13
Pitot A/C 2AC7R14
Pitot A/C 2AC7R15
Pitot A/C 2AC7R19
Pitot A/C 2AC9R3
Pitot A/C 2AC9R10
Pitot A/C 2AC9R11
Pitot A/C 2AC9R12
Pitot A/C 2AC9R17

4.0 CONCLUSIONS

The Advanced Hybrid system has struggled with operability and performance this quarter. Significant derates have been an issue at the Big Stone Power Plant due to the high differential pressure across the bags. One of the operability issues has been resolved but one remains. Most of the emphasis this quarter has been on establishing performance baselines and building a strategy to improve performance.

Operation

There were two operational concerns at the end of last quarter. These were,

- Plate rapper alignment concerns
- Compressed air flow limitations by the regulators

Much more information is known about the plate rappers at the end of this quarter, but final repairs will not be made until the scheduled June boiler wash outage. These fixes include the replacement of the section of rapper shafts that extends through the wall to the proper diameter, the modification of the shaft couplers to reduce the possibility of the connecting bolt from interfering with internal components, and the improved alignment of the components.

The compressed air flow limitation has been removed after much experimentation. Placing twelve individual regulators, one for each compartment, in the system rather than six regulators total, solved this problem.

Performance

The performance of the system has been documented and included in the Appendix in graphical format. The fundamental performance parameters are;

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

Opacity remains very low. Some damage has occurred to the bags, but the damage is rather insignificant and no noticeable increase in particulate emissions can be seen from the opacity monitor.

After increasing slightly in the beginning of the quarter (11.0 fpm), the air-to-cloth ratio of the system has actually decreased slightly this quarter(10.5 fpm). This is because the differential pressure of the system has risen to a point where load has had to be restricted. As we get closer to the summer months, if we are able to return the plant to full load, it is likely that we will see an air-to-cloth ratio of 12.0 fpm.

Tubesheet dP has risen to between 9 and 10 INH2O. This is a great concern especially since the overall air-to-cloth ratio has actually decreased during the quarter. The reasons for this are likely twofold. First, the residual drag is likely rising over time just due to normal operation and pulsing frequency. Second, the combustion of high potassium fuels in the boiler (soybeans) is likely causing a more restrictive ash cake to stick to the bags that cannot be removed by pulsing.

Compressed air flow has been varied as a solution to the pressure regulators has been sought. Compressed air flow of up to 3000 acfm has been seen but this was an abnormal condition. Now that the system has been set up correctly, it appears that the maximum normal compressed air flow is approximately 2200 acfm.

<u>Summary</u>

Some successes with the operation of the system have been realized, and we are optimistic of the future performance. Further efforts are needed to determine the true performance status and the potential improvements that can be made. The focus during the next quarter will center around three areas;

- Potential Improvements to the ESP portion
    - Repair and modification of the existing plate rappers
    - Improvement to the inlet ESP field
- Potential improvements from bag washing
- Potential improvements from different bag materials

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.

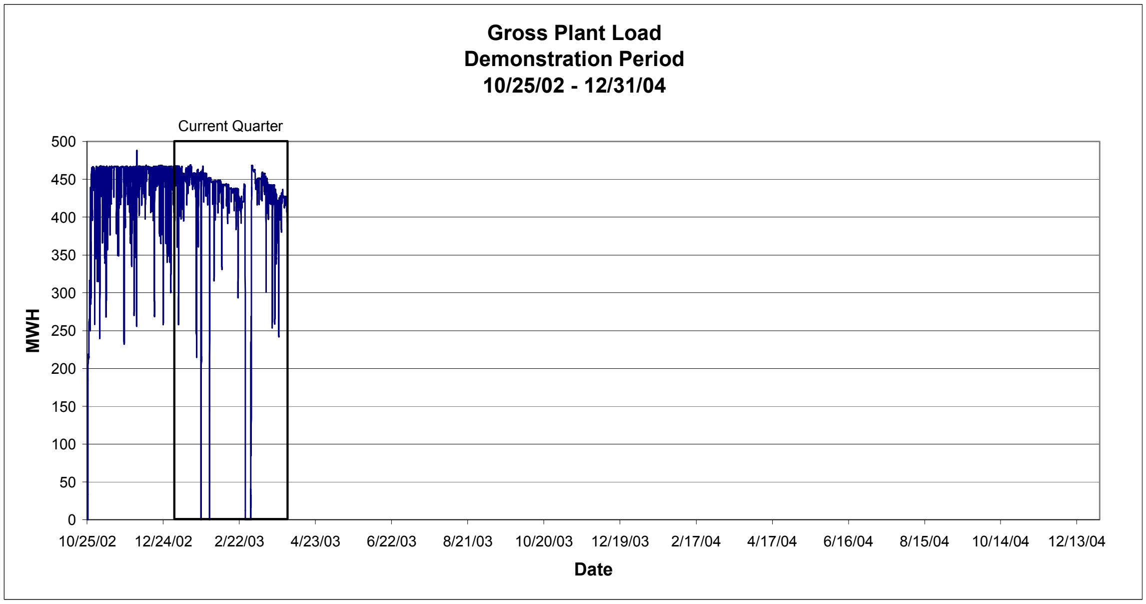
Appendix B8. Opacity Graph shows two spikes in the opacity reading that were not real (1/15/2003 & 3/1/2003). These spikes were instrumentation failures and/or calibrations.

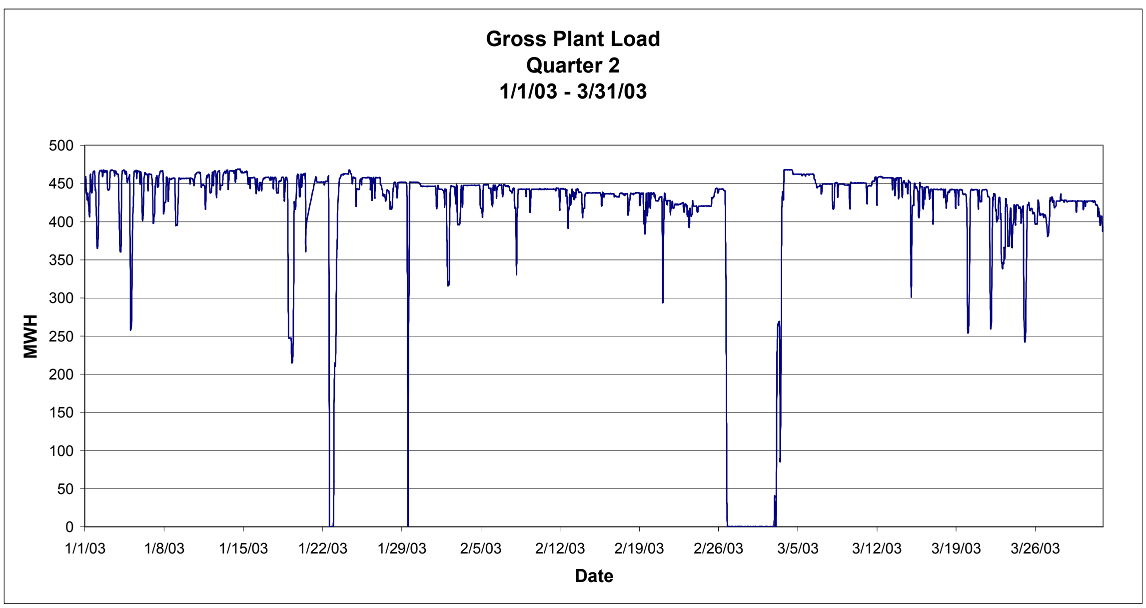
Appendix B15. bam, ebm, etc. are Powder River Basin mine codes

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

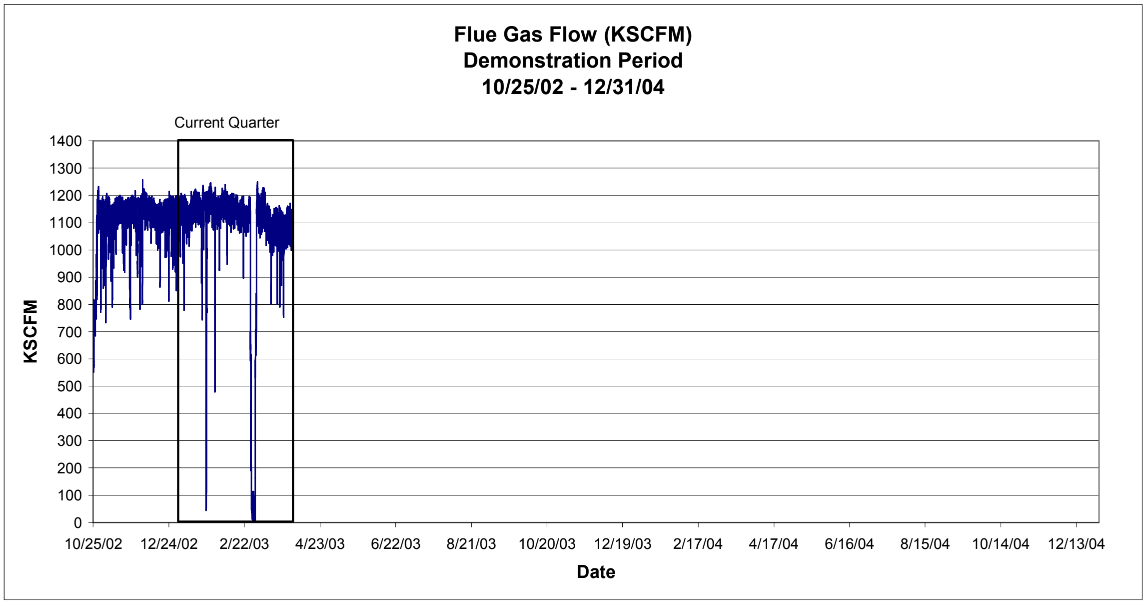
APPENDIX B – GRAPHICAL & TABULAR PERFORMANCE DATA

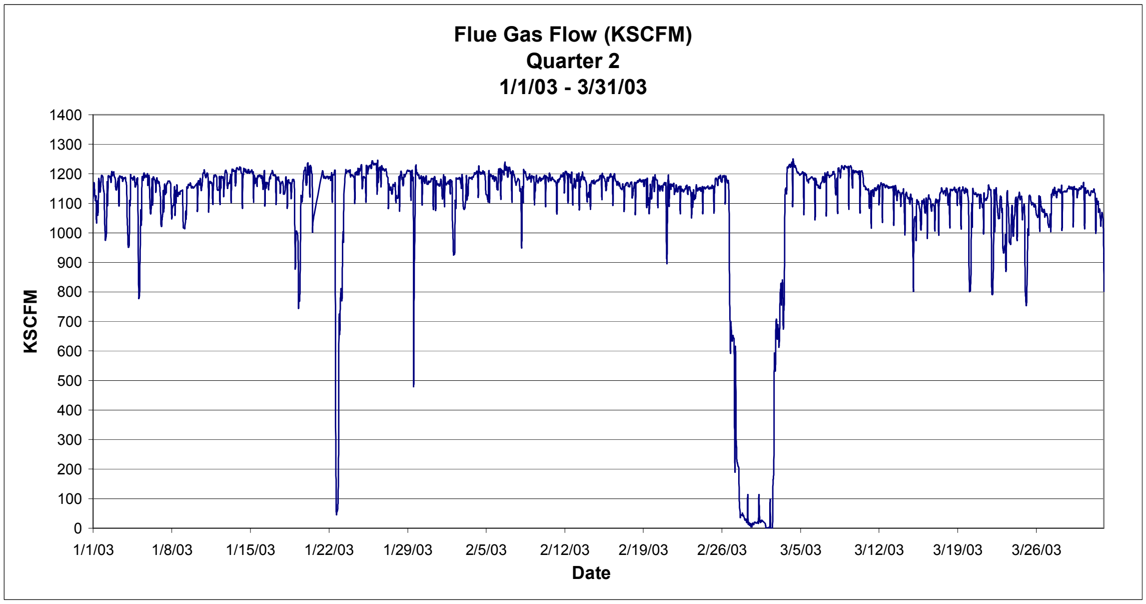
B1 Gross Plant Load



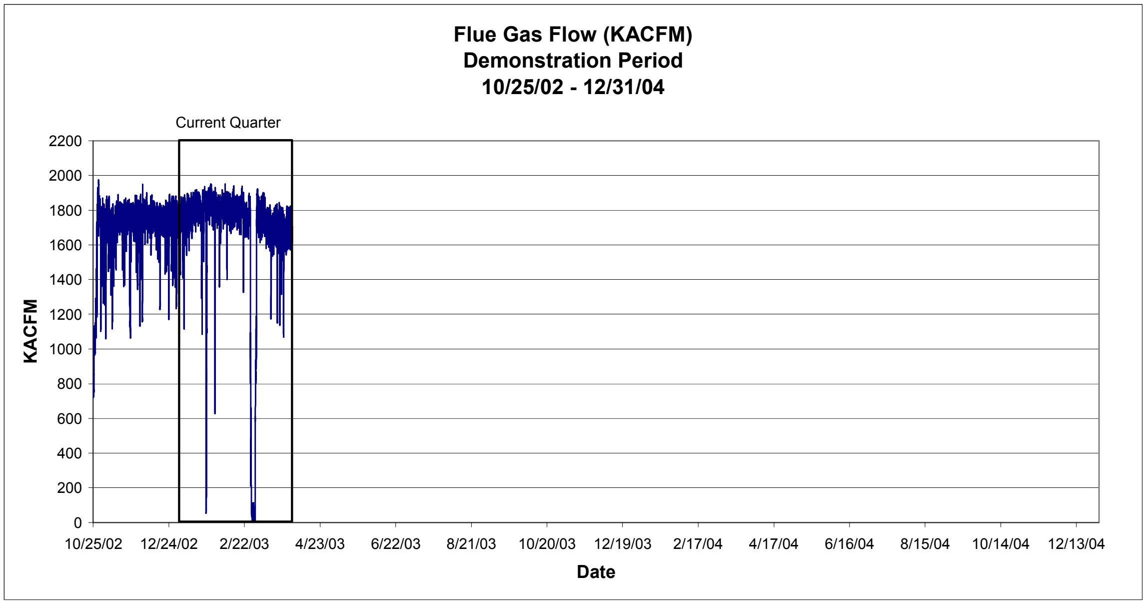


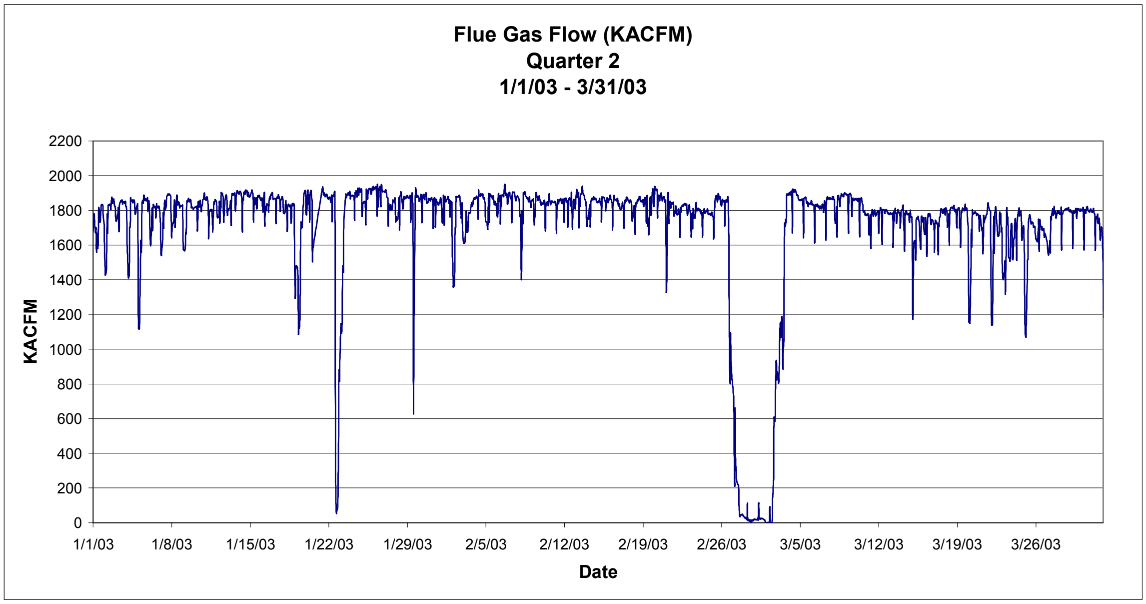
B2 Flue Gas Flow (KSCFM)



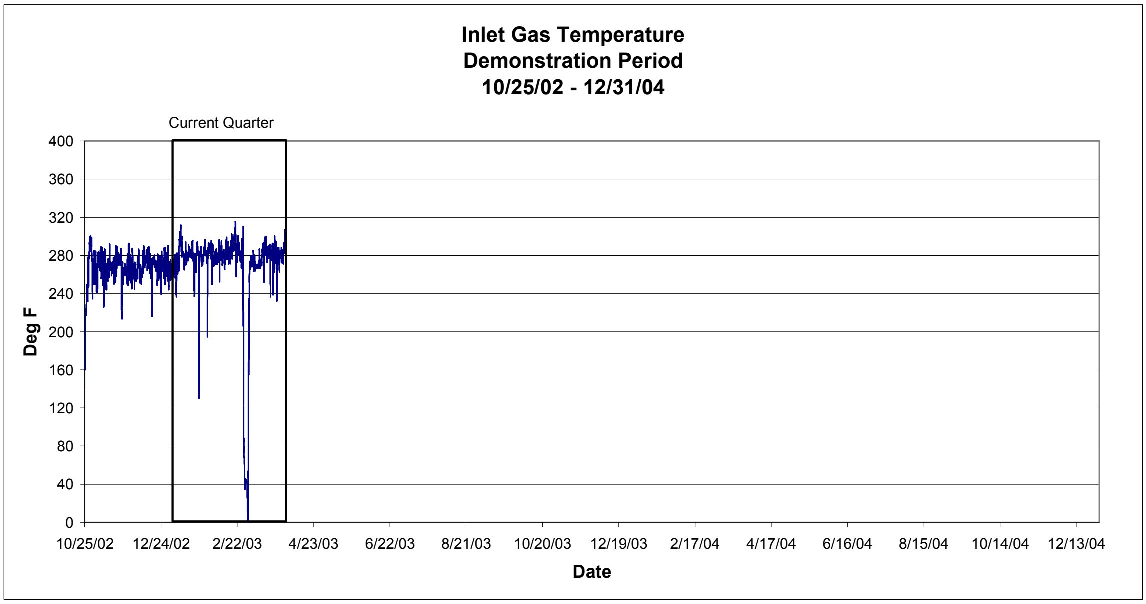


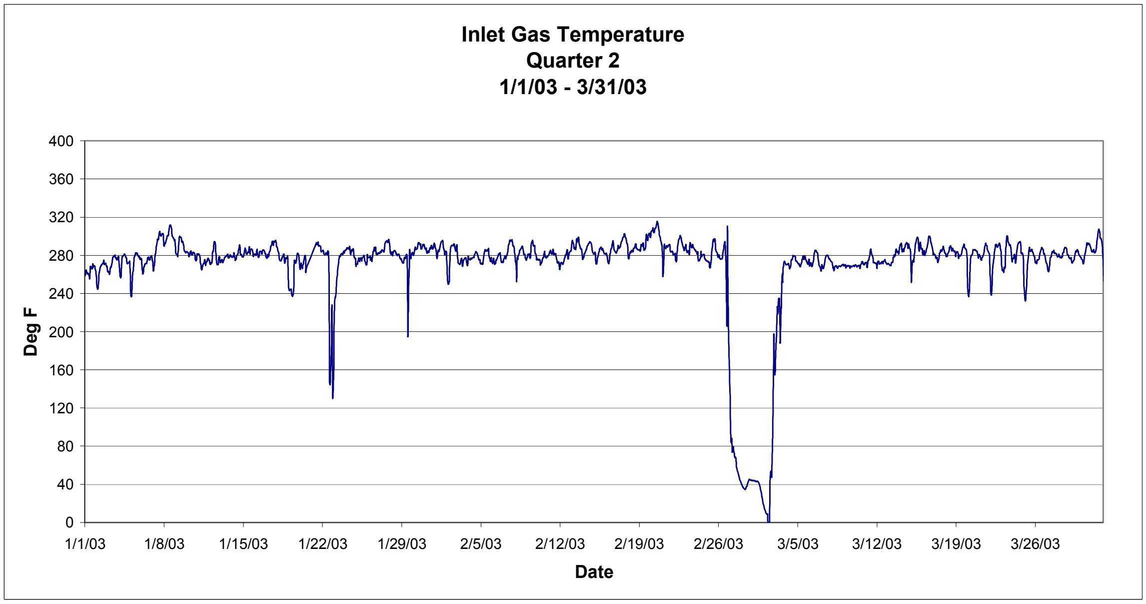
B3 Flue Gas Flow (KACFM)



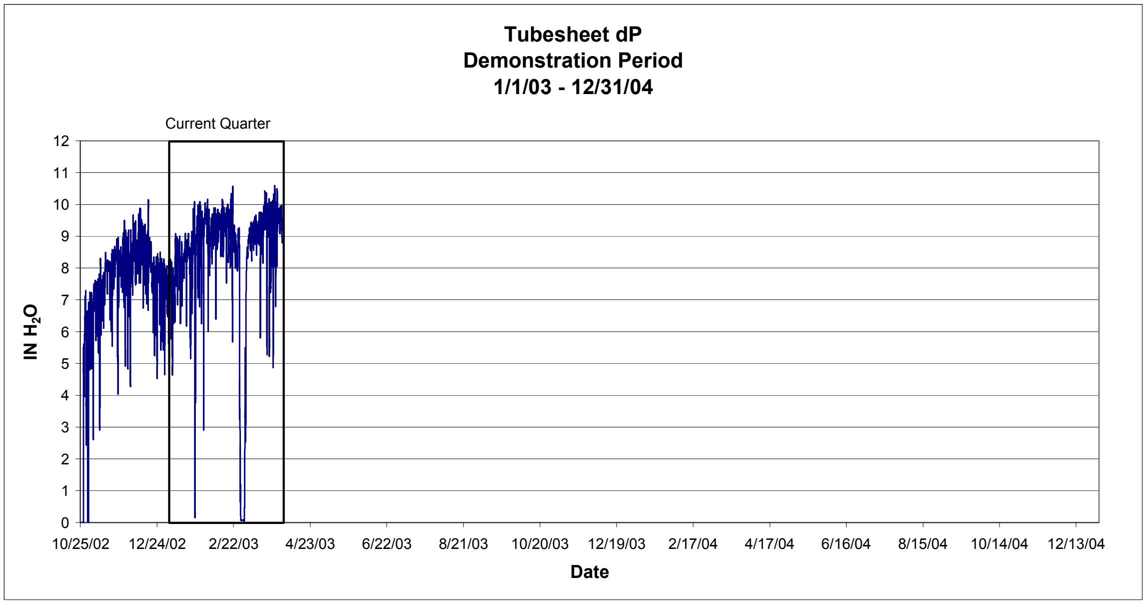


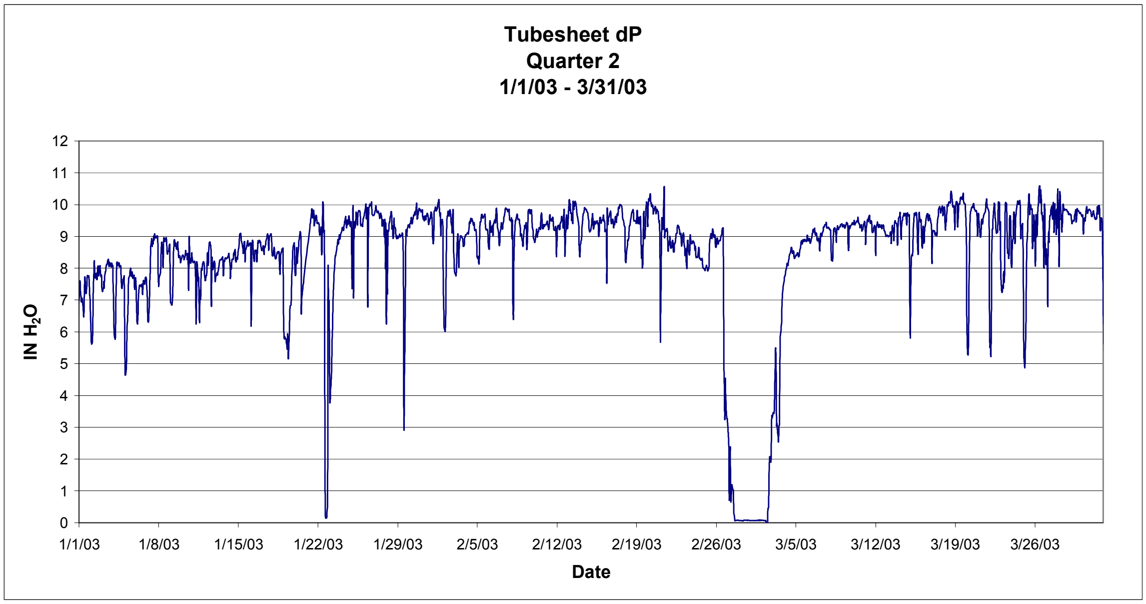
B4 Inlet Gas Temperature



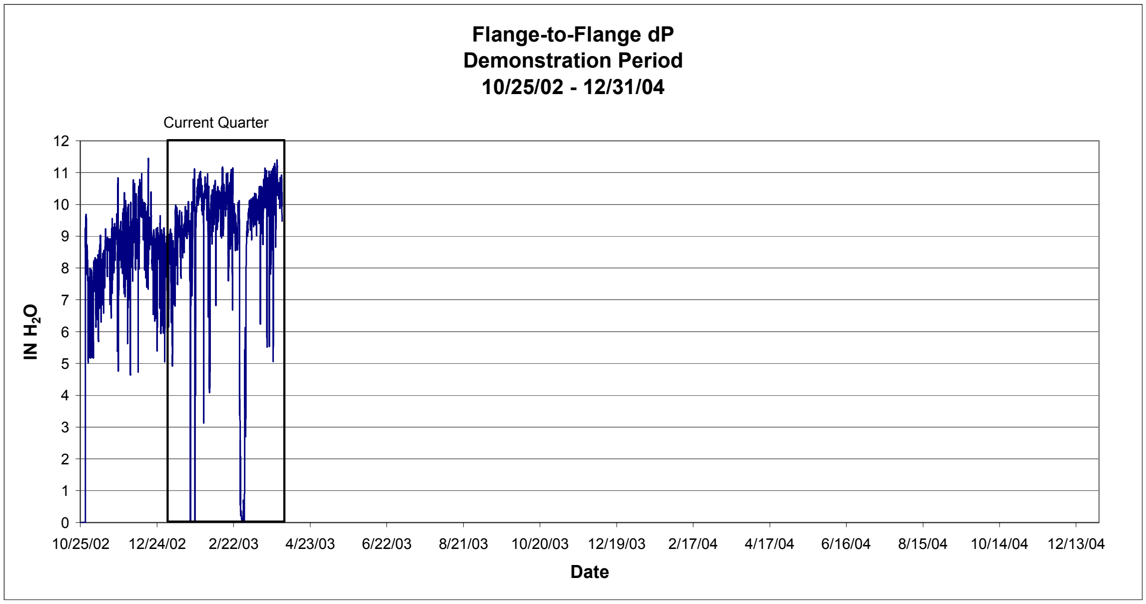


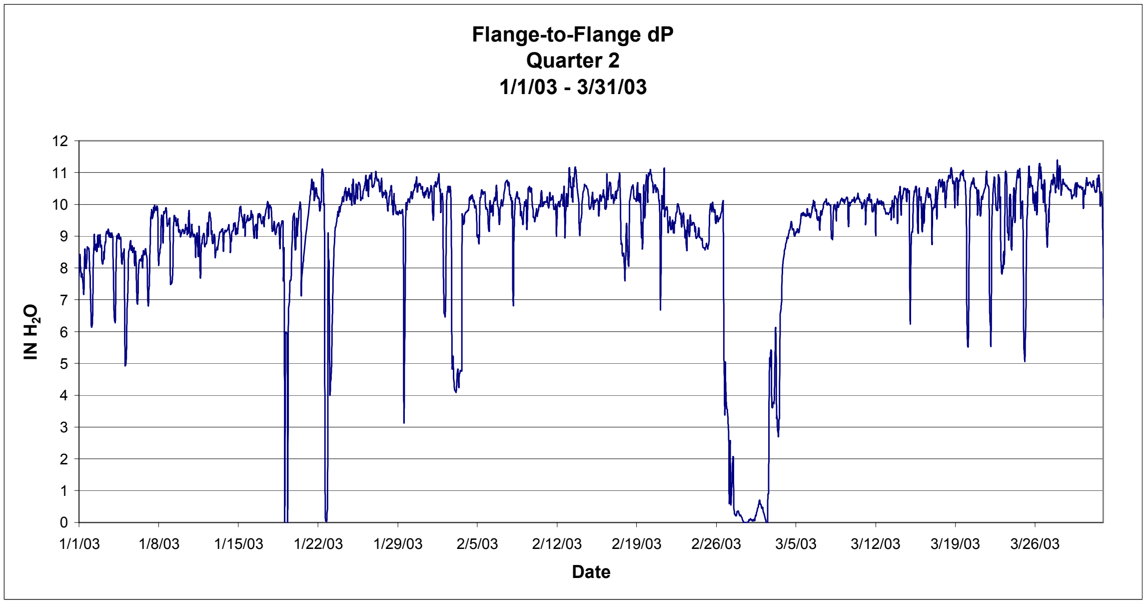
B5 Tubesheet dP



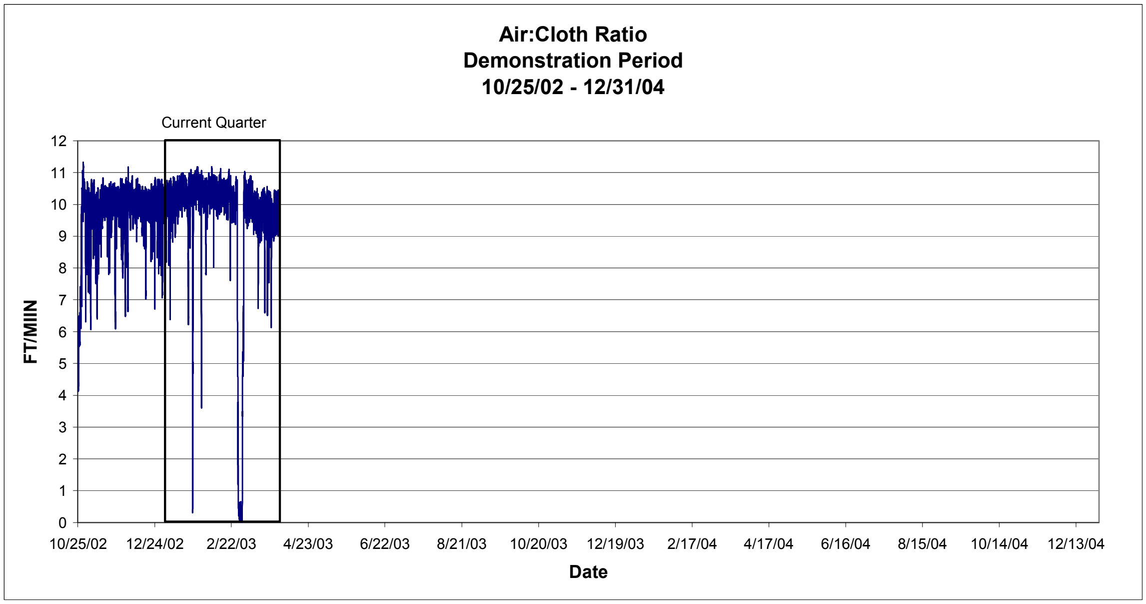


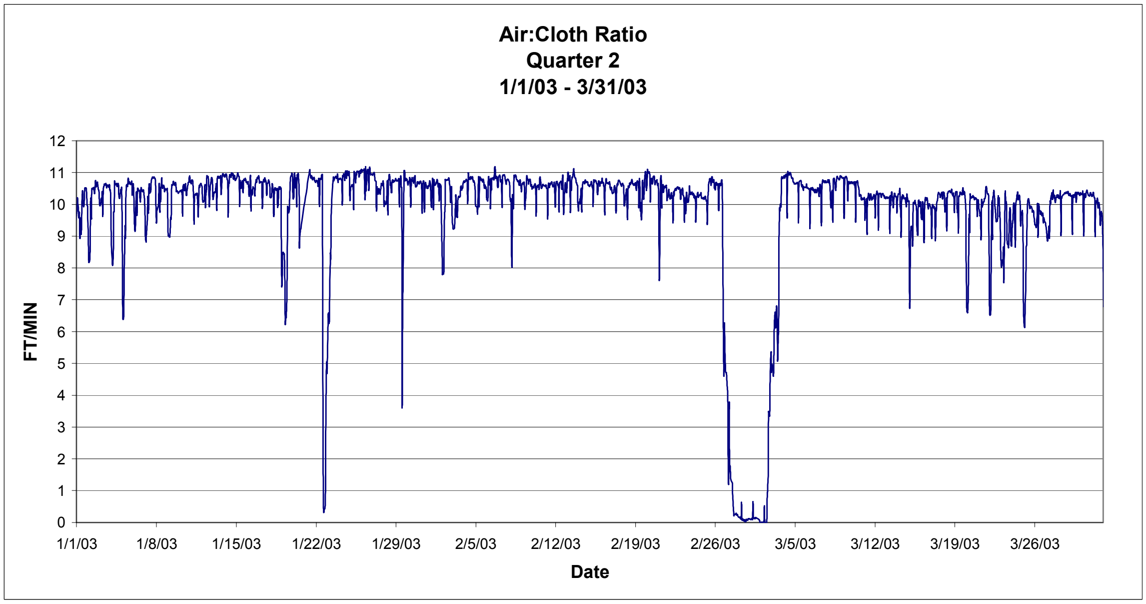
B6 Flange-to-Flange dP



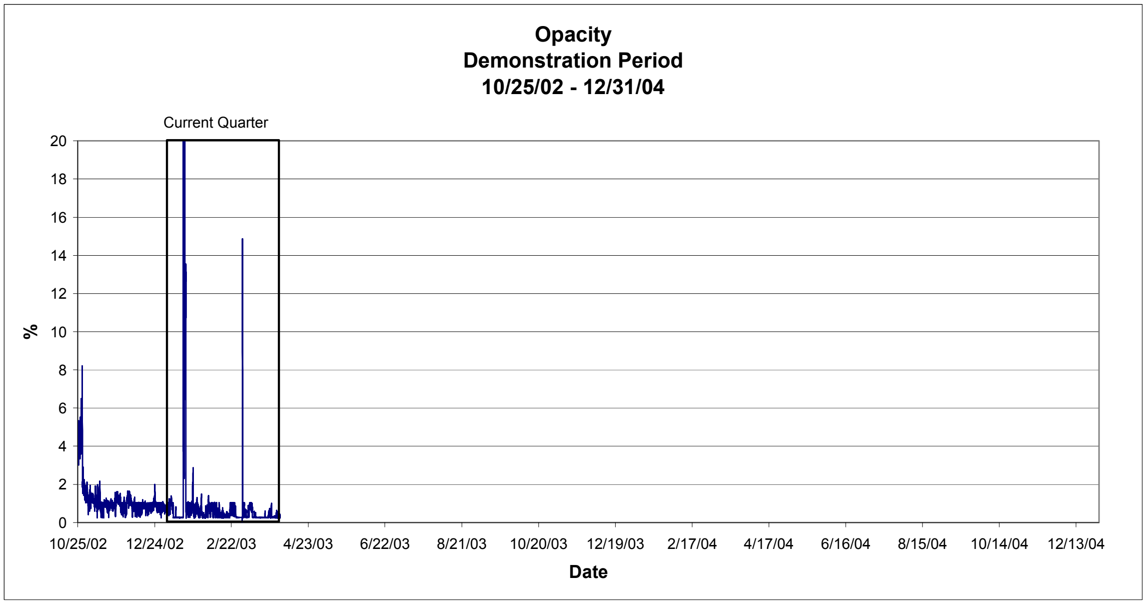


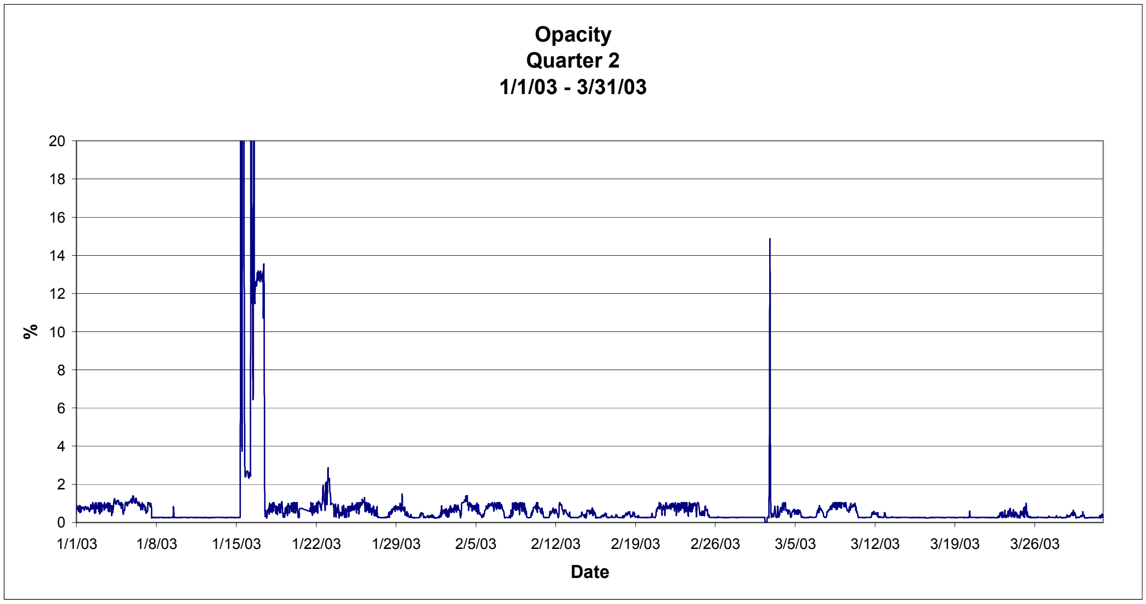
B7 Air-to-Cloth Ratio



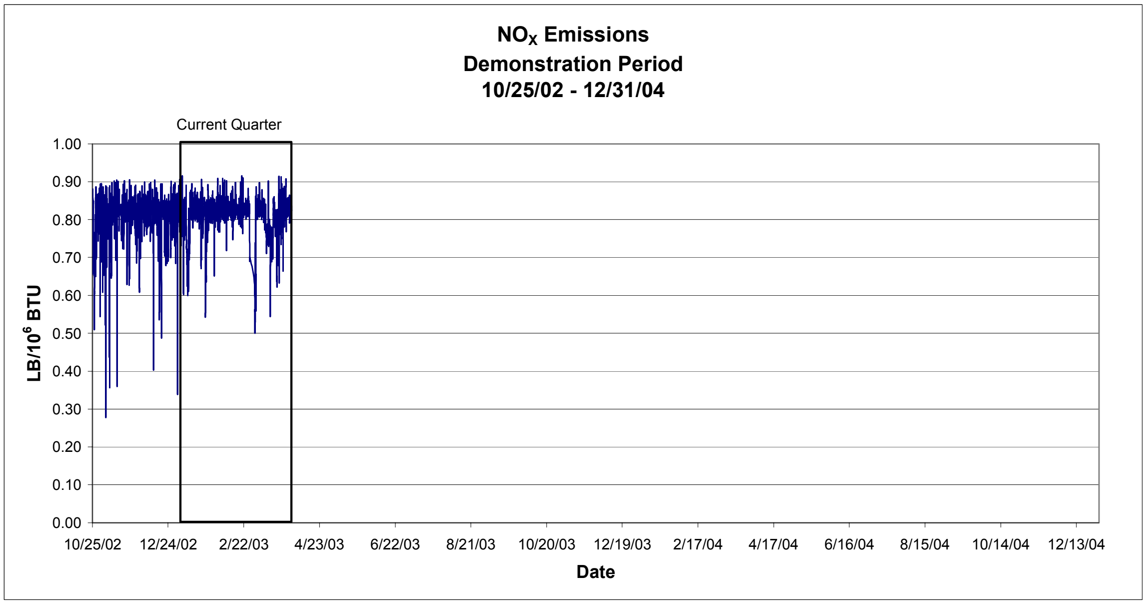


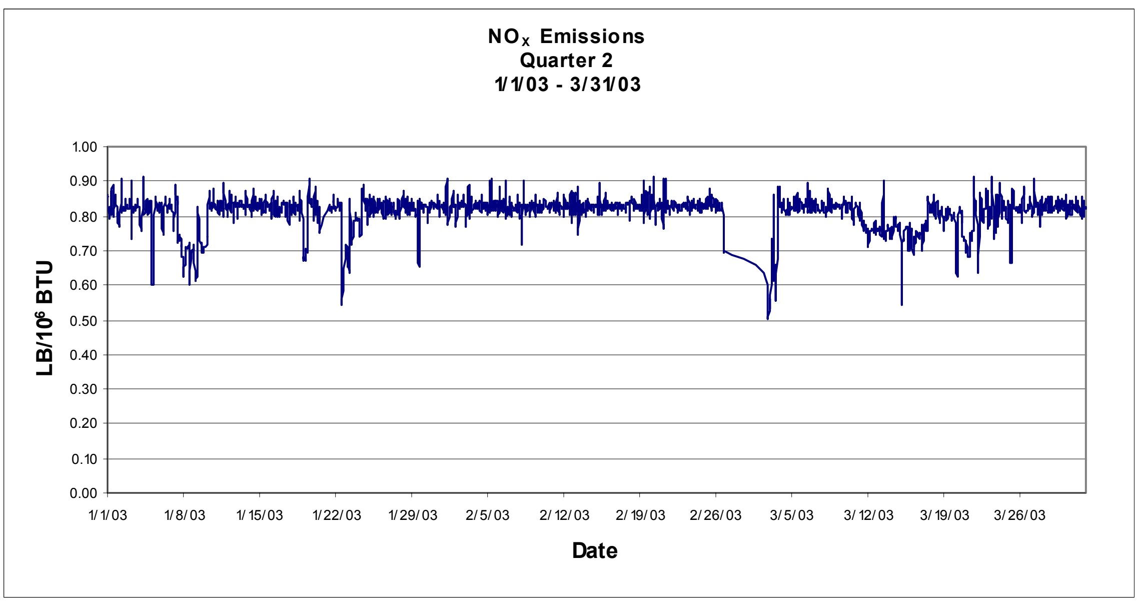
B8 Opacity


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

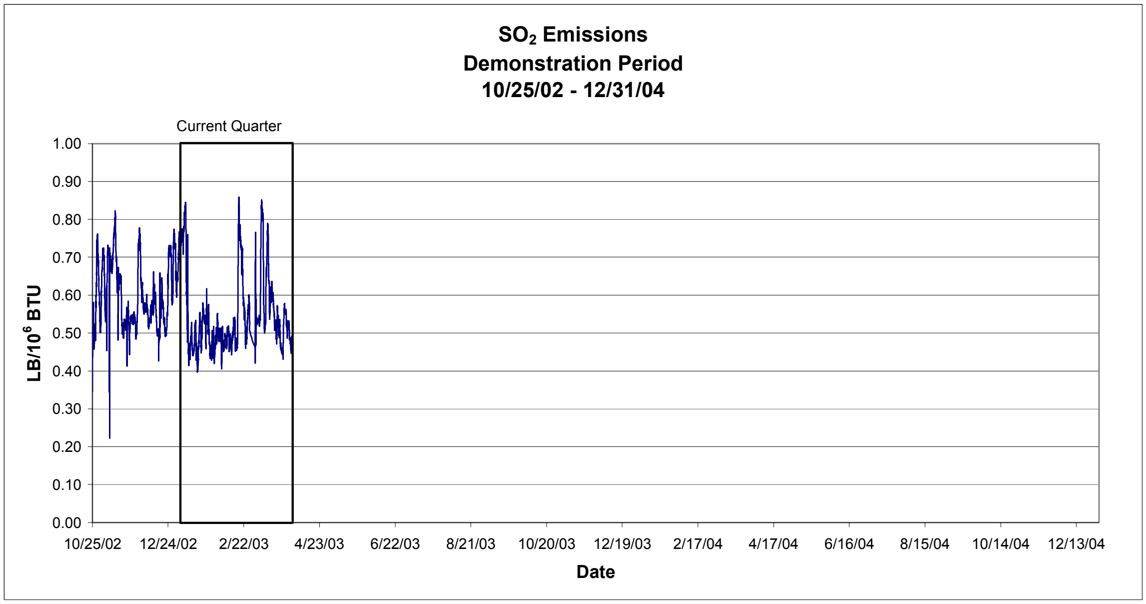

Opacity
Quarter 2
1/1/03 - 3/31/03
%
0
2
4
6
8
10
12
14
16
18
20
1/1/03
1/8/03
1/15/03
1/22/03
1/29/03
2/5/03
2/12/03
2/19/03
2/26/03
3/5/03
3/12/03
3/19/03
3/26/03
Date

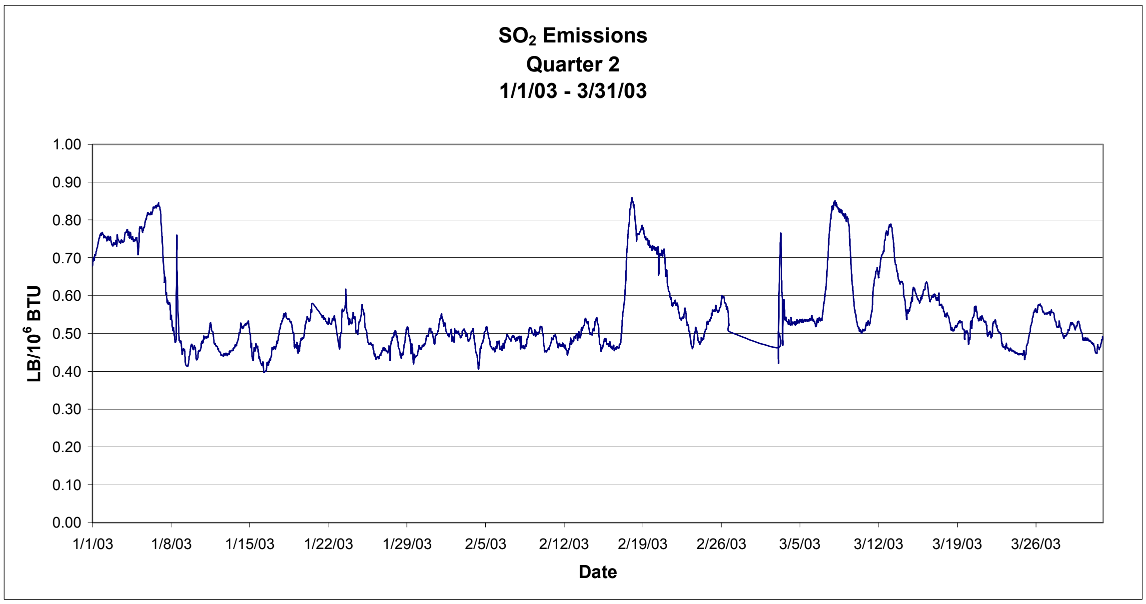
B9 NO_X Emissions



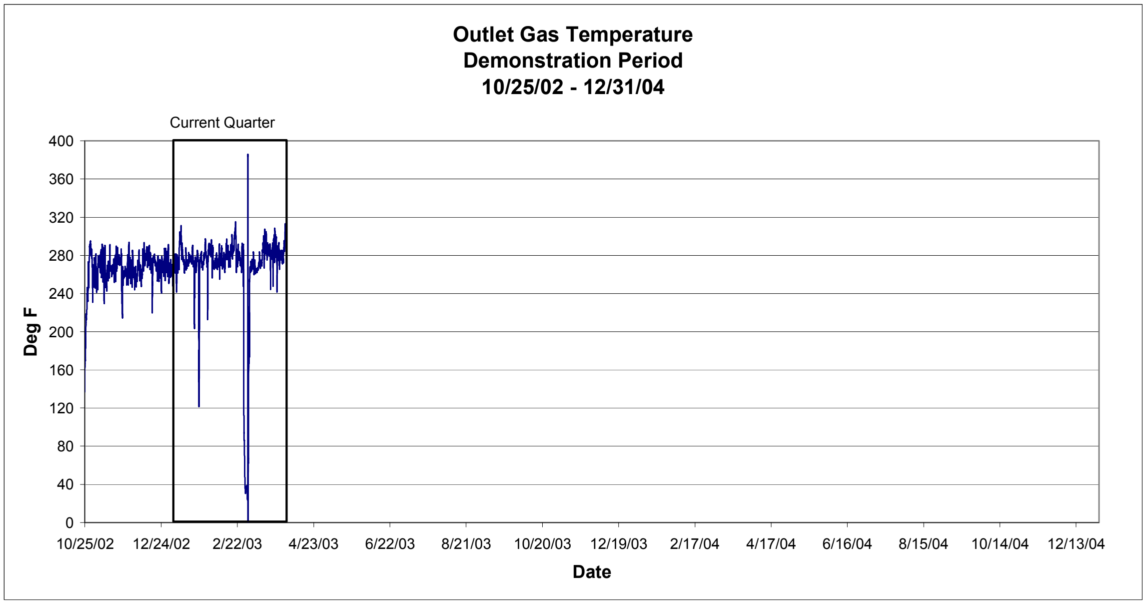


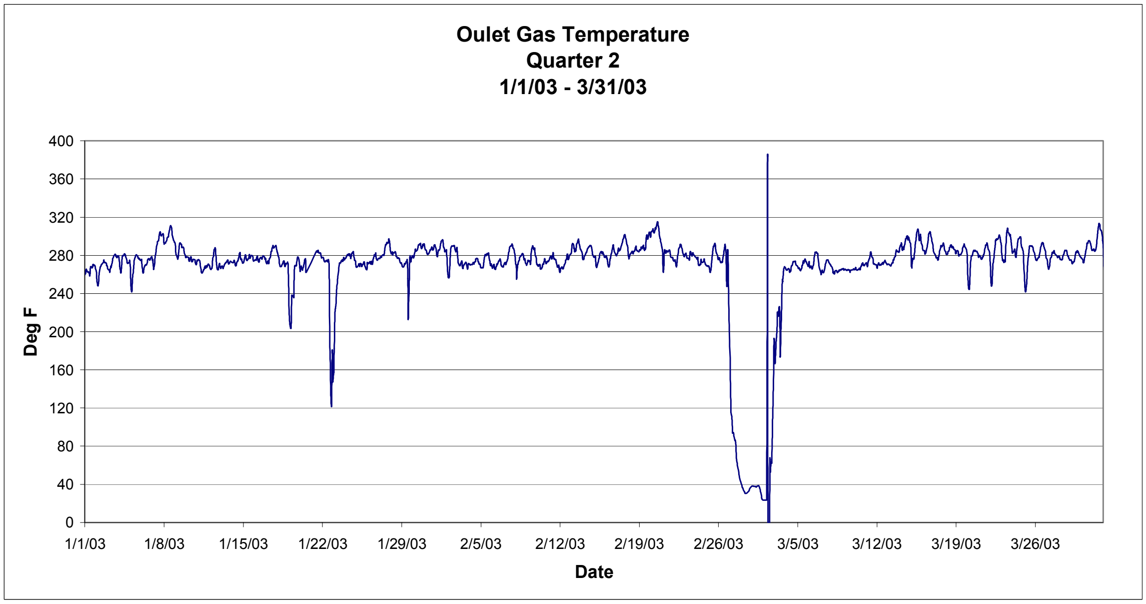
B10 SO_2 Emissions



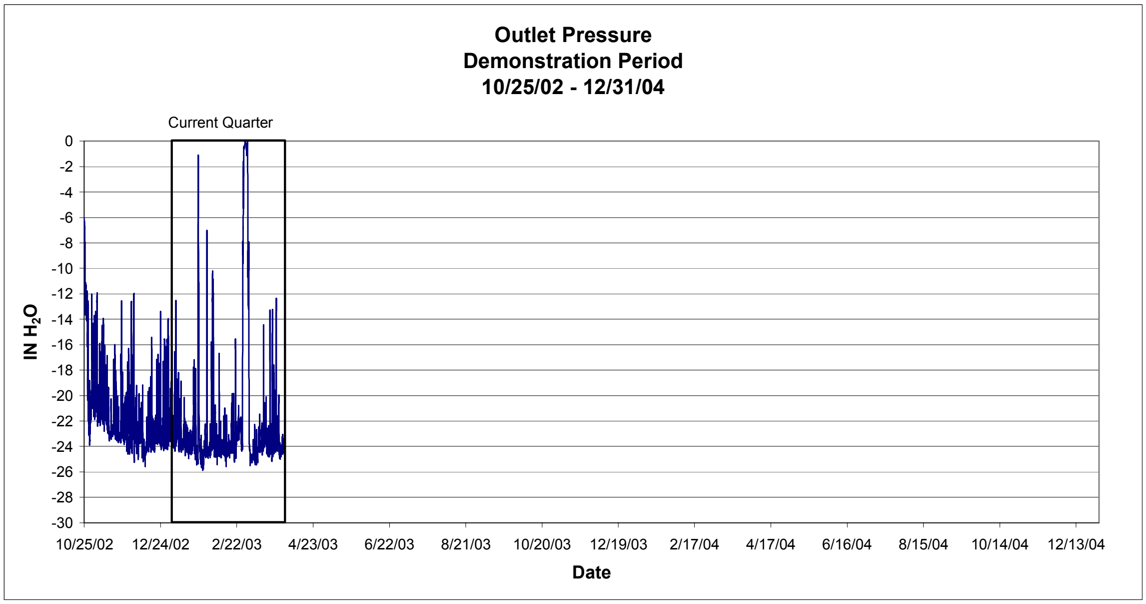


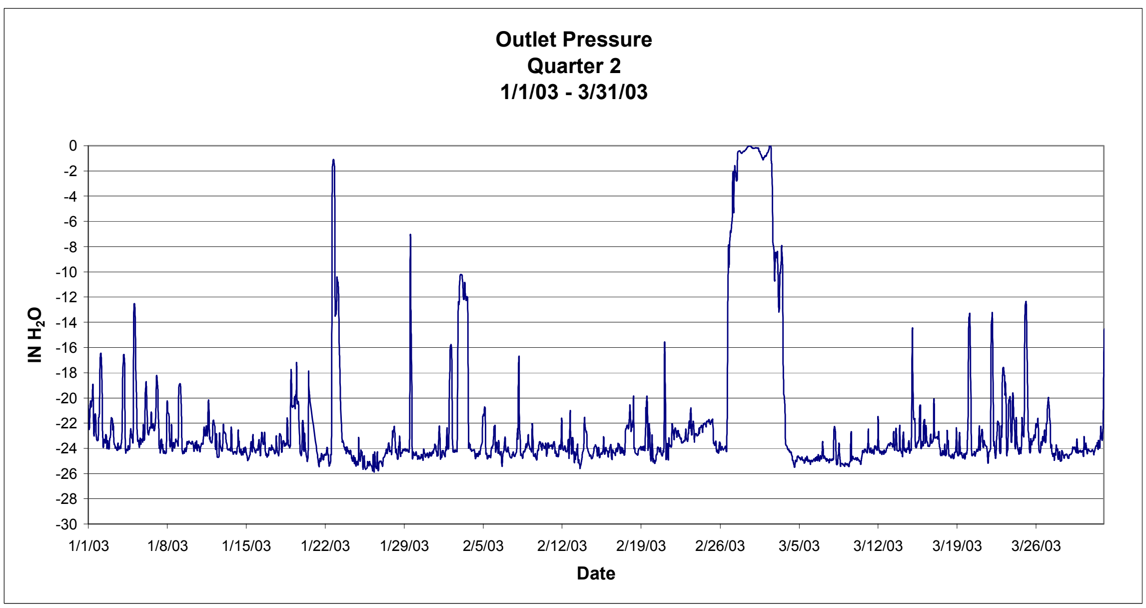
B11 Outlet Gas Temperature



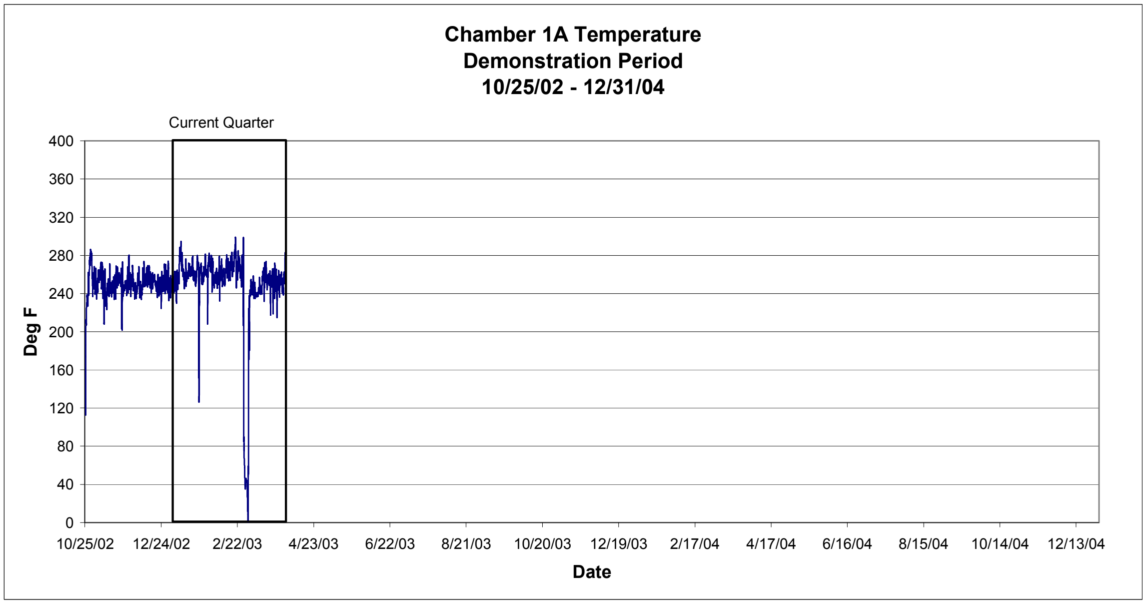


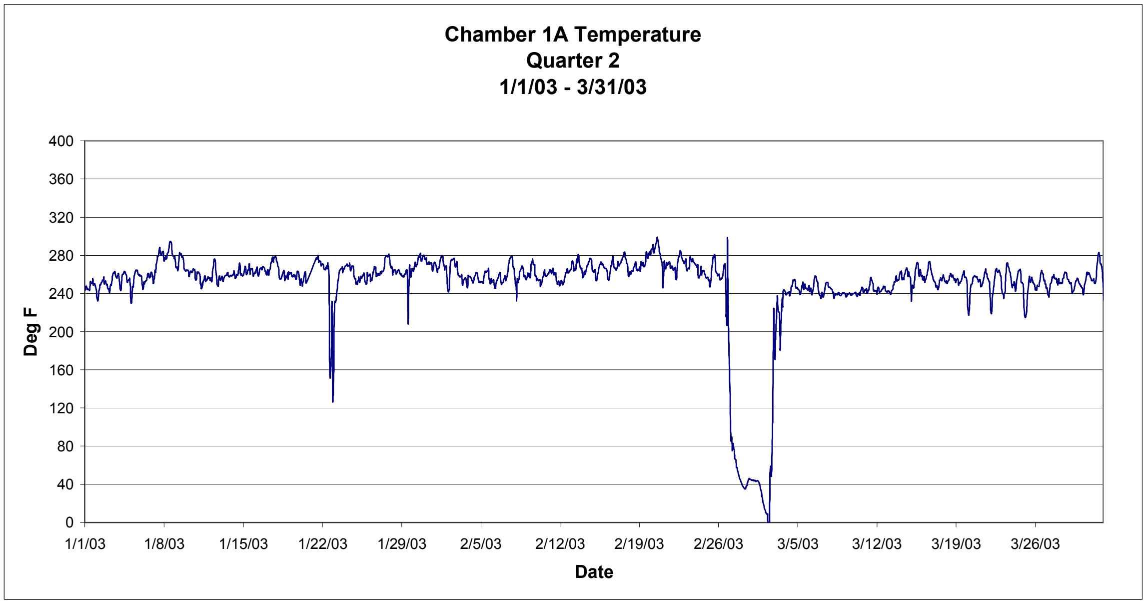
B12 Outlet Pressure

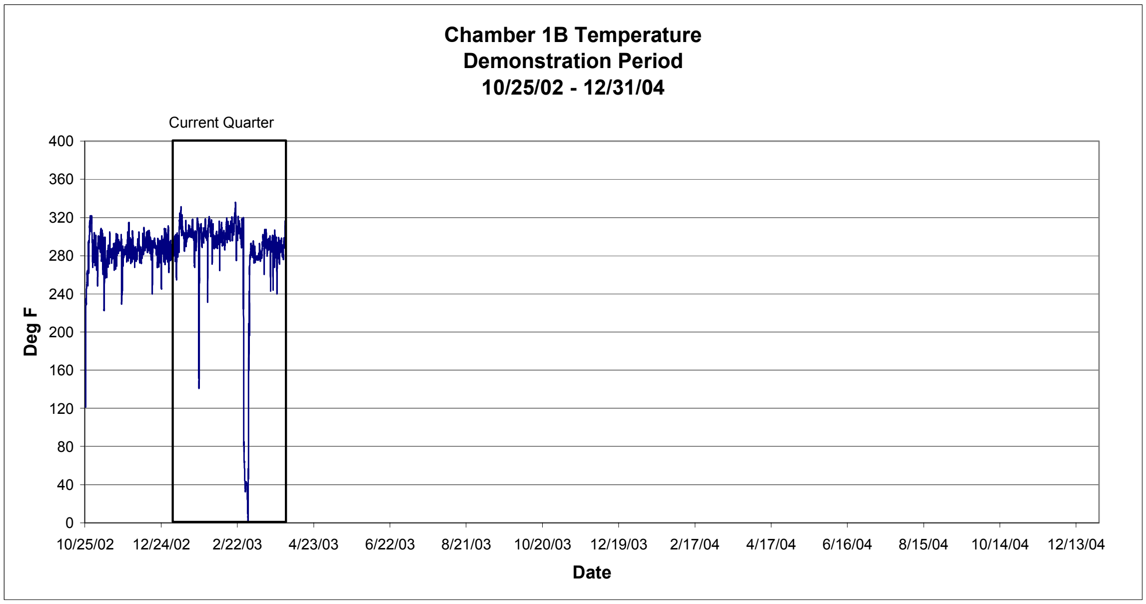


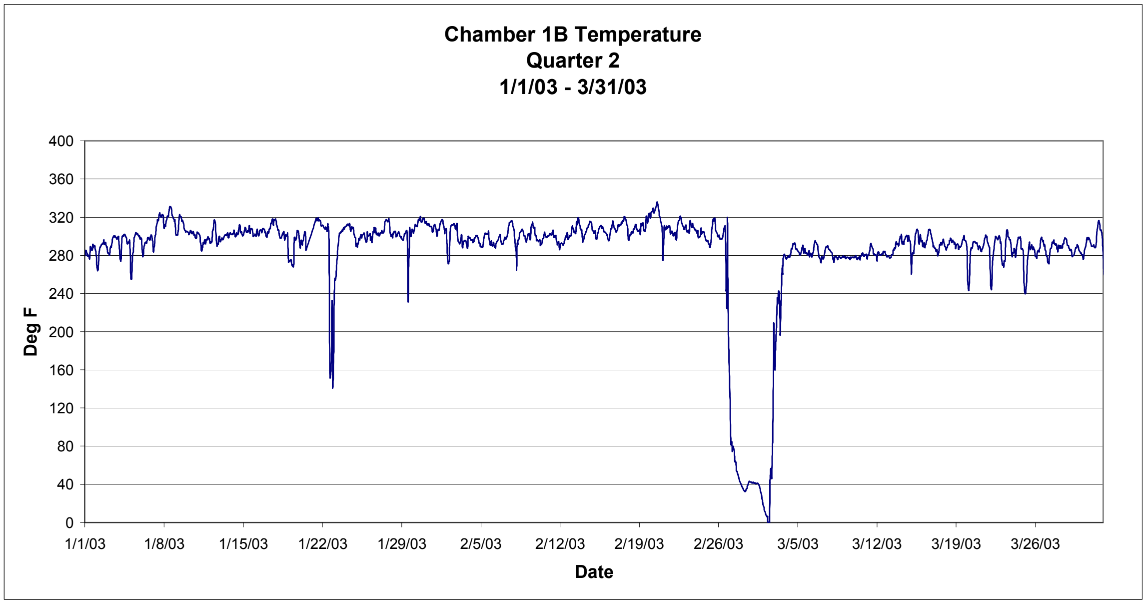


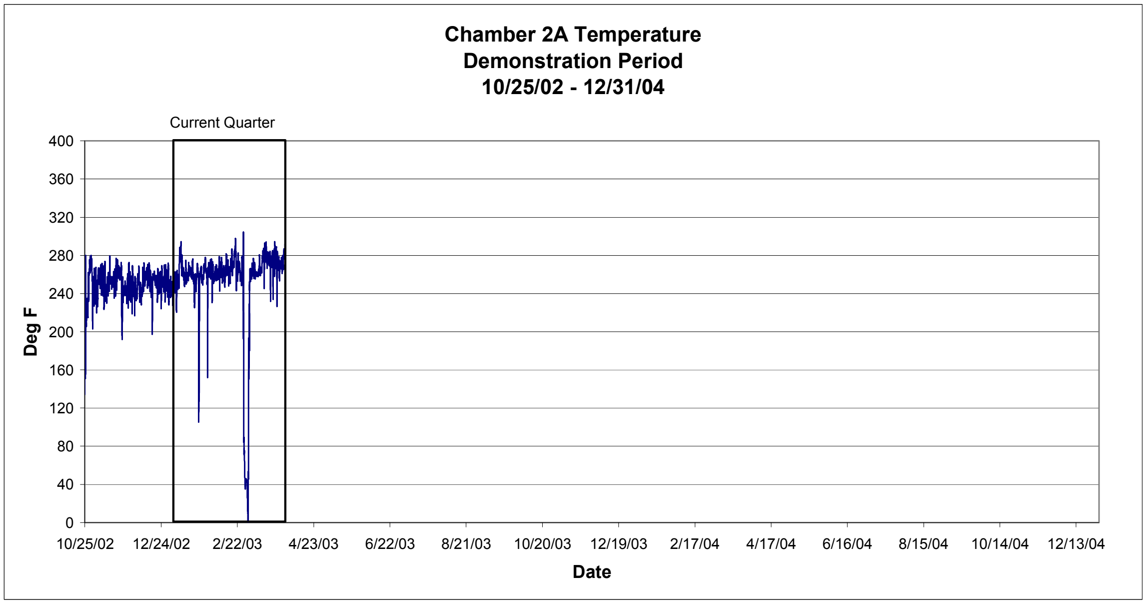
B13 Temperature per Chamber

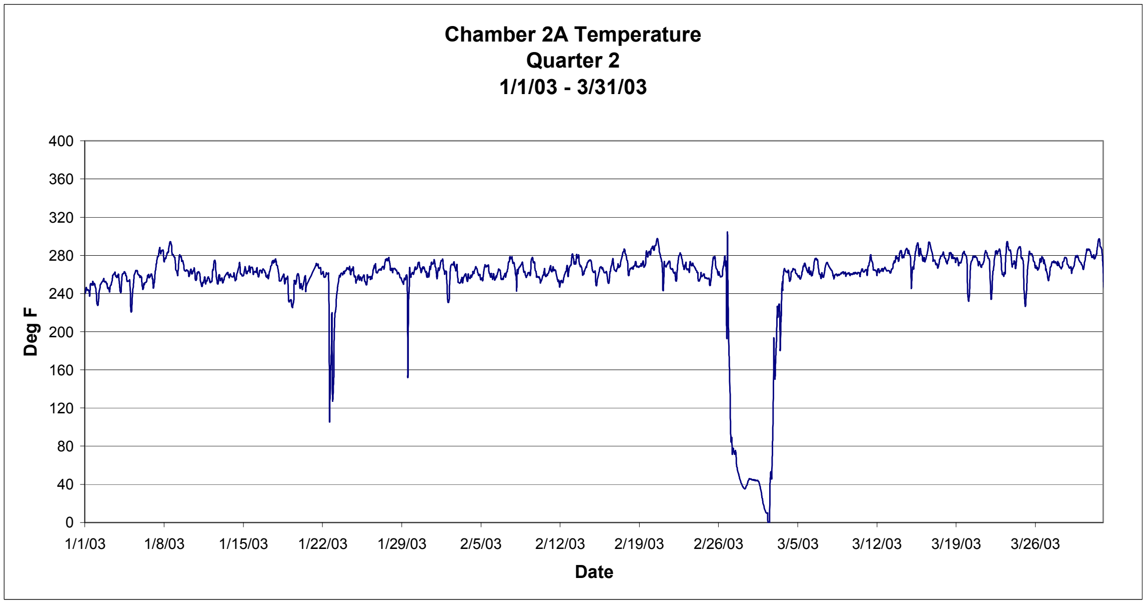


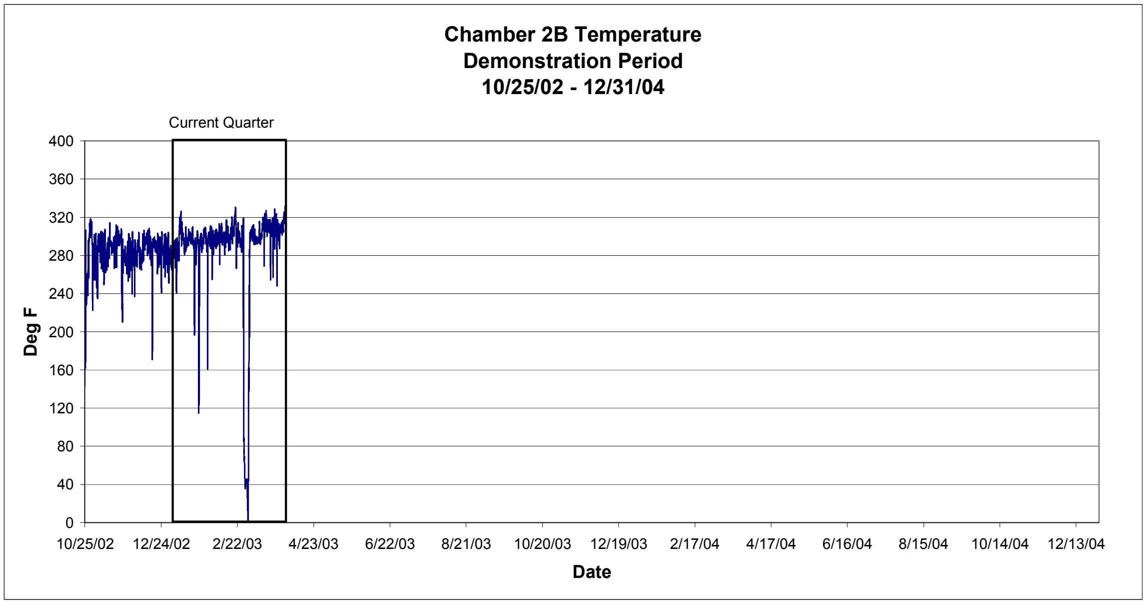


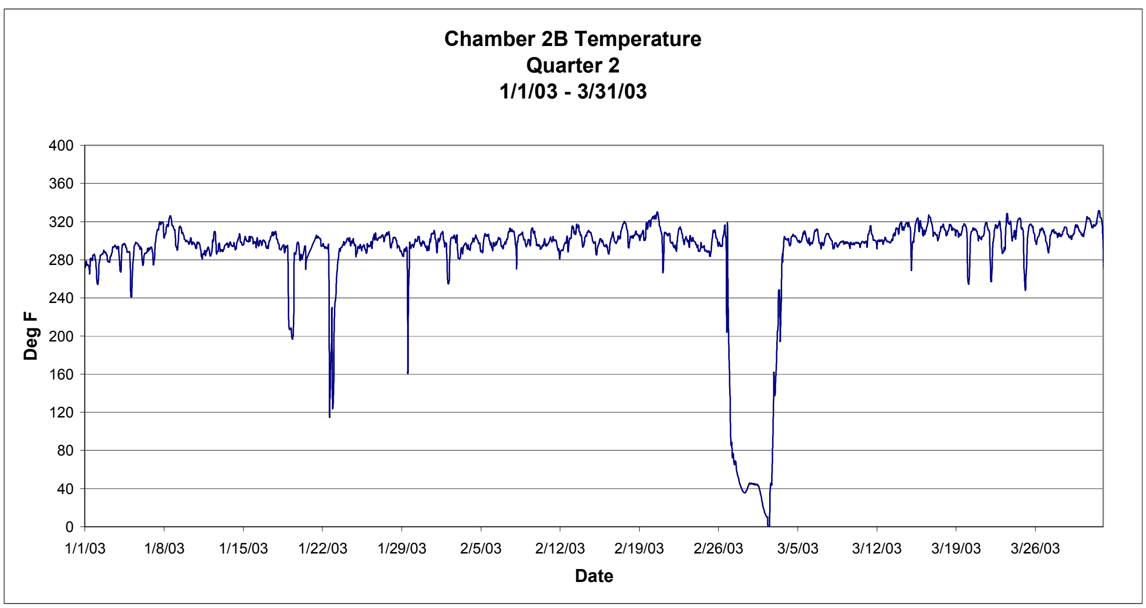

Chamber 1B Temperature
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
Deg F
400
360
320
280
240
200
160
120
80
40
0
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date


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


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


Chamber 2B Temperature
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
Deg F
0
40
80
120
160
200
240
280
320
360
400
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 2
1/1/03 - 3/31/03
Deg F
0
40
80
120
160
200
240
280
320
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400
1/1/03
1/8/03
1/15/03
1/22/03
1/29/03
2/5/03
2/12/03
2/19/03
2/26/03
3/5/03
3/12/03
3/19/03
3/26/03
Date

B14 Fuel Burn Record

BIG STONE PLANT
FUEL BURN RECORD
Jan-03

DATE	Coal	P. Coke	TDF	Waste Seeds	Toner	Gran. Insul.	Canvas Belting	Plastic Chips
	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)
1-Jan-03	6,184.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2-Jan-03	6,223.02	0.00	22.37	62.31	0.00	0.00	0.00	0.00
3-Jan-03	6,319.77	0.00	45.77	148.16	0.00	0.00	0.00	0.00
4-Jan-03	6,287.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-Jan-03	6,049.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-Jan-03	5,943.97	0.00	47.26	431.57	0.00	0.00	0.00	0.00
7-Jan-03	5,505.74	0.00	48.59	707.47	0.00	0.00	0.00	0.00
8-Jan-03	5,576.26	0.00	0.00	685.74	0.00	0.00	0.00	0.00
9-Jan-03	5,577.80	0.00	0.00	600.00	0.00	0.00	0.00	0.00
10-Jan-03	6,179.08	0.00	113.66	123.16	0.00	0.00	0.00	0.00
11-Jan-03	6,298.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12-Jan-03	6,378.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13-Jan-03	6,490.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14-Jan-03	5,816.07	0.00	85.58	649.45	0.00	0.00	0.00	0.00
15-Jan-03	5,903.21	0.00	22.25	501.34	0.00	0.00	0.00	0.00
16-Jan-03	5,714.59	0.00	22.39	607.02	0.00	0.00	0.00	0.00
17-Jan-03	5,764.70	0.00	21.32	650.88	0.00	0.00	0.00	0.00
18-Jan-03	6,306.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19-Jan-03	4,924.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20-Jan-03	5,896.70	0.00	89.30	430.20	0.00	0.00	0.00	0.00
21-Jan-03	6,340.98	0.00	0.00	76.42	0.00	0.00	0.00	0.00
22-Jan-03	3,694.64	0.00	85.16	0.00	0.00	0.00	0.00	0.00
23-Jan-03	5,248.81	0.00	0.00	267.79	0.00	0.00	0.00	0.00
24-Jan-03	6,305.73	0.00	22.79	258.18	0.00	0.00	0.00	0.00
25-Jan-03	6,292.92	0.00	0.00	258.18	0.00	0.00	0.00	0.00
26-Jan-03	6,222.60	0.00	0.00	258.20	0.00	0.00	0.00	0.00
27-Jan-03	5,989.95	0.00	0.00	269.15	0.00	0.00	0.00	0.00
28-Jan-03	5,962.19	0.00	66.12	211.39	0.00	0.00	0.00	0.00
29-Jan-03	5,537.96	0.00	45.82	293.22	0.00	0.00	0.00	0.00
30-Jan-03	6,049.60	0.00	60.00	200.00	0.00	0.00	0.00	0.00
31-Jan-03	5,930.53	0.00	77.47	220.00	0.00	0.00	0.00	0.00
Adjustment	3,500.00							
Total Burned	186,416.92	0.00	875.85	7,909.83	0.00	0.00	0.00	0.00
Total Delivered	177,149.11	0.00	875.85	8,352.78	0.00	0.00	0.00	0.00
HHV	8595	0	15000	9000	0	0	0	0
% Ash	4.49%	0.00	7.04%	4.00%	0.00%	0.00%	0.00%	0.00%
Tons Ash	8,377.48	0.00	61.66	316.39	0.00	0.00	0.00	0.00

BIG STONE PLANT
FUEL BURN RECORD
Feb-03

DATE	Coal	P. Coke	TDF	Waste Seeds	Toner	Gran. Insul.	Canvas Belting	Plastic Chips
	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)
1-Feb-03	5,984.90	0.00	0.00	220.00	0.00	0.00	0.00	0.00
2-Feb-03	5,587.95	0.00	0.00	222.95	0.00	0.00	0.00	0.00
3-Feb-03	6,017.17	0.00	45.99	159.24	0.00	0.00	0.00	0.00
4-Feb-03	5,920.68	0.00	45.07	417.35	0.00	0.00	0.00	0.00
5-Feb-03	6,006.06	0.00	0.00	261.54	0.00	0.00	0.00	0.00
6-Feb-03	6,188.40	0.00	0.00	260.00	0.00	0.00	0.00	0.00
7-Feb-03	6,038.76	0.00	85.34	317.00	0.00	0.00	0.00	0.00
8-Feb-03	5,878.50	0.00	0.00	317.00	0.00	0.00	0.00	0.00
9-Feb-03	6,067.20	0.00	0.00	315.00	0.00	0.00	0.00	0.00
10-Feb-03	6,066.62	0.00	21.19	288.99	0.00	0.00	0.00	0.00
11-Feb-03	6,050.17	0.00	0.00	186.63	0.00	0.00	0.00	0.00
12-Feb-03	5,829.92	0.00	43.13	377.75	0.00	0.00	0.00	0.00
13-Feb-03	5,933.10	0.00	0.00	300.00	0.00	0.00	0.00	0.00
14-Feb-03	5,666.96	0.00	113.84	465.00	0.00	0.00	0.00	0.00
15-Feb-03	5,849.10	0.00	0.00	465.00	0.00	0.00	0.00	0.00
16-Feb-03	5,875.29	0.00	0.00	465.11	0.00	0.00	0.00	0.00
17-Feb-03	6,093.09	0.00	0.00	235.81	0.00	0.00	0.00	0.00
18-Feb-03	5,753.45	0.00	43.27	568.28	0.00	0.00	0.00	0.00
19-Feb-03	5,749.92	0.00	90.18	450.00	0.00	0.00	0.00	0.00
20-Feb-03	5,925.30	0.00	25.00	475.00	0.00	0.00	0.00	0.00
21-Feb-03	5,237.62	0.00	91.58	847.00	0.00	0.00	0.00	0.00
22-Feb-03	5,307.10	0.00	0.00	847.00	0.00	0.00	0.00	0.00
23-Feb-03	5,211.31	0.00	0.00	849.29	0.00	0.00	0.00	0.00
24-Feb-03	6,015.68	0.00	45.43	72.19	0.00	0.00	0.00	0.00
25-Feb-03	6,154.61	0.00	86.29	1.60	0.00	0.00	0.00	0.00
26-Feb-03	4,497.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27-Feb-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28-Feb-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Adjustment	3,500.00							
Total Burned	154,405.86	0.00	736.31	9,384.73	0.00	0.00	0.00	0.00
Total Delivered	158,173.51	0.00	736.31	8,960.31	0.00	0.00	0.00	0.00
HHV	8551		15000	7187	0	0	0	0
% Ash	4.58%		7.05%	1.10%	0.00%	0.00%	0.00%	0.00%
Tons Ash	7,074.24	0.00	51.91	103.23	0.00	0.00	0.00	0.00

BIG STONE PLANT FUEL BURN RECORD Mar-03

DATE	Coal	P. Coke	TDF	Waste Seeds	Toner	Gran. Insul.	Canvas Belting	Plastic Chips
	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)
1-Mar-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2-Mar-03	127.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3-Mar-03	3,960.94	0.00	0.00	66.66	0.00	0.00	0.00	0.00
4-Mar-03	6,652.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5-Mar-03	6,493.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6-Mar-03	6,344.91	0.00	22.49	0.00	0.00	0.00	0.00	0.00
7-Mar-03	6,362.77	0.00	22.40	24.93	0.00	0.00	0.00	0.00
8-Mar-03	6,451.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9-Mar-03	6,504.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10-Mar-03	6,307.69	0.00	64.94	71.57	0.00	0.00	0.00	0.00
11-Mar-03	6,365.86	0.00	0.00	24.04	0.00	0.00	0.00	0.00
12-Mar-03	6,457.50	0.00	45.90	0.00	0.00	0.00	0.00	0.00
13-Mar-03	6,327.30	0.00	21.64	24.46	0.00	0.00	0.00	0.00
14-Mar-03	6,138.03	0.00	46.65	70.22	0.00	0.00	0.00	0.00
15-Mar-03	5,959.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16-Mar-03	6,199.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17-Mar-03	6,167.22	0.00	44.96	96.12	0.00	0.00	0.00	0.00
18-Mar-03	5,862.80	0.00	22.59	417.11	0.00	0.00	0.00	0.00
19-Mar-03	6,370.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20-Mar-03	5,727.87	0.00	46.66	72.77	0.00	0.00	0.00	0.00
21-Mar-03	6,160.10	0.00	45.25	77.95	0.00	0.00	0.00	0.00
22-Mar-03	5,656.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23-Mar-03	5,468.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24-Mar-03	5,771.78	0.00	22.18	122.64	0.00	0.00	0.00	0.00
25-Mar-03	5,276.36	0.00	44.19	100.35	0.00	0.00	0.00	0.00
26-Mar-03	5,672.84	0.00	22.08	123.18	0.00	0.00	0.00	0.00
27-Mar-03	5,965.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28-Mar-03	5,931.49	0.00	90.03	147.28	0.00	0.00	0.00	0.00
29-Mar-03	6,182.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30-Mar-03	6,139.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31-Mar-03	5,827.97	0.00	0.00	70.93	0.00	0.00	0.00	0.00
Adjustment	2,800.00							
Total Burned	177,636.53	0.00	561.96	1,510.21	0.00	0.00	0.00	0.00
Total Delivered	163,580.34	0.00	561.96	1,565.08	0.00	0.00	0.00	0.00
HHV	8562	0	15000	7187	0	0	0	0
% Ash	4.45%	0.00%	7.05%	1.10%	0.00%	0.00%	0.00%	0.00%
Tons Ash	7,907.69	0.00	39.62	16.61	0.00	0.00	0.00	0.00

B15 Fuel Analysis Record

BIG STONE PLANT COAL ANALYSIS PER TRAIN
Jan-03

DATE	TR #	MOIS. %	% ASH AR	HHV AR	S, % AR	% ASH DRY	HHV DRY	S, % DRY	NaO %	MAF HHV	COAL TONS	TONS OK
PREV. MO	bam93	28.64	4.45	8712	0.31	6.24	12208	0.44	1.29	13020	14,053.55	4,870.77
PREV. MO	ebm40	29.95	4.76	8457	0.42	6.79	12073	0.60	1.93	12952	13,881.20	13,881.20
1-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
2-Jan-03	ebm41	30.52	4.72	8364	0.41	6.79	12038	0.59	1.85	12915	14145.23	14,145.23
3-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
4-Jan-03	ebm01	29.97	4.85	8453	0.44	6.92	12071	0.63	1.8	12968	13,092.48	13,092.48
5-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
6-Jan-03	bam01	29.52	4.24	8614	0.27	6.02	12222	0.38	1.52	13005	14,090.35	14,090.35
7-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
8-Jan-03	bam02	29.26	4.37	8658	0.28	6.18	12239	0.4	1.35	13045	13,033.90	13,033.90
9-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
10-Jan-03	bam03	29.42	4.26	8688	0.25	6.03	12310	0.35	1.52	13100	11,730.45	11,730.45
11-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
12-Jan-03	bam04	29.5	4.39	8616	0.3	6.23	12221	0.42	1.48	13033	14,159.78	14,159.78
13-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
14-Jan-03	bam05	29.01	4.64	8640	0.29	6.53	12171	0.41	1.42	13021	9,762.10	9,762.10
15-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
16-Jan-03	bam06	29.01	4.64	8640	0.29	6.53	12171	0.41	1.42	13021	12,282.20	12,282.20
17-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
18-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
19-Jan-03	bam07	29.13	4.69	8678	0.3	6.62	12245	0.43	1.33	13113	13,522.30	13,522.30
20-Jan-03	bam08	29.62	4.44	8621	0.27	6.31	12249	0.38	1.46	13074	12,037.80	12,037.80
21-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
22-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
23-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
24-Jan-03	bam09	29.83	4.24	8629	0.26	6.04	12297	0.37	1.56	13087	13,318.28	13,318.28
25-Jan-03	bam10	29.95	4.43	8569	0.27	6.32	12233	0.39	1.5	13058	13,531.75	13,531.75
26-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
27-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
28-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
29-Jan-03	bam11	29.28	4.27	8704	0.28	6.04	12308	0.39	1.38	13099	13,322.95	12,958.34
30-Jan-03	bam12	29.85	4.42	8593	0.27	6.3	12250	0.39	1.42	13074	13,171.28	0.00
31-Jan-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
ADJ.												186,416.92
											Tons. OK	186,416.92
Weighted Average		29.57	4.49	8595	0.31	6.38	12202	0.44	1.54		Burn	186,416.92

Monthly Mercury Analysis

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

BIG STONE PLANT	COAL ANALYSIS PER TRAIN
	Feb-03

DATE	TR #	MOIS %	% ASH AR	HHV AR	S, % AR	% ASH DRY	HHV DRY	S, % DRY	NaO %	MAF HHV	COAL TONS	TONS OK
PREV. MO	bam11	29.3	4.27	8704	0.28	6.04	12308	0.39	1.38	13099	13,322.95	364.61
PREV. MO	bam12	29.9	4.42	8593	0.27	6.3	12250	0.39	1.42	13074	13,171.28	13171.28
1-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
2-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
3-Feb-03	bam13	30.2	4.24	8571	0.24	6.08	12285	0.35	1.63	13080	13082.78	13082.78
4-Feb-03	bam14	30.2	4.48	8530	0.25	6.42	12213	0.36	1.47	13051	13160.30	13160.30
5-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
6-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
7-Feb-03	bam15	30.1	4.29	8494	0.28	6.14	12158	0.4	1.66	12953	13275.88	13275.88
8-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
9-Feb-03	bam16	29.4	4.12	8681	0.28	5.84	12299	0.39	1.67	13062	12953.88	12953.88
10-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
11-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
12-Feb-03	bam17	29.2	4.5	8669	0.28	6.36	12244	0.4	1.43	13076	13273.08	13273.08
13-Feb-03	bam18	29.3	4.31	8651	0.27	6.09	12229	0.38	1.46	13022	12419.18	12419.18
14-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
15-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
16-Feb-03	ebm02	30.4	5.02	8413	0.45	7.21	12090	0.64	1.76	13029	12751.52	12751.52
17-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
18-Feb-03	ebm03	30.8	5.24	8316	0.39	7.57	12010	0.56	1.73	12994	13309.73	13309.73
19-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
20-Feb-03	bam19	29.2	4.51	8656	0.3	6.37	12218	0.43	1.51	13049	13185.42	13185.42
21-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
22-Feb-03	bam20	28.9	4.51	8639	0.28	6.35	12158	0.4	1.47	12982	13672.10	12727.61
23-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
24-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
25-Feb-03	bam21	30.4	4.3	8520	0.26	6.18	12234	0.37	1.53	13040	13671.40	0.00
26-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
27-Feb-03	bam22	29.2	4.46	8656	0.28	6.3	12230	0.39	1.47	13052	10746.15	0.00
28-Feb-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
ADJ.												143675.26
											Tons. OK	154405.86
Weighted Average		29.81	4.58	8551	0.30	6.53	12182	0.43	1.56		Burn	154405.86

Monthly Mercury Analysis

Train #	Sample #	% Moist.	Mercury ug/g dry basis	Chloride ug/g
	C303	30.26	0.103	<0.01

BIG STONE PLANT	COAL ANALYSIS PER TRAIN
	Mar-03

DATE	TR #	MOIS %	% ASH AR	HHV AR	S, % AR	% ASH DRY	HHV DRY	S, % DRY	NaO %	MAF HHV	COAL TONS	TONS OK
PREV.	bam20	28.9	4.51	8639	0.28	6.35	12158	0.4	1.5	12982	13672.10	944.49
PREV.	bam21	30.36	4.30	8520	0.26	6.18	12234	0.37	1.53	13040	13671.40	13671.40
1-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
2-Mar-03	0	29.2	4.46	8656	0.28	6.3	12230	0.39	1.5	13052	0.00	0.00
3-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
4-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
5-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
6-Mar-03	ebm04	30.4	4.71	8455	0.41	6.76	12143	0.59	1.8	13023	13682.43	13682.43
7-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
8-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
9-Mar-03	bam23	30.8	4.27	8457	0.25	6.17	12221	0.36	1.4	13025	13360.65	13360.65
10-Mar-03	ebm05	30.6	4.37	8466	0.36	6.3	12195	0.52	1.9	13015	13486.15	13486.15
11-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
12-Mar-03	bam24	29.3	4.48	8658	0.28	6.34	12239	0.39	1.5	13067	13064.15	13064.15
13-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
14-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
15-Mar-03	bam25	29.1	4.69	8612	0.3	6.61	12147	0.42	1.6	13007	13310.88	13310.88
16-Mar-03	bam26	29.2	4.37	8645	0.25	6.17	12212	0.36	1.6	13015	13176.13	13176.13
17-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
18-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
19-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
20-Mar-03	bam27	30	4.3	8578	0.27	6.15	12256	0.38	1.5	13059	14006.18	14006.18
21-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
22-Mar-03	bam28	29.5	4.16	8648	0.24	5.9	12270	0.34	1.6	13039	13148.65	13148.65
23-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
24-Mar-03	bam29	29.7	4.85	8543	0.3	6.9	12143	0.42	1.3	13043	14094.48	14094.48
25-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
26-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
27-Mar-03	bam30	30.1	4.58	8485	0.26	6.55	12132	0.37	1.5	12982	14088.83	14088.83
28-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
29-Mar-03	bam31	29.5	4.23	8621	0.25	6	12221	0.35	1.5	13001	14033.93	15501.37
30-Mar-03	0	0	0	0	0	0	0	0	0	0	0.00	0.00
31-Mar-03	bam32	29.6	4.78	8594	0.29	6.79	12205	0.41	1.4	13094	14127.90	0.00
ADJ.												165535.78
											Tons. OK	177636.53
Weighted Average		29.82	4.45	8562	0.29	6.35	12201	0.40	1.54		Burn	177636.53

Monthly Mercury Analysis

Train #	Sample #	% Moist.	Mercury ug/g dry basis	Chloride ug/g
	C550	29.23	0.116	<0.01

B16 Ash Analysis Record

COMMERCIAL TESTING & ENGINEERING CO.
GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 • TEL: 630-953-9300 FAX: 630-953-9306
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January 10, 2003

RAG COAL WEST, INC.
EAGLE BUTTE MINE
P.O. BOX 3040
GILLETTE WY 82717

Sample identification by
RAG Coal West, Inc.

SAMPLE ID:	36-104330
TRAIN #:	BMBSB001
TOTAL TONNAGE:	14090.350
CUSTOMER:	OTTERTAIL POWER
PLANT:	BIG STONE
LOAD DATE:	01/04/2003

Kind of sample reported to us	COAL
Sample taken at	Belle Ayr
Sample taken by	RAG Coal West, Inc.
Date sampled	January 4, 2003
Date received	January 10, 2003

Analysis report no. 44-59397

ANALYSIS OF ASH	% Weight Ignited Basis
Silica, SiO_2	31.47
Alumina, Al_2O_3	16.10
Titania, TiO_2	1.39
Ferric Oxide, Fe_2O_3	5.09
Lime, CaO	27.44
Magnesia, MgO	4.94
Potassium Oxide, K_2O	0.20
Sodium Oxide, Na_2O	1.52
Sulfur Trioxide, SO_3	8.60
Phosphorous Pentoxide, P_2O_5	1.31
Strontium Oxide, SrO	0.57
Barium Oxide, BaO	0.72
Manganese Oxide, Mn_3O_4	0.03
Undetermined	0.62

Silica Value= 45.65
Base: Acid Ratio= 0.80
T_{250} Temperature= 2219 °F

Type of Ash= LIGNITIC
Fouling Index= 1.52

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Kathy Boyer
Gillette Laboratory

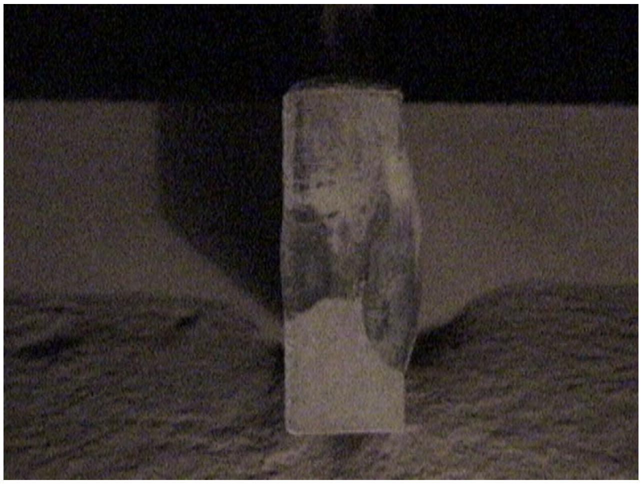
MEMBER ACIL

B17 Ultimate Coal Analysis

ULTIMATE ANALYSIS AS RECEIVED

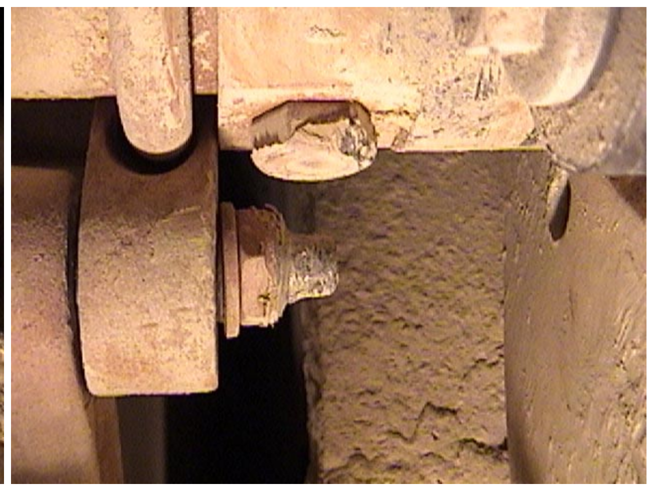
Sample Date	Moisture %	Ash %	Carbon %	Nitrogen %	Sulfur %	Hydrogen %	Oxygen %	HHV btu/lb	NaO %	Mercury ug/g Dry
05-Jan-03	30.31	4.60	48.51	0.65	0.50	3.43	12.00	8415	1.90	
06-Jan-03	29.75	4.79	48.86	0.64	0.39	3.43	12.14	8465	1.30	
07-Jan-03	29.82	4.74	48.39	0.67	0.39	3.03	12.96	8431	1.70	
08-Jan-03	28.79	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	

B18 Photographs - Advanced Hybrid Inspection - January 19, 2003


Anvil – Front View


Anvil – Angle View

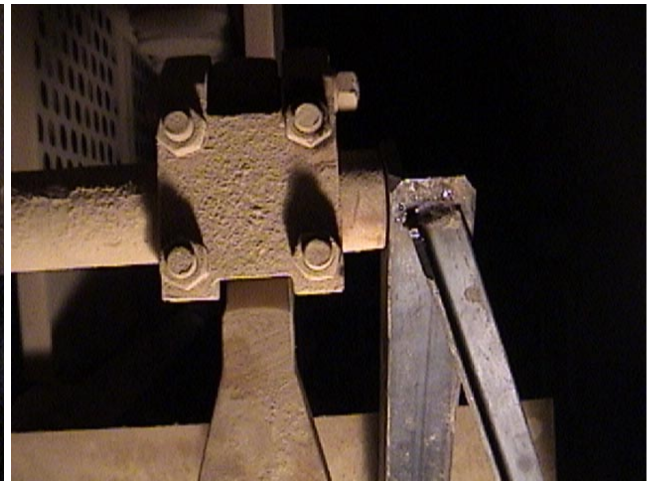

Missing Roller


Damaged Bolt & Nut

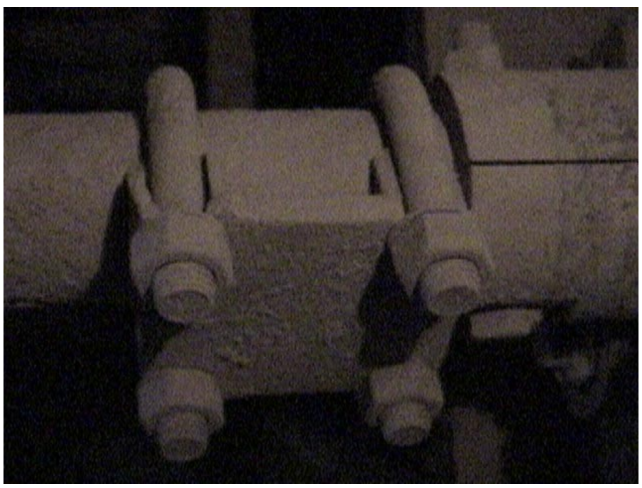

Rapper Shaft Coupler


Bent Support

New Thrust Support – End View



New Thrust Support – Side View

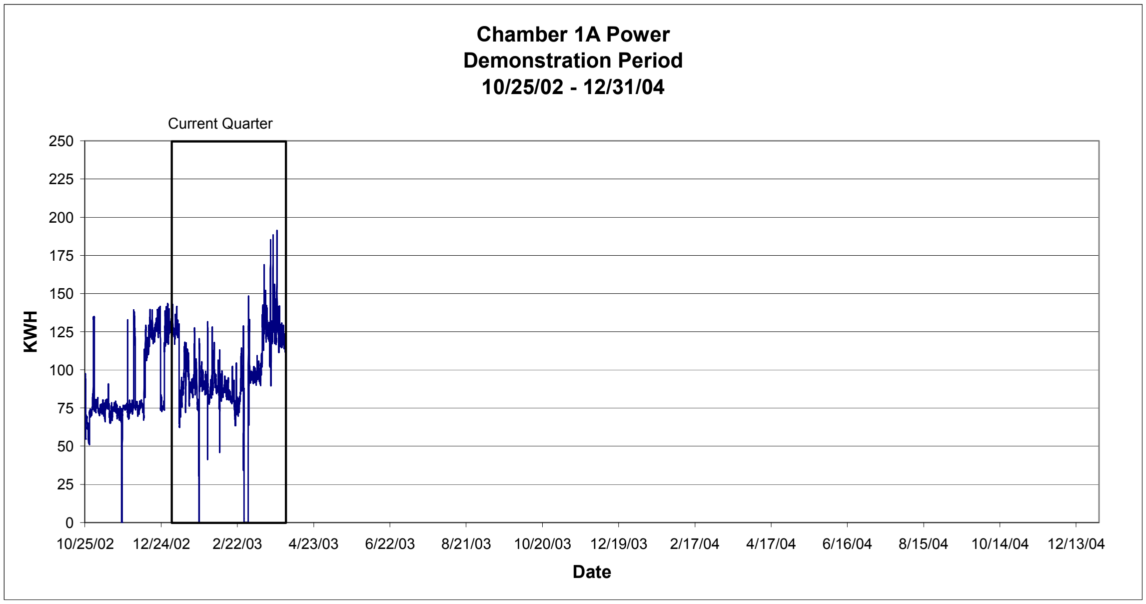


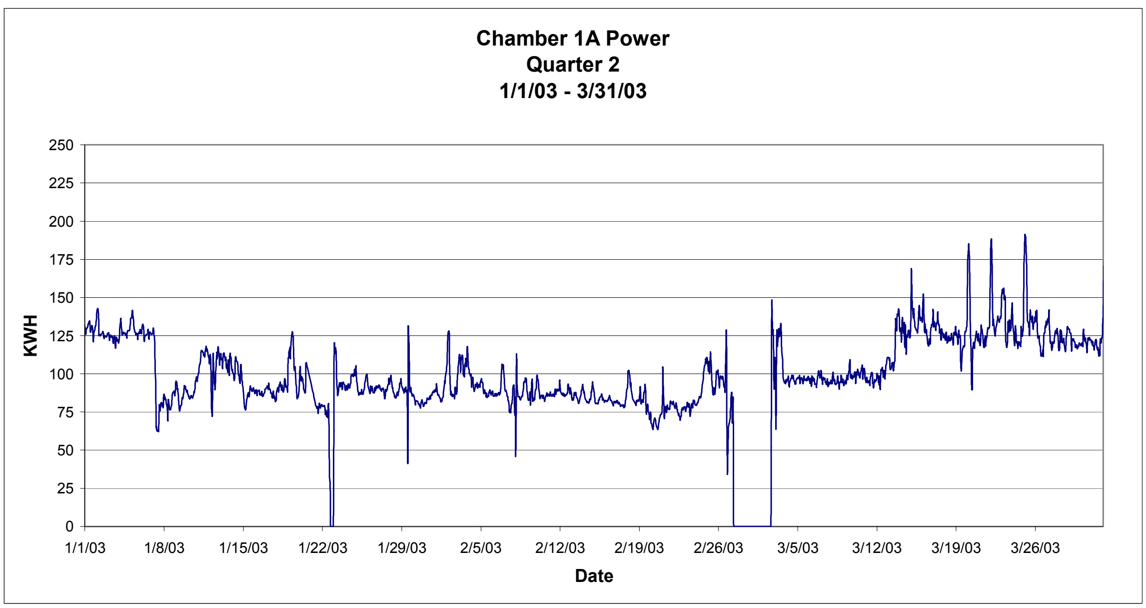
Missing Hammer

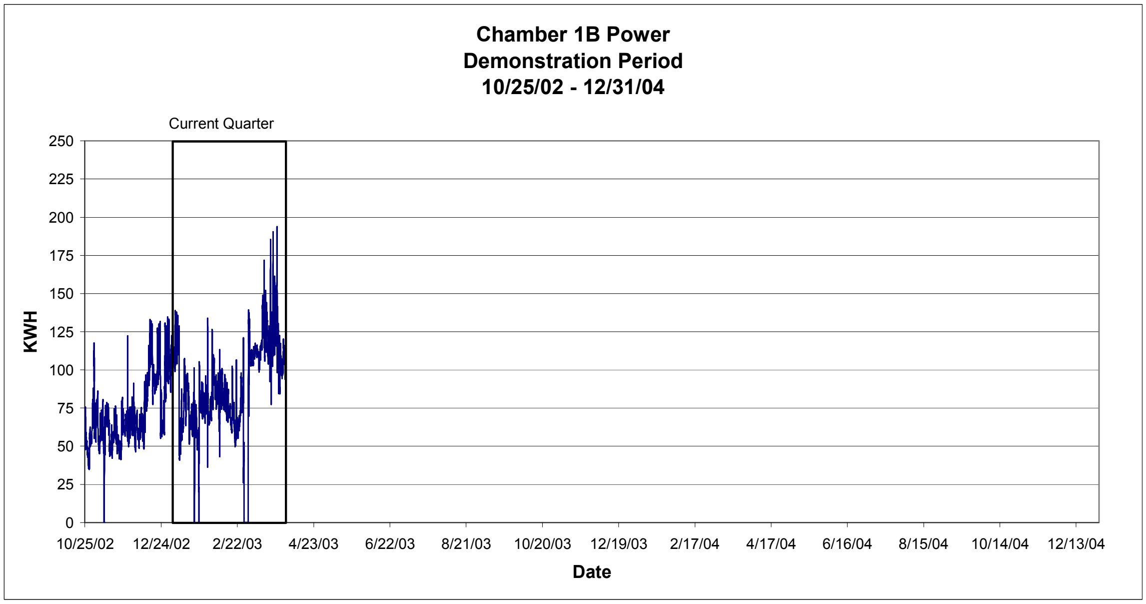
Broken Hammer Mount

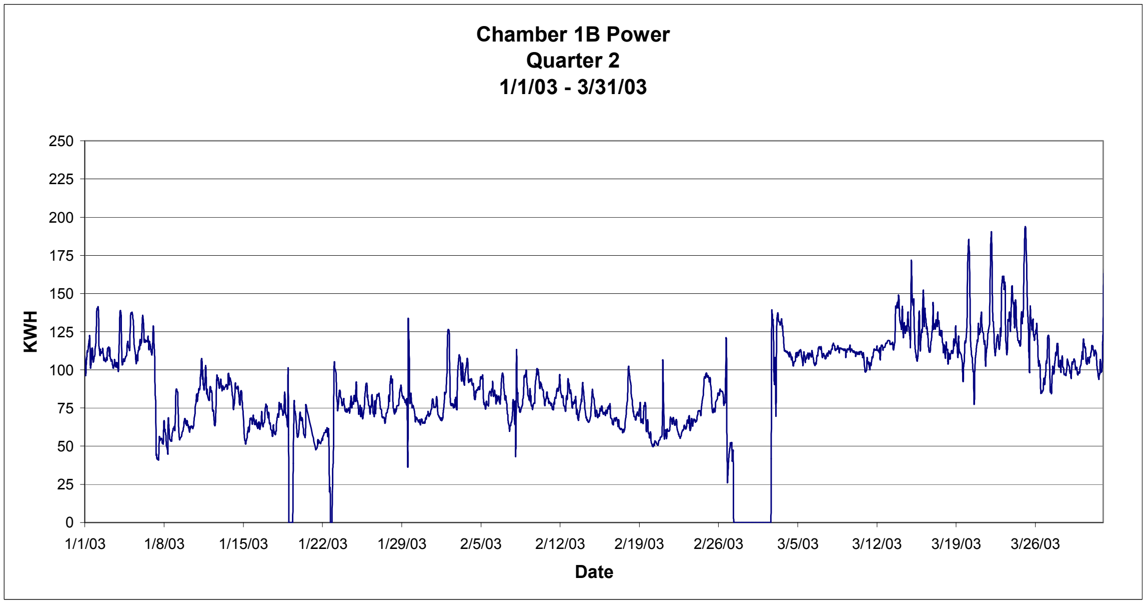
Broken Mount – Close Up View

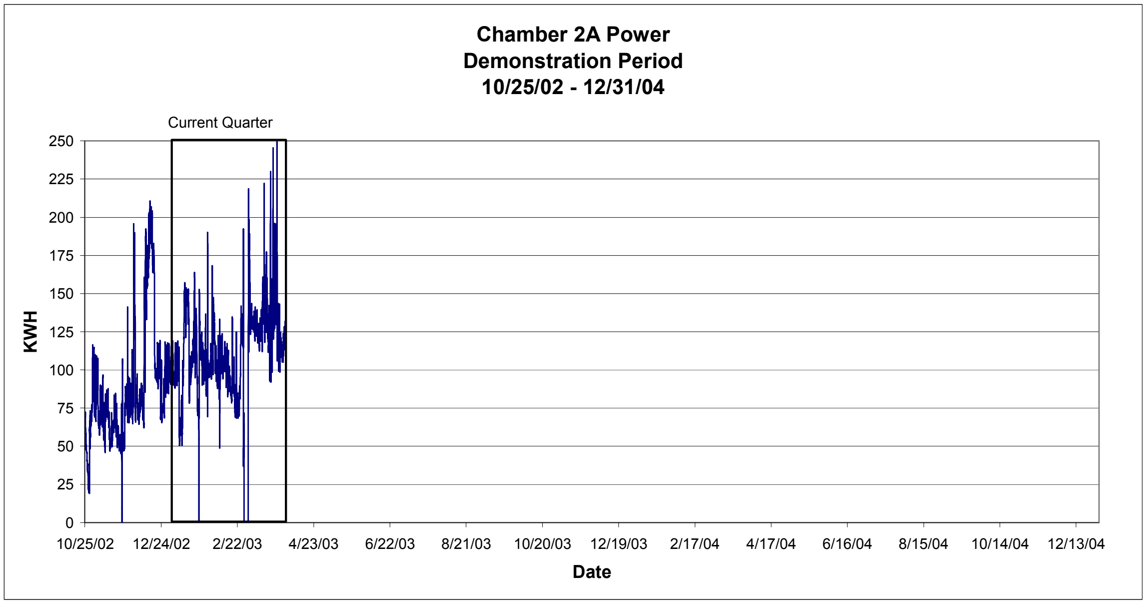
B19 ESP Power by Chamber

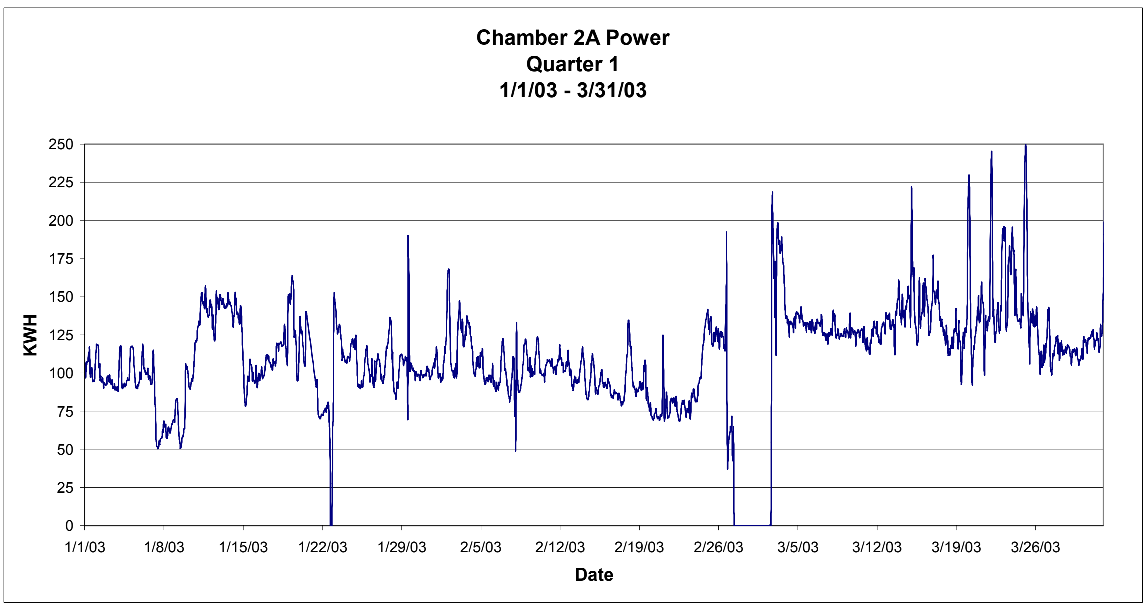


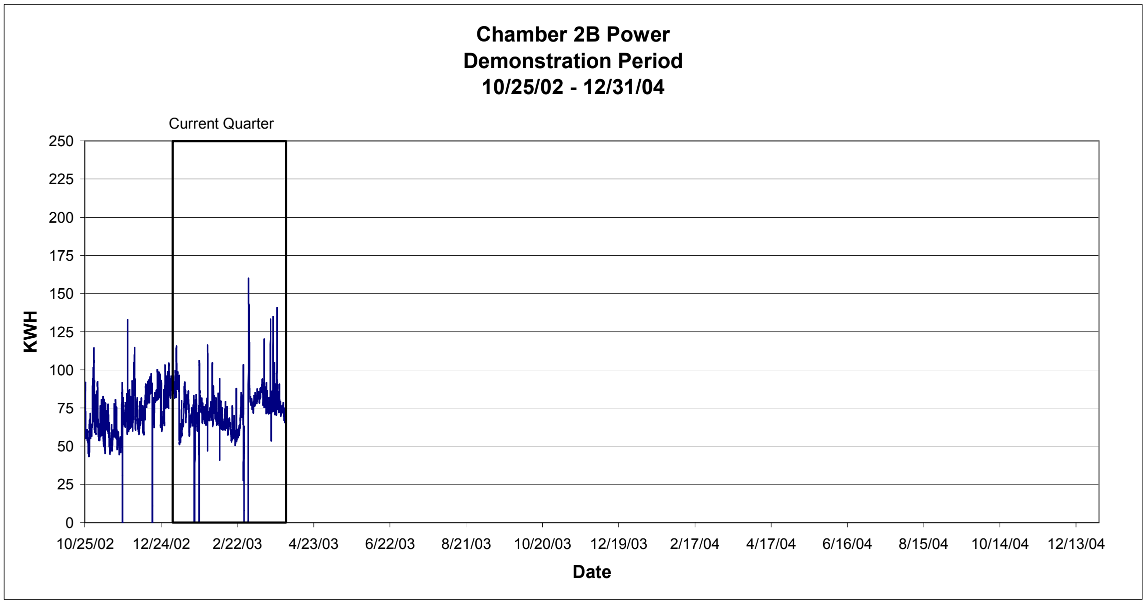


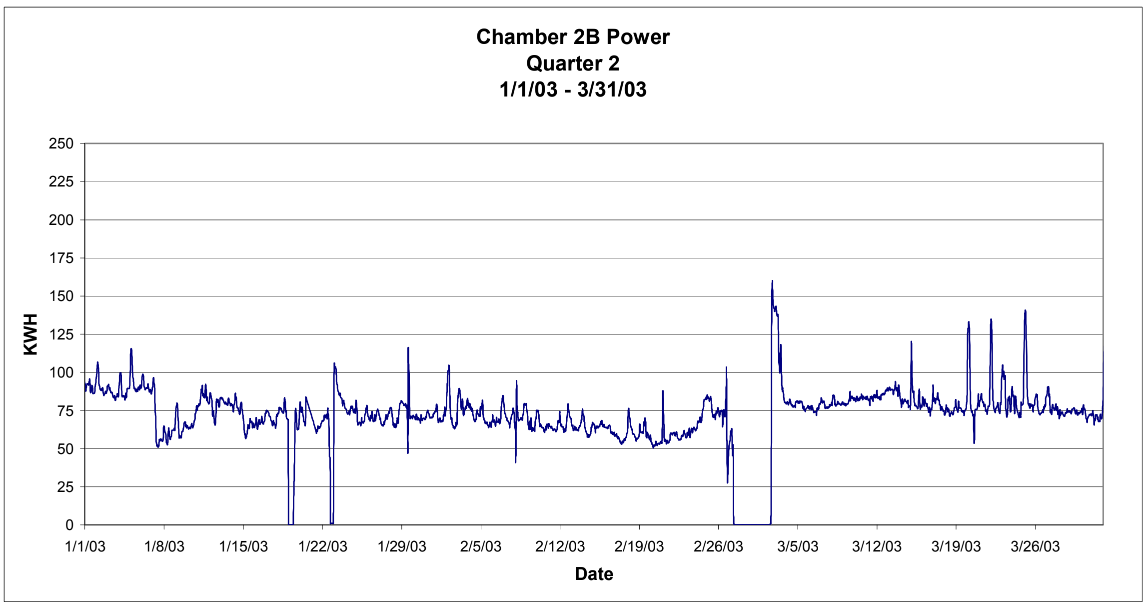

Chamber 1B Power
Demonstration Period
10/25/02 - 12/31/04
Current Quarter
KWH
250
225
200
175
150
125
100
75
50
25
0
10/25/02
12/24/02
2/22/03
4/23/03
6/22/03
8/21/03
10/20/03
12/19/03
2/17/04
4/17/04
6/16/04
8/15/04
10/14/04
12/13/04
Date


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

B20 ESP Tabular Data

OTPCO's Big Stone Advanced Hybrid Filter TR set Readings
rev March 4, 2003

1A CHAMBER

Date	Time	Load GMW	1ST FIELD mA	1ST FIELD kV	1ST FIELD spm	Inlet Temp (F)	2ND FIELD mA	2ND FIELD kV	2ND FIELD spm	3RD FIELD mA	3RD FIELD kV	3RD FIELD spm	4TH FIELD mA	4TH FIELD kV	4TH FIELD spm	ave ma for AH chambe
11/22/2002	9:00 AM						332	44	49	498	45	11	628	52	12	486.0
	11:10 AM						332	47	49	664	48	11	705	54.1	3	567.0
11/23/2002	18:00 pm						379	48	50	705	49	0	705	53	0	596.3
1/6/2003		450	515				706			705			705			705.3
began burning soybeans at 600 to 700 tons/day																
1/9/2003			130	57.4		270	379	47		705	50		705	54.2		596.3
1/10/2003			47	57.4		262	403	47		704	50		705	53		604.0
stopped burning soybeans																
1/13/2003			420	63.1		255	604	42		705	47		705	48.7		671.3
1/13/2003			355	47.1	82		705	51	36	705	46	0	704	48.4	0	704.7
1/14/2003	07:30am	455	118	63.2	70	256	394	49	49	705	52	0	705	55.6	0	601.3
1/15/2003	07:30am	455	154	65.5	75	261	426	48	50	705	51	0	705	53.6	0	612.0
inspected and repaired compartments 4 and 11 collecting plate rapper shafts 1/19/2003																
Burning soybeans at lower rate 60-200 tons/day																
1/20/2003	07:30am	460	142	60.9	95	255	426	47	51	705	49	0	705	51.7	0	612.0
1/22/2003	plant tripped @ 14:40 CT back on line at midnight															
1/23/2003		455	195	49.4	90	256	438	45	51	705	48	0	705	50.9	0	616.0
1/26/2003		440	272	53.4	86	251	462	45	50	705	48	3	705	50.3	0	624.0
1/28/2003	7:30 AM	445	177	65.6	66	261	409	45	50	705	49	0	705	51.7	0	606.3
	15:30 pm	445	207	64.7	55	264	438	46	49	705	49	2	705	52.5	0	616.0
1/28/2003	spark limit setpoint increased in2nd and 3rd fields to 99 spm															
1/29/2003	7:30 AM	450	189	65	76	261	420	44	99	705	49	1	705	52.2	0	610.0
1/30/2003	7:30 AM	450	130	61.3	100	270	320	45	101	711	48	1	705	51.8	0	578.7
2/3/2003	7:30 AM	445	355	65	52	259	480	56	101	705	47	0	705	49.2	0	630.0
2/4/2003	7:30 AM	445	237	60.2	72	249	373	44	100	711	49	0	705	52	0	596.3
2/5/2003	7:30 AM	445	201	46.9	70	260	438	45	99	711	49	0	705	51.4	0	618.0
2/6/2003	11:30 AM	turned off all AH c.s. rappers														
2/6/2003	15:20 pm	447	150	65	55	259	380	45	101	711	50	0	705	54	0	598.7
	17:00 pm	447	140	65	27	260	355	45	100	705	48	0	705	53	0	588.3
2/7/2003	8:15 AM	441	118	58	36	257	367	47	102	711	50	0	711	54	0	596.3
	12:05 PM	turned all AH c.s. rappers back on														
	16:00 pm	435	112	59	99	277	284	46	99	705	48	17	711	53	0	566.7
2/8/2003	3:00	414	284	64	29	249	420	43	102	711	48	0	705	51	0	612.0
	4:42	275	468		95	226	705		0	706		0	706		0	705.7
	12:00	441	130	61	90	263	337	45	100	705	50	1	705	53	0	582.3
	19:00	442	213	64	18	268	403	43	100	705	48	0	705	51	0	604.3
2/9/2003	10:00	418	249	57	97	260	450	45	100	705	68	0	705	50	0	620.0
tempoarily raised TR current limit setpoints when compartments were not at 100 spm - max was 1000 mA																
	13:00	442	177	64	97	275	360	44	96	806	49	26	918	52	54	694.7
	14:45	442	94	58	99	275	302	42	100	705	48	4	705	51	1	570.7
	17:00	443	83	59	97	268	379	44	99	705	49	0	705	51	0	596.3
2/10/2003	10:00	442	142	64	63	251	379	45	100	705	49	0	705	51	0	596.3
	19:10	443	118	58	92	259	355	49	100	705	48	0	705	51	0	588.3
2/11/2003	8:45	443	189	62	94	267	385	45	100	705	49	0	705	51	0	598.3
2/12/2003	7:30	443	166	60.9	69	251	391	46	102	705	49	0	711	52	0	602.3
2/12/2003	10:40	445	124	65	41	255	391	45	101	711	50	0	711	53	0	604.3
Each field was individually power off rapped starting with #2,#3,#4, and then 1st field																
Increased soybean burn rate to 500 ton/day on 13th																
	17:00	383	210	63	92	272	509	46	99	705	47	0	705	50	0	639.7
2/13/2003	7:30	435	106	64	74	269	361	46	100	711	50	1	711	53.3	0	594.3
2/16/2003	7:30	436	249	65.3	83	255	391	42	98	693	48	7	705	51.9	0	596.3
2/19/2003	7:30	435	136	59.3	99		284	45	101	705	51	74	711	54.5	20	566.7
2/21/2003	7:30	425	71	57	57		272	48	99	705	54	9	705	57	0	560.7
2/24/2003	7:30	420	118	65	14		337	47	101	705	52	0	711	54.5	0	584.3
Plant down for boiler wash, replaced first section of collecting plate rapper shafts and outboard bearing. Rapped all plates off-line, pu																
3/3/2003	9:00	225	847	62	99		705	45	0	711	41	0	711	43	0	709.0
	14:31	288	521	58	100		705	47	0	705	42	0	705	45	0	705.0
	18:35	352	367	61	99		492	43	100	705	43	0	705	46	0	634.0
	20:12	397	260	62	99		575	44	99	711	45	0	705	47	0	663.7
	23:42	397	308	64	98		508	44	100	705	45	0	70-5	48	0	606.5
3/4/2003	7:20	396	160	62	97		450	44	94	705	47	1	711	50	0	622.0

1B CHAMBER

		Inlet													
Date	Time	Temp	1ST FIELD			2ND FIELD			3RD FIELD			4TH FIELD			ave mA for
er		(F)	mA	kV	spm	mA	kV	spm	mA	kV	spm	mA	kV	spm	AH Chambe
11/22/2002	9:00 AM		off			190	51	12	480	49.4	12	379	47.7	12	349.7
	11:10 AM					278	51.3	50	557	49.1	12	213	43.2	11	349.3
11/23/2002	18:00 pm					346	53.5	50	705	52.1	2	705	53.3	0	585.3
1/6/2003			575			570			705			701			658.7
began burning soybeans at 600 to 700 tons/day															
1/9/2003		309.0	94	57.3		379	50.4		468	48.4		420	48.5		422.3
1/10/2003		303.0	112	62.4		400	53.4		509	52		569	53.6		492.7
stopped burning soybeans															
1/13/2003		297.0	302	58.4		581	50.8		717	50.2		711	51.4		669.7
1/13/2003			456	67.1	99	616	51.7	50	723	49.6	6	705	51.4	1	681.3
1/14/2003	07:30am	300.0	124	58.1	99	332	53.7	50	509	50.9	12	557	52.8	11	466.0
1/15/2003	07:30am	305.0	130	60.7	100	373	53.4	50	498	50.6	12	681	53.3	11	517.3
inspected and repaired compartments 4 and 11 collecting plate rapper shafts 1/19/2003															
Burning soybeans at lower rate 60-200 tons/day															
1/20/2003	07:30am	298.0	71	60.9	92	379	52.5	49	397	48.9	12	622	52.6	11	466.0
1/22/2003	plant tripped @ 14:40 CT back on line at midnight														
1/23/2003		296.0	94	57	99	343	48.7	52	486	47.6	12	640	50.2	8	489.7
1/26/2003		296.0	94	55.5	100	462	47.5	49	492	48.7	12	604	48.4	11	519.3
1/28/2003	7:30 AM	300.0	231	59.4	62.5	521	49.5	49	640	49.7	11	723	51.9	12	628.0
	15:30 pm	304.0	189	50.8	100	468	50.3	53	616	50.3	11	723	50.2	10	602.3
1/28/2003	spark limit setpoint increased in2nd and 3rd fields to 99 spm														
1/29/2003	7:30 AM	303.0	130	58.1	99	498	49.8	101	735	50.1	95	622	48.2	4	618.3
1/30/2003	7:30 AM	312.0	106	52	101	337	41.1	102	575	46.9	101	652	49.2	9	521.3
2/3/2003	7:30 AM	300.0	343	60.5	99	521	43.6	98	711	49.8	1	705	51.3	1	645.7
2/4/2003	7:30 AM	290.0	189	58.9	99	403	48.4	100	687	49.3	100	735	51.6	5	608.3
2/5/2003	7:30 AM	302.0	177	54.7	99	468	46.4	101	634	49.3	100	711	53	83	604.3
2/6/2003	11:30 AM														
2/6/2003	15:20 pm	299.0	170	61	100	500	51	100	690	51	99	705	55	38	631.7
	17:00 pm	301.0	130	58	100	480	50	100	690	50	99	705	53	66	625.0
2/7/2003	8:15 AM	299.0	142	56	100	569	49	100	634	50	100	705	54	25	636.0
	12:05 PM														
	16:00 pm	313.0	83	56	100	355	43	100	569	45	101	598	48	54	507.3
2/8/2003	3:00	288.0	177	58	99	480	49	102	687	49	78	705	51	0	624.0
	4:42	256.0	527		3	705		0	707		0	707		0	706.3
	12:00	301.0	142	60	100	426	51	101	640	49	100	705	53	0	590.3
	19:00	308.0	284	61	98	474	50	100	711	50	13	705	52	0	630.0
2/9/2003	10:00	299.0	237	63	100	652	52	98	711	52	11	711	50	0	691.3
tempoarily raised TR current limit setpoints when compartments were not at 100 spm - max was 1000 mA															
	13:00	313.0	130	54	100	430	49	100	570	49	100	806	51	100	602.0
	14:45	315.0	124	56	99	450	49	99	628	49	100	705	51	2	594.3
	17:00	308.0	106	60	99	533	50	99	509	44	100	705	52	0	582.3
2/10/2003	10:00	292.0	142	55	101	492	47	99	616	49	97	705	54	53	604.3
	19:10	300.0	201	63	89	438	50	101	699	50	86	711	53	1	616.0
2/11/2003	8:45	308.0	184	61	100	379	49	101	604	48	100	705	51	225	562.7
2/12/2003	7:30	293.0	118	58.2	100	361	44.8	101	675	49.7	100	705	51.5	0	580.3
2/12/2003	10:40	296.0	166	57	100	438	52	101	646	51	100	687	53	96	590.3
Each field was individually power off rapped starting with #2,#3,#4, and then 1st field															
Increased soybean burn rate to 500 ton/day on 13th															
	17:00	308.0	332	64	99	474	46	99	705	49	0	705	49	0	628.0
2/13/2003	7:30	302.0	142	53.7	100	397	48.7	100	616	49.8	100	634	49.5	100	549.0
2/16/2003	7:30	296.0	189	60.2	99	450	46.7	100	521	49.1	101	515	44.6	50	495.3
2/19/2003	7:30		118	55.7	99	320	46.9	99	616	49.7	99	640	49.5	99	525.3
2/21/2003	7:30		154	60.8	99	343	50.8	99	563	50.7	99	675	53.5	100	527.0
2/24/2003	7:30		189	63.5	100	361	53.1	100	592	52.7	101	711	54.7	8	554.7
Plant down for boiler wash, replaced first section of collecting plate rapper shafts and outboard bearing. Rapped all plates off-															
3/3/2003	9:00		901	63	101	705	49	0	711	43.7	0	705	43	0	707.0
	14:31		824	65	6	705	49	0	705	44	0	705	43	0	705.0
	18:35		723	62	99	705	50	0	705	46	0	705	45	0	705.0
	20:12		474	63	93	705	52	1	705	47	0	705	47	0	705.0
	23:42		346	61	78	705	52	0	705	48	0	711	48	0	707.0
3/4/2003	7:20		296	64	7	681	51	1	705	50	0	705	49	0	697.0

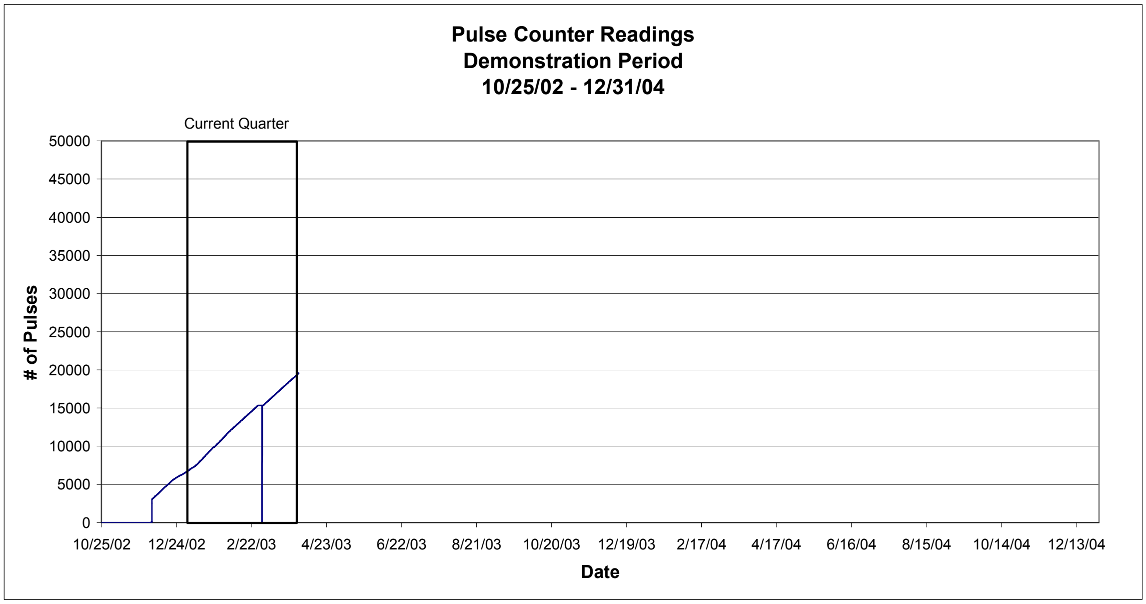
2A CHAMBER

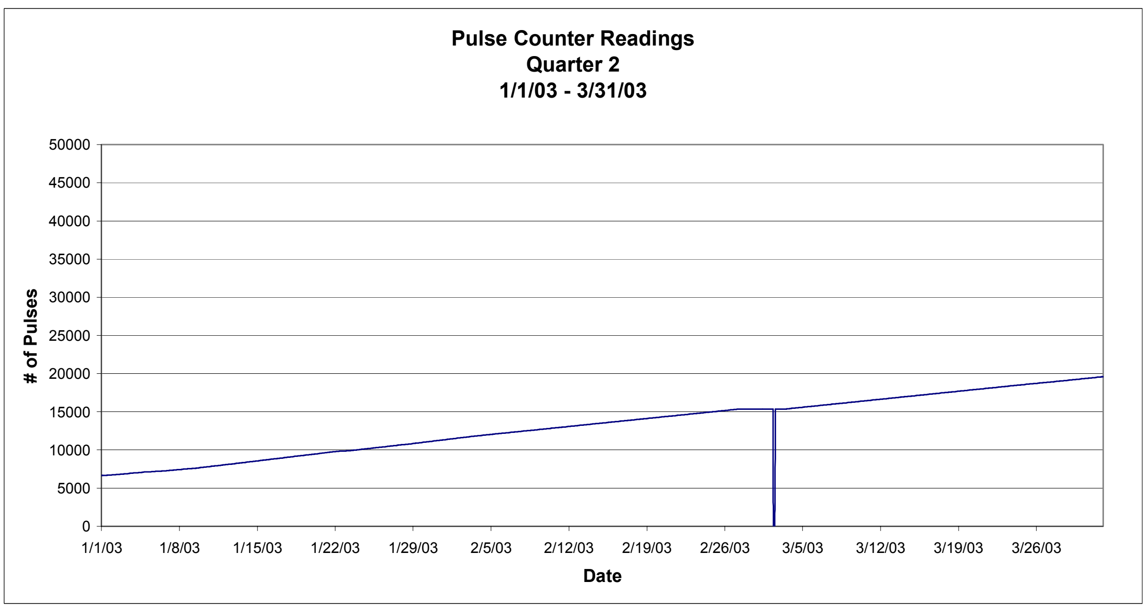
r	Date	1ST FIEL mA	kV	spm	Inlet Temp (F)	2ND FIELD mA	kV	spm	3RD FIELD mA	kV	spm	4TH FIELD mA	kV	spm	ave mA AH chamber
	11/22/2002	off				296	53.8	12	249	57.8	12	521	52	12	355.3
	11/22/2002					361	51.8	50	284	44.7	12	592	50.9	12	412.3
	11/23/2002					438	56.8	50	515	52.5	11	705	52.7	1	552.7
	1/6/2003	23				672			546			705			641.0
	1/9/2003	0	0		268	349	58.4		260	51.3		575	56.1		394.7
	1/10/2003	124	65		263	569	56.5		379	53		705	55.2		551.0
	1/13/2003	492	65		255	699	54.5		652	54.1		705	48.9		685.3
	1/13/2003	527	52.6	3		711	54.5	42	664	54.8	12	705	48.4	1	693.3
	1/14/2003	94	65.1	0	255	557	57.7	49	343	52.3	11	586	52.7	11	495.3
	1/15/2003	136	65	2	260	557	55.2	51	415	52	11	687	52.7	2	553.0
	1/19/2003														
	1/20/2003	201	65.2	0	249	586	52	46	415	51.2	12	705	51.5	0	568.7
	1/23/2003	249	65	1	253	699	57.7	34	403	50.5	13	705	51.3	0	602.3
	1/26/2003	195	65.1	0	251	640	55.7	45	403	50.9	11	705	52	8	582.7
	1/28/2003	201	65	0	264	723	58.1	27	403	51.3	12	705	52.5	0	610.3
	1/28/2003	136	65.1	0	259	664	53.9	51	415	52.8	12	705	53.5	0	594.7
	1/29/2003	183	65.1	4	255	705	59.2	11	438	59.2	100	705	52.3	0	616.0
	1/30/2003	189	65	4	267	711	58.6	45	373	50.8	100	705	52	0	596.3
	2/3/2003	367	65	3	255	723	54.5	8	563	52.7	100	705	49.8	0	663.7
	2/4/2003	171	65	1	262	705	58.8	8	432	52.8	100	705	52.5	0	614.0
	2/5/2003	94	65.2	2	265	581	54.8	102	343	50	101	675	51.7	52	533.0
	2/6/2003	130	65	5	265	711	58	94	379	52	98	705	55	1	598.3
	2/6/2003	140	65	0	264	699	59	99	380	52	100	711	55	0	596.7
	2/7/2003	83	65	0	261	634	58	100	355	52	51	705	55	32	564.7
	2/7/2003	142	65	1	275	610	54	100	332	48	100	711	52	4	551.0
	2/8/2003	213	65	3	259	705	58	22	616	56	101	705	51	0	675.3
	2/8/2003	496		0	238	705		0	705		0	706		0	705.3
	2/8/2003	106	65	3	269	563	56	99	379	51	100	711	53	8	551.0
	2/8/2003	177	65	1	264	705	58	11	426	51	100	705	52	0	612.0
	2/9/2003	166	65	0	260	705	58	12	474	51	99	705	50	0	628.0
	2/9/2003	189	65	0	278	680	55	87	379	49	100	800	53	1	619.7
	2/9/2003	166	65	0	278	687	54	82	367	49	100	705	52	0	586.3
	2/9/2003	124	65	6	273	640	56	100	349	50	100	711	52	1	566.7
	2/10/2003	106	65	0	254	664	56	100	415	51	100	705	53	0	594.7
	2/10/2003	130	65	0	257	705	60	40	391	49	101	705	52	0	600.3
	2/11/2003	177	65	0	265	711	57	67	415	50	100	705	52	0	610.3
	2/12/2003	166	65	15	252	634	55.9	98	373	49.4	99	711	52.4	69	572.7
	2/12/2003	94	65	0	262	664	55	92	420	53	100	705	54	0	596.3
	2/12/2003	177	65	28	267	705	57	1	533	52	100	705	49	0	647.7
	2/13/2003	85	65.1	0	270	634	58.4	99	379	47.9	100	705	53.8	28	572.7
	2/16/2003	189	65	0	251	652	56.5	29	462	53.2	100	711	52.2	0	608.3
	2/19/2003	112	65	0		509	47.3	100	320	50.4	101	675	52.5	79	501.3
	2/21/2003	94	65.1	3		432	50.3	97	290	52.5	100	669	47.7	98	463.7
	2/24/2003	130	65.1	0		699	59.7	98	373	62	99	711	55.6	0	594.3
-line, pulsed bags at low load															
	3/3/2003	1114	63	##		705	50	0	705	53	0	711	43	0	707.0
		966	65	0		711	51	0	705	53	0	711	43	0	709.0
		758	65	1		705	51	0	705	54	0	705	44	0	705.0
		604	65	1		705	52	3	705	55	9	711	46	0	707.0
		509	65	3		705	54	0	687	53	89	705	47	0	699.0
	3/4/2003	367	65	0		705	56	7	509	50	98	705	48	0	639.7

2B CHAMBER

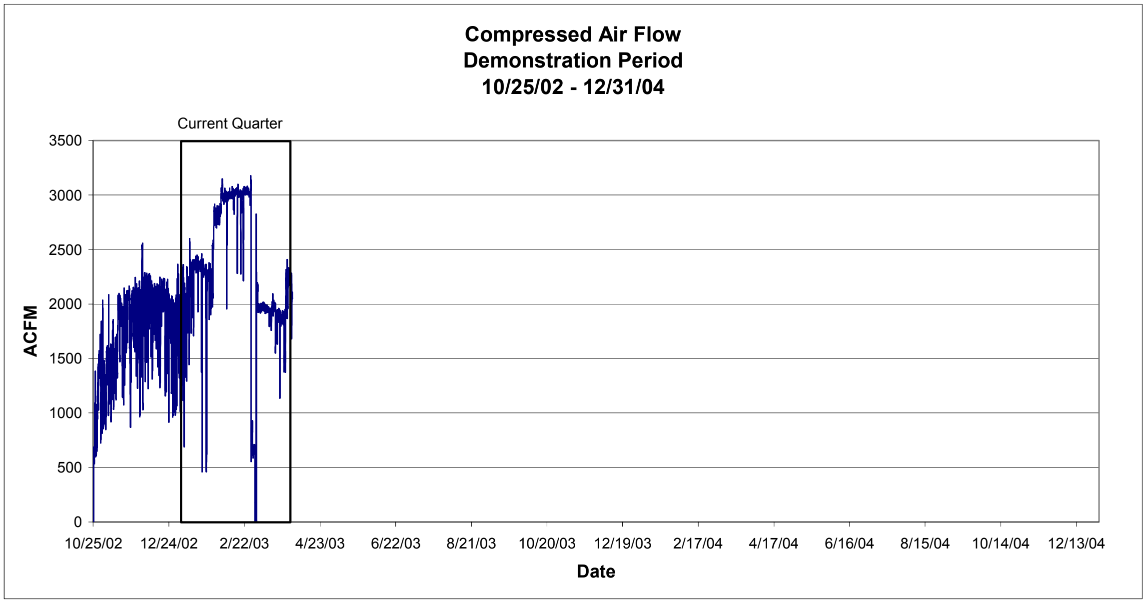
Date	Time	Inlet Temp (F)	1ST FIELD mA	1ST FIELD kV	1ST FIELD spm	2ND FIELD mA	2ND FIELD kV	2ND FIELD spm	3RD FIELD mA	3RD FIELD kV	3RD FIELD spm	4TH FIELD mA	4TH FIELD kV	4TH FIELD spm	ave mA AH chamber
11/22/2002	9:00 AM		off			320	48.9	12	545	48.6	12	509	46.4	12	458
	11:10 AM					367	50.9	49	391	49.5	12	616	46.6	12	458
11/23/2002	18:00 pm					320	53.3	50	705	51.2	1	705	51.9	5	577
1/6/2003			85			491			708			705			635
began burning soybeans at 600 to 700 tons/day															
1/9/2003		303.0	35	47.1		296	52.7		533	50.5		521	51.6		450
1/10/2003		303.0	94	49		374	56.5		509	53.9		503	51.6		462
stopped burning soybeans															
1/13/2003		292.0	94	50		409	50.2		598	51.6		711	51.3		573
1/13/2003			94	52.6	99	486	51.3	51	610	52.9	12	634	50.5	12	577
1/14/2003	07:30am	295.0	106	48.6	101	320	50.4	48	462	53	11	486	50.4	11	423
1/15/2003	07:30am	298.0	88	49.3	99	420	55.3	51	557	53.9	12	581	48.3	12	519
inspected and repaired compartments 4 and 11 collecting plate rapper shafts 1/19/2003															
Burning soybeans at lower rate 60-200 tons/day															
1/20/2003	07:30am	285.0	59	46.9	99	355	52.7	50	616	49.7	12	669	52.7	12	547
1/22/2003	plant tripped @ 14:40 CT back on line at midnight														
1/23/2003		287.0	59	48.8	97	379	52	51	669	51.3	12	675	51.5	8	574
1/26/2003		296.0	71	49.1	98	385	50.1	49	592	48.2	12	521	49.8	10	499
1/28/2003	7:30 AM	303.0	53	49.1	98	401	53.2	50	581	52	10	634	52.8	10	539
	15:30 pm	291.0	83	49.9	100	415	54	51	616	50.9	12	575	52.7	10	535
1/28/2003	spark limit setpoint increased in2nd and 3rd fields to 99 spm														
1/29/2003	7:30 AM	288.0	94	49	99	450	53	99	640	53.4	96	705	53.7	36	598
1/30/2003	7:30 AM	302.0	118	51.9	99	308	50.6	101	705	50.8	99	711	52	36	575
2/3/2003	7:30 AM	293.0	112	46.7	100	450	48.6	100	604	50.6	100	729	50.6	20	594
2/4/2003	7:30 AM	301.0	71	49.7	101	438	50.9	101	723	51.3	95	551	43.9	95	571
2/5/2003	7:30 AM	303.0	77	46.9	100	373	46.2	101	628	49.9	100	664	49.6	97	555
2/6/2003	11:30 AM														
2/6/2003	15:20 pm	300.0	70	50	99	280	50	101	695	49	100	604	51	65	526
	17:00 pm	302.0	40	54	100	390	52	100	581	51	100	580	53	92	517
2/7/2003	8:15 AM	299.0	106	48	99	391	54	99	640	51	100	735	52	61	589
	12:05 PM														
	16:00 pm	307.0	94	47	99	415	48	101	581	48	99	705	49	36	567
2/8/2003	3:00	293.0	77	51	98	486	54	96	699	51	88	711	51	1	632
	4:42	265.0	92		98	663		78	707		0	706		0	692
	12:00	307.0	94	50	101	379	52	99	652	50	101	711	51	4	581
	19:00	302.0	59	49	98	450	52	99	646	49	97	705	52	15	600
2/9/2003	10:00	296.0	65	49	98	426	77	100	515	50	100	705	50	21	549
tempoarily raised TR current limit setpoints when compartments were not at 100 spm - max was 1000 mA															
	13:00	315.0	94	50	100	272	52	99	580	51`	100	664	50	66	505
	14:45	315.0	59	49	100	373	53	100	498	48	100	640	48	86	504
	17:00	311.0	94	47	99	355	46	99	450	46	100	634	46	97	480
2/10/2003	10:00	294.0	96	51	100	379	54	98	577	51	100	604	43	100	520
	19:10	293.0	59	53	100	385	54	100	509	49	100	557	48	101	484
2/11/2003	8:45	301.0	59	54	99	355	52	99	557	51	100	551	47	93	488
2/12/2003	7:30	288.0	71	47.1	99	403	51.9	99	498	44.5	99	675	50.5	99	525
2/12/2003	10:40	299.0	71	50	99	385	52	101	486	51	100	569	49	98	480
Each field was individually power off rapped starting with #2,#3,#4, and then 1st field															#DIV/0!
Increased soybean burn rate to 500 ton/day on 13th															
	17:00	302.0	71	48	100	476	52	100	545	51	100	705	50	1	575
2/13/2003	7:30	308.0	94	43.3	99	391	53.8	100	563	52	100	652	50	99	535
2/16/2003	7:30	286.0	71	52.3	99	397	52.2	101	456	51	99	693	51.4	98	515
2/19/2003	7:30		130	54.2	99	367	49.8	99	391	50.1	101	521	50.4	99	426
2/21/2003	7:30		53	49.1	99	243	48.1	101	438	46.3	100	616	50.5	100	432
2/24/2003	7:30		59	53.4	100	355	54.1	99	450	53.8	101	581	50.4	39	462
Plant down for boiler wash, replaced first section of collecting plate rapper shafts and outboard bearing. Rapped all plates off-line, pulse															
3/3/2003	9:00		326	50	98	711	53	0	705	45	0	705	44	0	707
	14:31		166	57	99	705	54	5	705	46	0	711	45	0	707
	18:35		71	53	98	533	49	100	705	48	0	705	48	0	648
	20:12		71	50	101	480	51	101	711	49	1	705	49	2	632
	23:42		118	49	98	462	50	99	699	47	93	711	50	1	624
3/4/2003	7:20		47	57	100	468	48	99	717	50	84	711	51	0	632

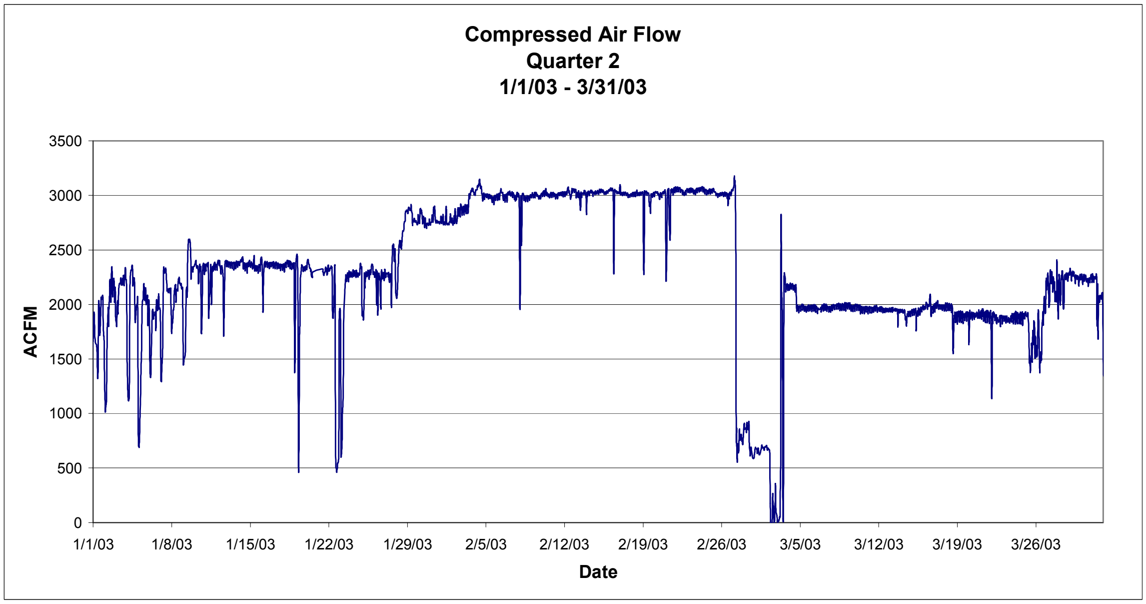
B21 Pulse Counter Readings



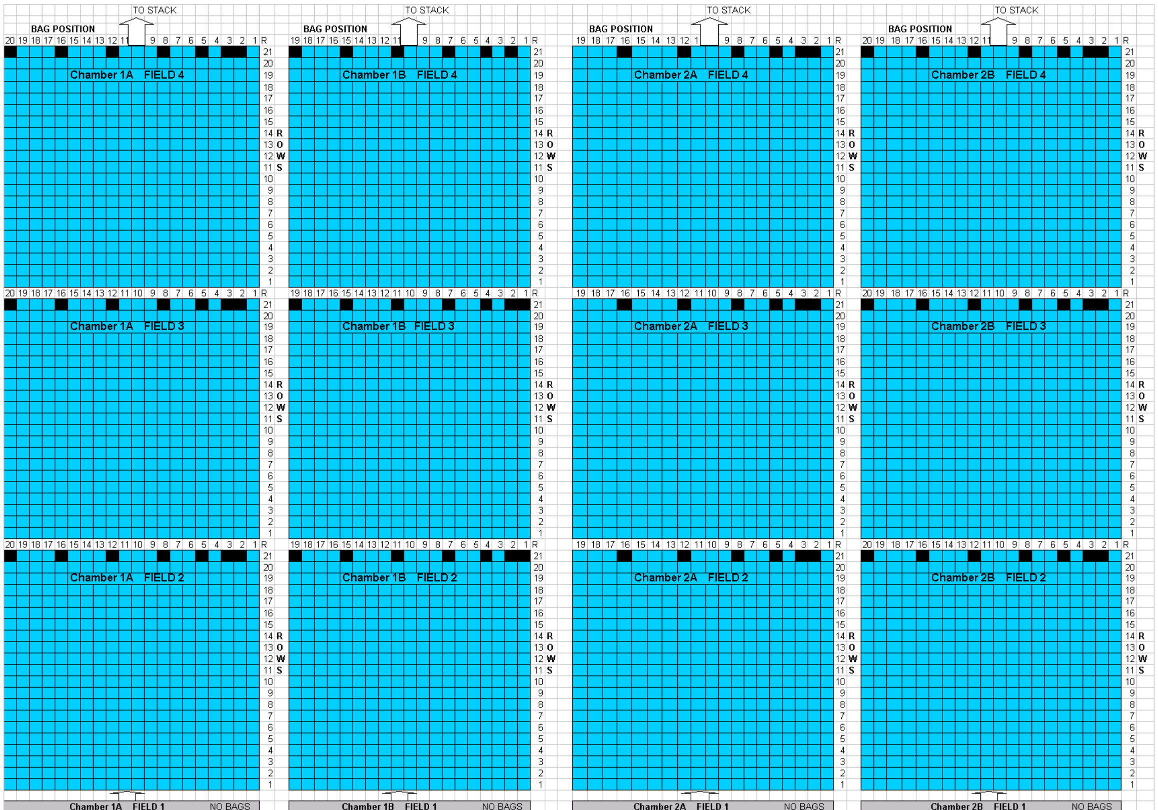


B22 Compressed Air Flow





B23 Bag Layout Diagram



■ No Filter Bag

■ Conductive Gore-Tex Membrane/Conductive Gore-Tex Felt (Installed 10/02)

B24 Alternative Fuel Analysis

MINNESOTA VALLEY TESTING LABORATORIES, INC.
1126 N. Front St. - New Ulm, MN 56073 - 800-782-3557 - Fax 507-359-2890
1411 S. 12th St. - Bismarck, ND 58502 - 800-279-6885 - Fax 701-258-9724
710 S. 14th St. - Grand Forks, ND 58201 - 800-272-7645 - Fax 701-772-0028
35 W. Lincoln Way - Nevada, IA 50201 - 800-362-0855 - Fax 515-382-3885
MEMBER ACIL

Sample Number: 03-C99 — Report Date: 1/21/03

Tom Hrdlicka
Ottertail Power - Big Stone
PO Box 218
Big Stone City SD 57216-0218

Work Order #: 89-51
P.O. #: 7830

Sample Description: Soybeans
Sample Site: OTP Big Stone

* PROXIMATE *

ANALYTE	AS RECEIVED	DRY BASIS
Total Moisture	9.85 wt. %	
Ash	4.28 wt. %	4.75 wt. %
BTU/lb	9338 BTU/lb	10359 BTU/lb
Total Sulfur	0.31 wt. %	0.34 wt. %

* ULTIMATE *

ANALYTE	AS RECEIVED	DRY BASIS
Total Moisture	9.85 wt. %	
Ash	4.28 wt. %	4.75 wt. %
Carbon	48.97 wt. %	54.32 wt. %
Hydrogen	7.50 wt. %	7.10 wt. %
Nitrogen	5.71 wt. %	6.33 wt. %
Total Sulfur	0.31 wt. %	0.34 wt. %
Oxygen by Difference	33.23 wt. %	27.16 wt. %

* SULFUR FORMS *

ANALYTE	AS RECEIVED	DRY BASIS
Total Sulfur	0.31 wt. %	0.34 wt. %

* ASH FUSION *

ANALYTE	REDUCING	OXIDIZING

* MINERAL ANALYSIS OF ASH *

ANALYTE	DRY BASIS
Potassium Oxide in Ash	43.39 wt. %
Sodium Oxide	1.30 wt. %

* MISCELLANEOUS *

ANALYTE	AS RECEIVED	DRY BASIS
Hydrogen less H2O	6.40	
Oxygen Less H2O	24.48	

Approved By: D. Zander

MINNESOTA VALLEY TESTING LABORATORIES, INC.
1126 N. Front St. - New Ulm, MN 56073 - 800-782-3557 - Fax 507-359-2890
1411 S. 12th St. - Bismarck, ND 58502 - 800-279-6885 - Fax 701-258-9724
710 S. 14th St. - Grand Forks, ND 58201 - 800-272-7645 - Fax 701-772-0028
35 W. Lincoln Way - Nevada, IA 50201 - 800-362-0855 - Fax 515-382-3885
MEMBER ACIL

Sample Number: 03-C98

Report Date: 1/21/03

Tom Hrdlicka
Ottertail Power - Big Stone
PO Box 218
Big Stone City SD 57216-0218

Work Order #: 89-51
P.O. #: 7830

Sample Description: Corn
Sample Site: OTP Big Stone

*** PROXIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	14.51	wt. %		
Ash	1.03	wt. %	1.20	wt. %
BTU/lb	6925	BTU/lb	8100	BTU/lb
Total Sulfur	0.35	wt. %	0.41	wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	14.51	wt. %		
Ash	1.03	wt. %	1.20	wt. %
Carbon	40.12	wt. %	46.93	wt. %
Hydrogen	6.79	wt. %	6.04	wt. %
Nitrogen	1.14	wt. %	1.33	wt. %
Total Sulfur	0.35	wt. %	0.41	wt. %
Oxygen by Difference	50.57	wt. %	44.08	wt. %

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	0.35	wt. %	0.41	wt. %

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS	
Potassium Oxide in Ash	29.39	wt. %
Sodium Oxide	0.50	wt. %

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED	DRY BASIS
Hydrogen less H2O	5.17	
Oxygen Less H2O	37.68	

Approved By: D. Zander

B25 E-mail from Stan Miller on Soybean Burn

Hrdlicka, Thomas

From: Miller, Stanley J. [smiller@undeerc.org]

Sent: Friday, April 11, 2003 11:07 AM

To: Swanson, William; Hrdlicka, Thomas; Rich Gebert (rgebert@wlgore.com); Dwight R. Davis (ddavis@wlgore.com); Craig Rinschler (P.E.) (crinschl@wlgore.com); Rick Bucher (rbucher@wlgore.com)

Cc: Jones, Michael L.; Olderbak, Michelle

Subject: Effect of Soy Bean Burning on AH performance

I received two samples from Rich of ash brushed from the bags removed in the full-scale Big Stone AH in November and March. Our first XRF analysis shows the November potassium level to be 0.4% compared to 3.2% for the March bag sample. Keep in mind that these samples would likely be a mixture of the entire dust cake going back to start up so at times the actual potassium level of additional ash on the surface may be much higher. The sulfate level was also much higher for the March sample. We are doing some additional scanning electron microscopy analysis of undisturbed ash from a bag sample which may provide further insight as to the effect of the high potassium levels.

I also looked at the pilot-scale data from February and saw an immediate increase in residual drag and decrease in bag cleaning interval on Feb 4, which is the day when there was a large increase in the amount of waste seeds being burned. The pilot unit was operated until Feb 11, but much of the operation was with single bank and a short pulse interval. However, before shutting down, we operated for about a day in baseline conditions again. By this time the residual drag and bag cleaning interval had deteriorated even more. The waste seed rate feed rate from Feb 5 to 11 was 260 to 315 tons per day. From Feb 12 until Feb 23 the seed feed rate was increased significantly and was over 800 tons per day from Feb 21 to 23.

All of this points to the waste seed burning as having a significant negative effect on the pressure drop.

It should also be noted that in the EERC small-scale pilot tests in January, we saw higher pressure drop when we increased the rate of TDF up to 10%. This is higher than the 5% that is occasionally burned at Big Stone, but it is another indication that alternative fuel burning can have a very negative effect on the pressure drop.

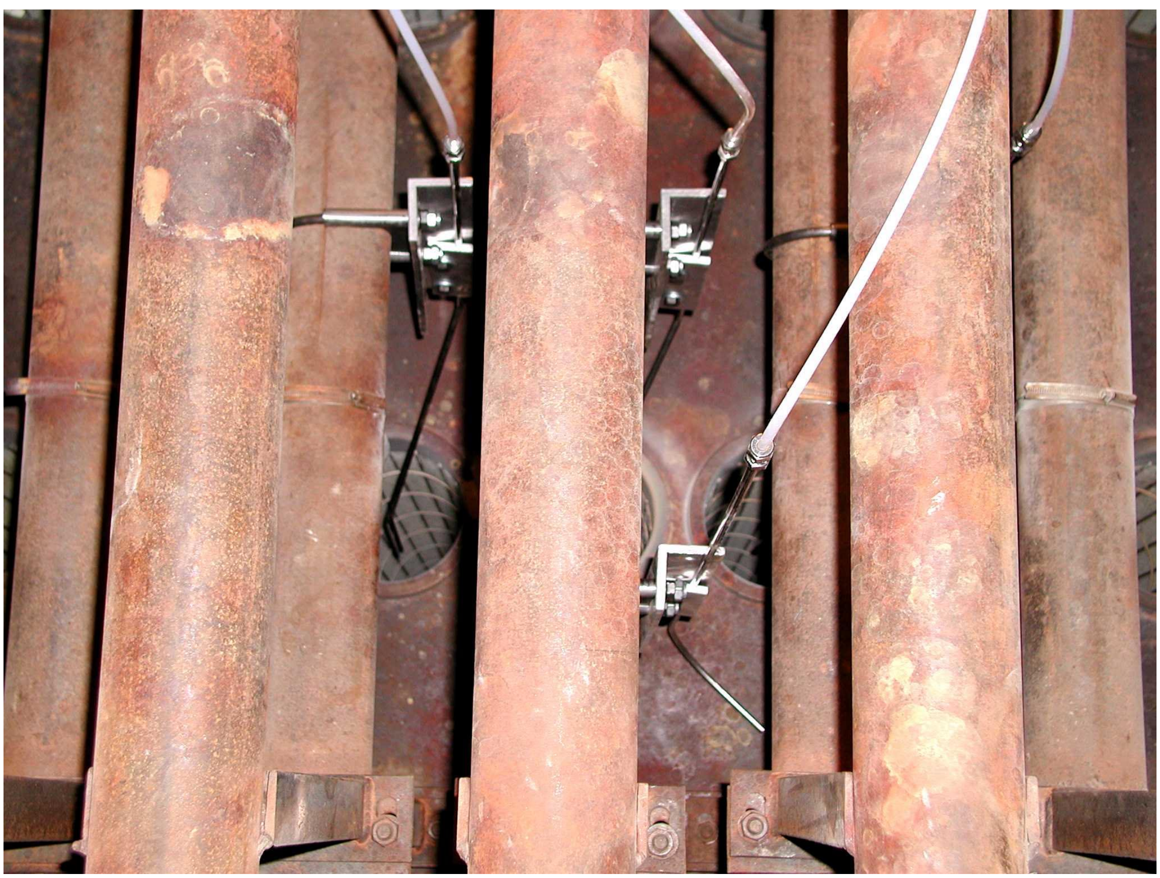
I suggest that all waste seed and TDF burning be stopped at the plant, at least until the pressure drop issues are solved. This is especially important for the time immediately after washing the bags. It may be shown in the future that a level of alternative fuels can be tolerated, but for the near term if we are looking for all ways to minimize pressure drop, it seems to be the way to go.

I will be out of the office on vacation from April 14 through 22, but can be reached if necessary.

Thanks,

Stan

B26 Photographs of Pitot Tube Equipment



B27 Specific Information on the Construction of the Pitot Tubes

Pitot Tube in a Filter Bag, Gas Flow Measurement Device
Big Stone Application with 19 inch Spacing between Blowpipe and Tubesheet

Revised on May 28, 2003

Material List

Material	Size	Quantity
304 stainless steel tubing	ID 0.12 inch, OD 0.25 inch x 0.065 inch wall Length of each piece 40 inch	10
U bolt clamp steel	3.0 inch diameter steel pipe with 3.5" O.D. Bolt spacing 4.0 inch McMaster-Carr # 3042T21	10
Aluminum or steel angle for Plate Mount	1.5" x 2.0"x 12"x 0.25"	10
Aluminum or steel bar for Plate Clamp	1.5 " x 6" x 0.25"	10
Steel Bolts	5/16 x 18 x 1.25"	20
Steel locking nuts (optional)	5/16 x 18 steel locking	20
Flat steel washers	5/16	20
Flat steel washers	3/8	20
Steel locking nuts (for 500F), (optional)	3/8 steel locking	20

Instructions:

304 stainless steel tubing

- Cut to 40 inch length
- Create round nose on one end (radius of 0.100-0.125 inch) from center of tubing
- Make 2 bends in same plane ,45 degrees each, as per drawing .
- First bend 45 degrees 10 inches from Nose of tubing
- Second bend 45 degrees 10 inches from previous bend in opposite direction.
- With tubing cutter cut and trim end of tubing for compression fitting

Aluminum or steel angle for Plate Mount 1.5" x 2.0"x 12"x 0.25"

- Drill 2 through holes oversize for 3/8 inch diameter U bolt.
- Drill 2 through holes over size for 5/16 x 18 bolts
- Machine groove (0.125 inch radius) to (0.080 inch depth) for ¼ inch OD tubing

Aluminum or steel bar for Plate Clamp 1.5 " x 6" x 0.25"

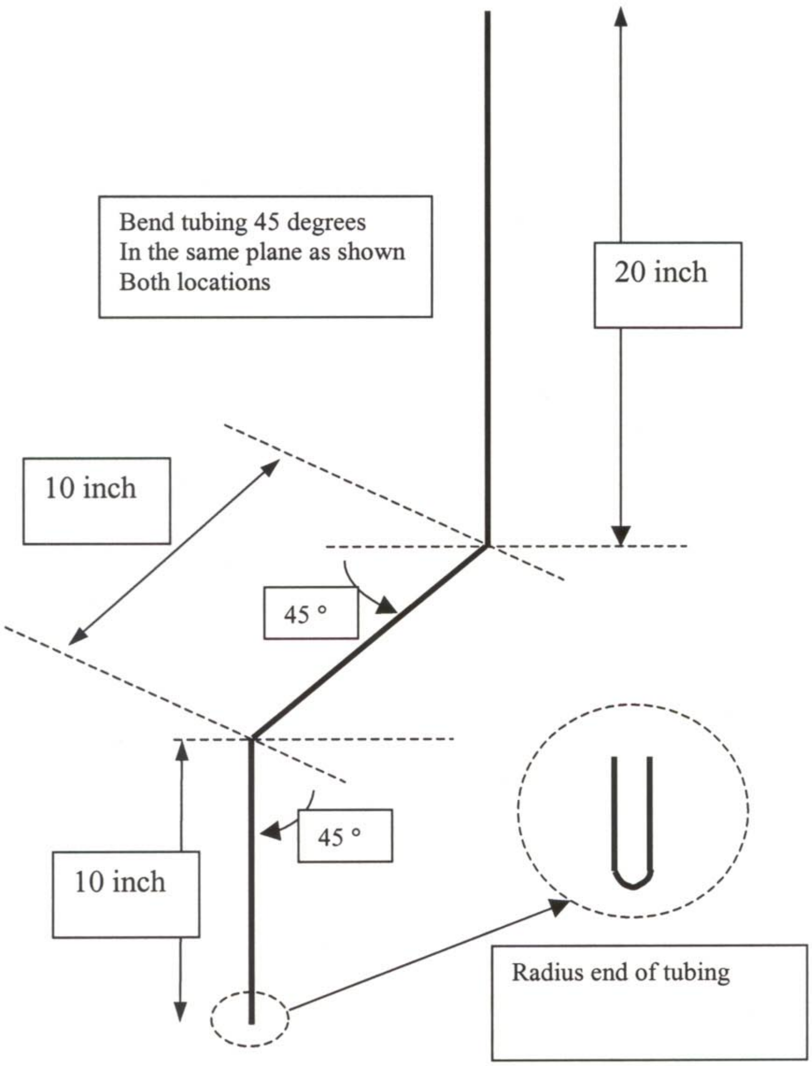
- Drill 2 through holes over size for 5/16 x 18 bolts
- Machine groove (0.125 inch radius) to (0.080 inch depth) for ¼ inch OD tubing

Bag Flow Pitot Tube Measurement Device

Tubing – Pitot Tube

304 stainless steel tubing   40 inch length

- Create round nose on one end (radius of 0.100-0.125 inch) from center of tubing
- Make 2 bends in same plane ,45 degrees each, as per drawing .
- First bend 45 degrees 10 inches from Nose of tubing
- Second bend 45 degrees 10 inches from previous bend in opposite direction.
- Debur opposite end of tubing for compression fitting



Bag Flow Pitot Tube Measurement Device

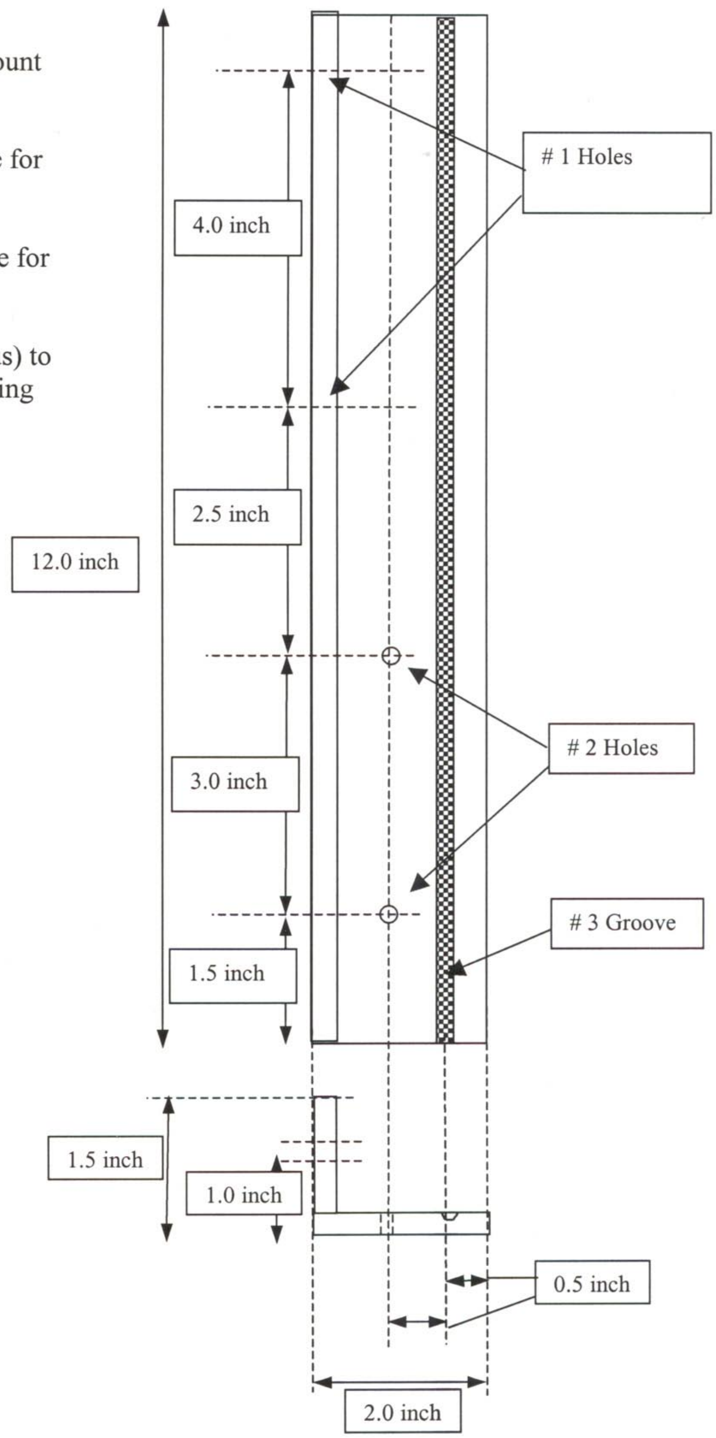
Plate Mount

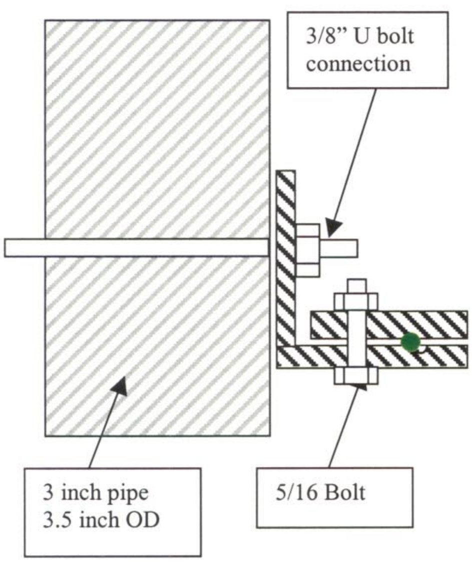
Aluminum or steel angle for Plate Mount
1.5" x 2.0"x 12"x 0.25"

1. Drill 2 through holes and oversize for 3/8 inch diameter U bolt.

2. Drill 2 through holes and over size for 5/16 x 18 bolts

3. Machine groove (0.125 inch radius) to (0.080 inch depth) for ¼ inch OD tubing





Assembly Drawing

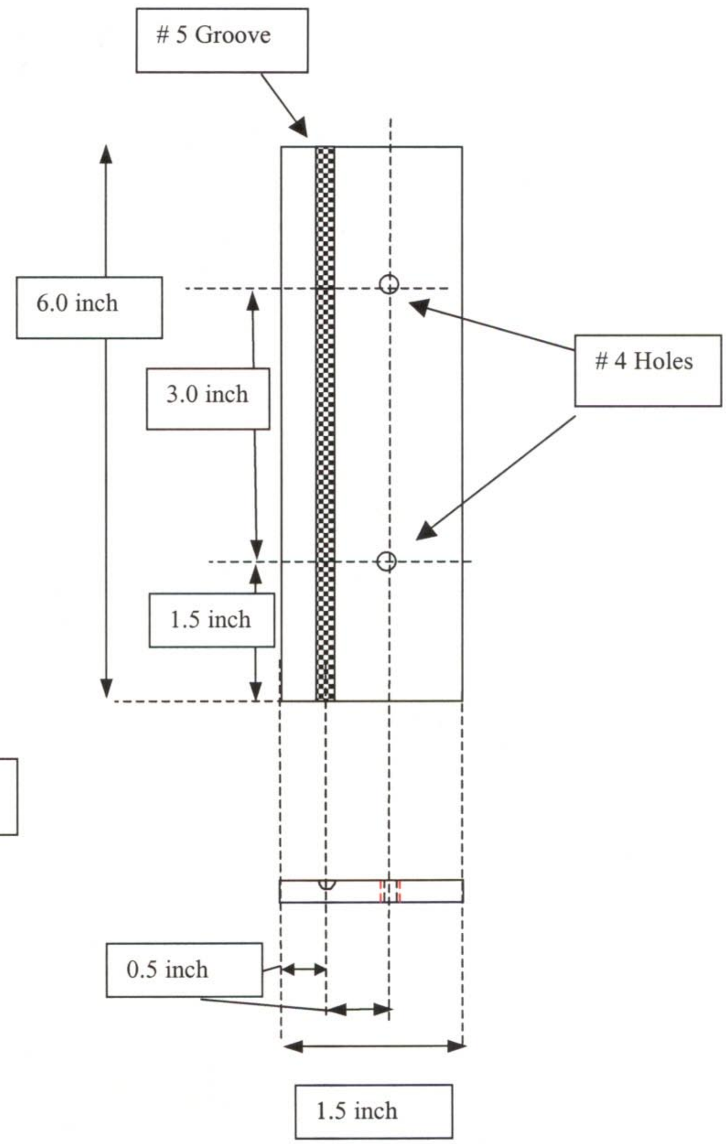
Bag Flow Pitot Tube Measurement Device

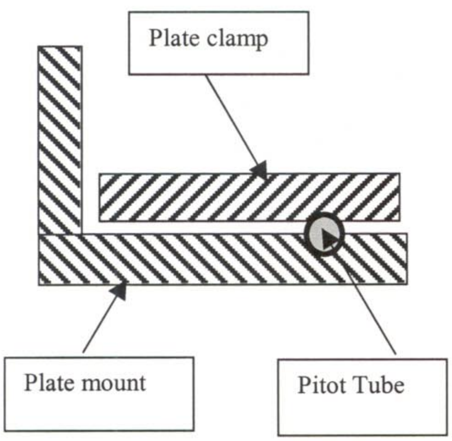
Plate Clamp

<u>Aluminum or steel bar for Plate Clamp 1.5 " x 6" x 0.25"</u>

4. Drill 2 through holes over size for 5/16 x 18 bolts

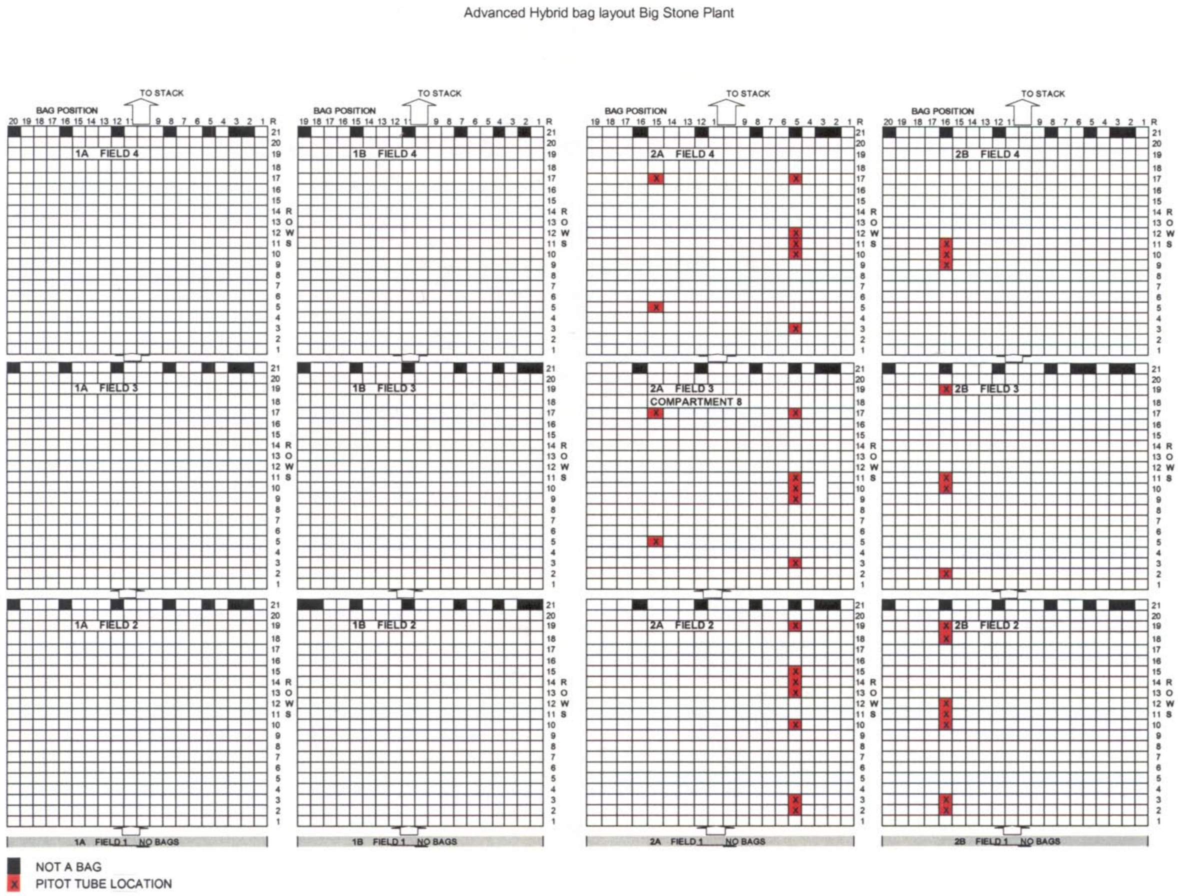
5. Machine 0.125 inch radius groove 0.080 inch depth for ¼ inch tubing





Assembly Drawing

B28 Specific Pitot Tube Placement on Bag Layout Diagram



B29 Photograph of Pitot Tube Transmitters