January 25, 2012

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Dear Dr. Berndt:

Subject: Revised Final Report Entitled “Project 4: Evaluation for a Slipstream Baghouse for the Taconite Industry”; EERC Fund 15726

Please find enclosed the revised subject final report.

If you have any questions or require clarification of any point, please contact me by phone at (701) 777-5138 or by e-mail at dlaudal@undeerc.org.

Sincerely,

Dennis L. Laudal  
Senior Research Advisor

DLL/kal  
Enclosures  
c/enc: Ryan Siats, U.S. Steel
PROJECT 4: EVALUATION OF A SLIPSTREAM BAGHOUSE FOR THE TACONITE INDUSTRY

Revised Final Report

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ABSTRACT

Over the past 20 years, there has been a concerted effort by national and state agencies to reduce mercury emissions from all sources. In November of 2011, the U.S. Environmental Protection Agency (EPA) is required to issue an air toxic rule that will include mercury based on maximum achievable control technology (MACT) requirements for the coal-fired power industry. Although utilities are the largest source of anthropogenic mercury emissions, they are not the only source. In Minnesota, one of these sources is the taconite industry. As a result, the Energy & Environmental Research Center tested a mercury control technology utilizing a slipstream baghouse with activated carbon injection at the United States Steel Corporation, Minnesota Ore Operations – Keetac Plant. Results showed that by using as little as 2.2 lb/Macf of standard activated carbon or 1.1 lb/Macf of a treated carbon >75% mercury removal can be achieved.

ACKNOWLEDGMENTS

The authors of this report would like to thank Mike Berndt of the Minnesota Department of Natural Resources for all of his support and input. We would also like to thank Region 5 EPA for providing funding for the project. In addition, we thank Keith Hanson of Barr Engineering. Lastly, we gratefully acknowledge and thank Ryan Siats and Keetac for supporting this project and allowing the installation of the slipstream baghouse at their site.
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# NOMENCLATURE

| AC    | activated carbon |
| ACI   | activated carbon injection |
| BH    | baghouse |
| \(C_a\) and \(C_b\) | mercury concentrations measured by the paired sorbent traps |
| \(C_m\) | meter constant |
| CMM   | continuous mercury monitor |
| CVAA  | cold vapor atomic adsorption |
| CVAF  | cold-vapor atomic fluorescence |
| EERC  | Energy & Environmental Research Center |
| EPA   | U.S. Environmental Protection Agency |
| FOB   | freight on board |
| ISP   | inertial separation probe |
| Keetac | United States Steel Corporation, Minnesota Ore Operations – Keetac |
| Lt    | long ton |
| Macf  | million actual cubic feet |
| MACT  | maximum achievable control technology |
| MNDNR | Minnesota Department of Natural Resources |
| NIST  | National Institute of Standards and Technology |
| PAC   | powdered activated carbon |
| PPS   | polyphenylene sulfide |
| PRB   | Powder River Basin |
| QA/QC | quality assurance/quality control |
| RSD   | relative standard difference |
| scfm  | standard cubic feet per min |
| TPE   | total purchased equipment |
EXECUTIVE SUMMARY

Introduction

Over the past 20 years, there has been a concerted effort by national and state agencies to reduce mercury emissions from all sources. In December of 2011, the U.S. Environmental Protection Agency (EPA) issued an air toxic rule for the coal-fired power industry. This rule will included mercury and is based on maximum achievable control technology requirements.

Although utilities are the largest source of anthropogenic mercury, they are not the only source. In Minnesota, one of these sources is the taconite industry. Taconite processing has two potential sources of mercury: mercury released from processing the ore and mercury released from the fuels used during processing. The greatest percentage of mercury emissions results from mercury inherent in the ore, which is related to the ore’s geographical location in the Biwabik Iron Formation.

The taconite industry formed a working group to evaluate and help fund research to reduce mercury emissions. This group, the Minnesota Taconite Mercury Control Advisory Committee, along with the Minnesota Department of Natural Resources and EPA, funded five projects. One of those projects was an Energy & Environmental Research Center (EERC) project to evaluate the use of a slipstream baghouse (BH) with activated carbon injection (ACI) to reduce mercury emissions.

Although the technology would be expected to provide effective mercury control for any of the taconite plants (straight grate or grate kilns), in reality, the technology would only be economical for those plants where, in addition to mercury, particulate control is a potential concern. The plant chosen for this project was the United States Steel Corporation, Minnesota Ore Operations – Keetac (Keetac) Plant. The primary goal of the project was to provide a minimum of 75% reduction in mercury emissions, where mercury reduction is defined by:

\[
\text{(BH Inlet Hg Conc. – BH Outlet Hg Conc.) ÷ BH Inlet Hg Conc. × 100%} \quad [\text{Eq. 1}]
\]

The EERC slipstream baghouse is a trailer-mounted baghouse that was transported to the test site and connected in slipstream fashion to allow for testing “real” flue gases under actual operating conditions. Because the slipstream baghouse was located after a wet scrubber, the flue gas at the inlet was saturated at about 132°F. To avoid wetting the bags and fan, an additional drip leg and heating elements were installed to raise the inlet flue gas temperature to about 165°F. For a full-scale unit, it would be expected that a portion of the flow (prior to the wet scrubber) would be routed to the baghouse to maintain a temperature above the water dew point.

For the Keetac test, the baghouse was operated at a nominal air-to-cloth ratio of 6 ft/min (actual ft³/min of gas per ft² of cloth). The bags that were used for this test were Ryton® PPS
(polyphenylene sulfide). Because the gas flow rate was about 600 scfm (720 acfm at 190°F), a total of seven bags were needed to maintain an actual air-to-cloth ratio of 5.45. A picture of the portable baghouse is shown in Figure ES-1. Ports were installed so that the mercury concentrations at both the baghouse inlet and outlet could be measured using continuous mercury monitors (CMMs) and sorbent traps.

**Approach**

The original test plan is shown in Table ES-1. However, several problems were encountered during this testing that altered the overall test plan as originally proposed. It was planned that most, if not all, of the testing would occur when coal was fired, but the plant had difficulty operating its coal feed unit. As a result, more testing was conducted when natural gas was fired than was planned. In a taconite plant, the mercury emitted by the fuel is only a fraction of the total mercury, so the mercury control technology could still be evaluated. The second problem that occurred was a result of the shutdown of the Minnesota state government on July 1, 2011. Therefore, the project ended somewhat earlier than intended. Finally, the mercury removal was such that the tests using the higher add rates were not necessary. The actual tests that were completed are shown in Table ES-2.

![Figure ES-1. Baghouse, trailer, and control room.](image_url)
Table ES-1. Project Test Plan

<table>
<thead>
<tr>
<th>Test</th>
<th>Carbon</th>
<th>Carbon Feed Rate, lb/Macf</th>
<th>Test Duration, days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Standard ACI</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Standard ACI</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Standard ACI</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Treated ACI</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Treated ACI</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Treated ACI</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Contingency tests</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

Table ES-2. Actual Tests Conducted at Keetac

<table>
<thead>
<tr>
<th>Test</th>
<th>Date/Time Start</th>
<th>Date/Time End</th>
<th>Fuel</th>
<th>Sorbent</th>
<th>Add Rate, g/hr</th>
<th>Add Rate, lb/Macf</th>
<th>Run Time, hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6/17/11 17:30</td>
<td>6/19/11 12:05</td>
<td>Natural gas</td>
<td>Baseline</td>
<td>0</td>
<td>0</td>
<td>42.5</td>
</tr>
<tr>
<td>4</td>
<td>6/24/11 12:36</td>
<td>6/24/11 16:10</td>
<td>Natural gas</td>
<td>Standard</td>
<td>42.50</td>
<td>2.2</td>
<td>3.6</td>
</tr>
<tr>
<td>5</td>
<td>6/24/11 16:10</td>
<td>6/26/11 08:28</td>
<td>Natural gas</td>
<td>Baseline</td>
<td>0</td>
<td>0</td>
<td>40.7</td>
</tr>
<tr>
<td>6</td>
<td>6/26/11 09:05</td>
<td>6/27/11 10:59</td>
<td>Natural gas</td>
<td>Bromine-treated</td>
<td>12.11</td>
<td>0.6</td>
<td>25.9</td>
</tr>
<tr>
<td>7</td>
<td>6/27/11 10:59</td>
<td>6/27/11 18:31</td>
<td>PRB</td>
<td>Bromine-treated</td>
<td>12.11</td>
<td>0.6</td>
<td>7.5</td>
</tr>
<tr>
<td>8</td>
<td>6/27/11 18:31</td>
<td>6/28/11 16:00</td>
<td>Natural gas</td>
<td>Bromine-treated</td>
<td>12.11</td>
<td>0.6</td>
<td>21.3³</td>
</tr>
<tr>
<td>9</td>
<td>6/28/11 08:26</td>
<td>6/28/11 08:39</td>
<td>PRB</td>
<td>Bromine-treated</td>
<td>12.11</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>10</td>
<td>6/28/11 16:00</td>
<td>6/29/11 10:07</td>
<td>Natural gas</td>
<td>Bromine-treated</td>
<td>21.36</td>
<td>1.1</td>
<td>18.1</td>
</tr>
<tr>
<td>13</td>
<td>6/30/11 06:28</td>
<td>7/1/11 07:57</td>
<td>PRB</td>
<td>Bromine-treated</td>
<td>21.36</td>
<td>1.1</td>
<td>25.4</td>
</tr>
</tbody>
</table>

1 Based on an actual gas flow rate of 720 acf.
2 Powder River Basin coal
3 Does not include the short time the coal was on (Test 9).

Results and Discussion

The slipstream baghouse operated very well, and particulate emissions were very low during the entire test period. There were no unplanned down periods. However, additional external heaters and insulation were needed to prevent wetting of the bags. In a full-scale installation of a baghouse to control mercury, a wet scrubber bypass of about 18%–20% of the flow would be needed to prevent condensation.

The primary goal of this project was to provide a minimum of 75% reduction in mercury emissions utilizing a slipstream baghouse with two different types of activated carbon. The first was a standard activated carbon and the second a bromine-treated activated carbon (DARCO Hg-LH). The mercury reductions achieved were determined by measuring the mercury at the inlet and the outlet of the slipstream baghouse utilizing CMMs and sorbent traps. The mercury
removals achieved are shown in Table ES-3, where it can be seen that the goal of 75% removal can be achieved consistently using 2.0 lb/Macf of standard activated carbon or 1.1 lb/Macf of treated activated carbon.

A preliminary cost estimate was also made. The results showed that the capital costs for purchasing and installing a pulse-jet baghouse and activated carbon systems at Keetac would be between $10 million and $12 million for the baghouse and $1.5 million – $2 million for an ACI system. The yearly operating cost for the baghouse would be about $2.0 million. The operating cost for the ACI system is greatly impacted by the cost of the sorbent and selected injection rates. Based on the results above and current costs, the annual operating cost would be about $725,000/yr using the treated carbon at an injection rate of 1.1 lb/Macf or about $870,000/yr with standard activated carbon (2 lb/Macf).

Conclusions and Recommendations

Based on the results of the testing, the following conclusions can be made:

- 75% mercury removal can be achieved at the Keetac Plant with either standard or bromine-treated activated carbon at feed rates of 2 lb/Macf and 1.1 lb/Macf, respectively.
- Very low particulate emissions are achieved.
- Because of the relatively high cost of installing a fabric filter, the most economic installation would be for those taconite facilities that require fuel flexibility and/or have concerns about particulate emissions.
- If a baghouse is to be installed at the Keetac taconite plant, about 18%–20% of the flue gas would need to bypass the wet particulate scrubber to prevent wetting of the bags.

<table>
<thead>
<tr>
<th>Type of Activated Carbon</th>
<th>Fuel</th>
<th>Feed Rate, lb/Macf</th>
<th>Inlet Hg Conc., µg/Nm³</th>
<th>Outlet Hg Conc., µg/Nm³</th>
<th>Mercury Removal, %</th>
<th>Std. Dev., %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>Natural gas</td>
<td>1.1</td>
<td>6.00</td>
<td>1.42</td>
<td>76.3</td>
<td>6.3</td>
</tr>
<tr>
<td>Standard</td>
<td>Natural gas</td>
<td>2.0</td>
<td>5.99</td>
<td>0.93</td>
<td>84.5</td>
<td>7.7</td>
</tr>
<tr>
<td>Standard</td>
<td>Natural gas</td>
<td>2.2</td>
<td>5.18</td>
<td>0.47</td>
<td>91.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Treated</td>
<td>Natural gas*</td>
<td>0.60</td>
<td>5.18</td>
<td>0.89</td>
<td>82.9</td>
<td>4.9</td>
</tr>
<tr>
<td>Treated</td>
<td>PRB coal</td>
<td>0.60</td>
<td>5.25</td>
<td>0.60</td>
<td>88.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Treated</td>
<td>Natural gas</td>
<td>1.1</td>
<td>4.55</td>
<td>0.55</td>
<td>88.1</td>
<td>4.8</td>
</tr>
<tr>
<td>Treated</td>
<td>PRB coal</td>
<td>1.1</td>
<td>4.38</td>
<td>0.19</td>
<td>95.6</td>
<td>2.0</td>
</tr>
</tbody>
</table>

* Only the last 28 hours of the test was considered.
If this is to be a viable technology, the following recommendations are made for future testing:

- Longer-term testing is needed to determine the resultant steady-state pressure drop across the baghouse as a function of air-to-cloth ratio.

- Longer-term tests are also needed to ensure that required mercury control will be maintained over time.

- The economic evaluation presented in this report is based on a model developed for utilities and may or may not be totally valid for a taconite plant. Therefore, more specific economic data are needed.
1.0 INTRODUCTION AND BACKGROUND

Mercury is a naturally occurring element that is ubiquitous in the Earth’s crust. Both anthropogenic activities such as combustion and mining processes and natural sources such as volcanoes release mercury into the atmosphere. Through transport and deposition, some mercury enters the aquatic systems, resulting in an increase in mercury loading in fish. Over the past 20 years, there has been a concerted effort by national and state agencies to reduce anthropogenic mercury emissions from all sources. For example, in December of 2011, the U.S. Environmental Protection Agency (EPA) issued an air toxic rule for the coal-fired power industry that will included mercury. This rule was based on maximum achievable control technology (MACT) requirements.

Although utilities are the largest source of anthropogenic mercury, they are not the only source. In Minnesota, one of these sources is the taconite industry. It has been estimated that these plants emit 250–350 kg of mercury a year into the atmosphere (1). Taconite processing has two potential sources of mercury: mercury released from processing the ore and mercury released from the fuels used when the ore is processed. Unlike coal-fired utilities, the major source of mercury is not the combustion fuel but the processing of the ore into taconite pellets. Even for those facilities that fire coal, it only takes 20–30 lb of coal to process 1 long ton (Lt) of green balls. The concentration of mercury in the unprocessed ore is related to the ore’s geographical location in the Biwabik Iron Formation.

Because of EPA’s intent to issue a small boiler MACT and continued pressure on the Minnesota Pollution Control Agency to regulate mercury emissions from taconite plants. The taconite industry formed a working group to evaluate and help fund research to reduce mercury emissions. This group, the Minnesota Taconite Mercury Control Advisory Committee, along with the Minnesota Department of Natural Resources (MNDNR) and EPA, funded five projects. One of those was an Energy & Environmental Research Center (EERC) project to evaluate the potential of using a slipstream baghouse (BH) with activated carbon injection (ACI) to reduce mercury emissions.

Although the technology would be expected to provide effective mercury control for any of the taconite plants (straight grate or grate kilns), in reality, the technology would only be economical for those plants where, in addition to mercury, particulate control is a potential concern. All Minnesota taconite plants have rod-type venturi scrubbers for particulate control. For plants with a straight grate configuration, the only fuel that can be utilized is natural gas, and therefore, these scrubbers provide enough control so that particulate emissions are not usually a concern. However, for plants using grate kilns and burn coal, there is the potential for increased particulate emissions. Because the United States Steel Corporation, Minnesota Ore Operations – Keetac (Keetac) Plant has a grate kiln and burns coal, it volunteered to host the EERC project. The Keetac Plant has the following configuration:
• Line type: grate kiln
• Number of lines: one
• Production: 700 Lt/hr
• Pellets: acid
• Fuel: natural gas and Powder River Basin (PRB) coal
• Gas flow rate: 550–650 kscfm
• Particulate control: rod-type venturi scrubber (may also add lime to control \( \text{SO}_2 \) emissions)

This report provides the results of the EERC project.

2.0 PROJECT OBJECTIVES

The primary goal of this project was to provide a minimum of 75% reduction in mercury emissions, where mercury reduction is defined by:

\[
\frac{(\text{BH Inlet Hg Conc.} – \text{BH Outlet Hg Conc.})}{\text{BH Inlet Hg Conc.}} \times 100\% \quad \text{[Eq. 1]}
\]

Specific objectives of the project are as follows:

• Determine the effectiveness of a slipstream baghouse to reduce mercury utilizing both a standard activated carbon (DARCO® Hg) and a bromine-treated activated carbon (DARCO® Hg-LH).
• Determine the required feed rate for the two types of carbon to meet the goal of 75% mercury removal.
• Determine the mercury speciation (elemental and oxidized mercury) at both the inlet and outlet of the baghouse.
• Determine the particulate removal across the slipstream baghouse.

3.0 EXPERIMENTAL APPROACH

As stated previously, the overall approach was to install a slipstream baghouse at the outlet of the wet scrubber at the Keetac taconite plant. Activated carbon would then be fed into the inlet piping of the slipstream baghouse. Mercury would be continuously measured at the inlet and outlet of the baghouse, thereby determining the mercury removal. Because this is a true
slipstream of the plant gas flow, the mercury removal obtained during the testing should be directly comparable to that obtained if the plant installed a full-scale baghouse.

3.1 Description of Equipment

All of the equipment used for testing at Keetac was owned by the EERC. However, help was provided by the plant and its contractors to install the slipstream baghouse at Keetac.

3.1.1 EERC Portable Slipstream Baghouse

The EERC slipstream baghouse is a trailer-mounted baghouse that was transported to the test site and connected in slipstream fashion to the existing duct at the outlet of the wet scrubber to allow for testing “real” flue gases under actual operating conditions. The slipstream baghouse chamber was designed to accommodate up to twelve 6-inch bags, with lengths of 12 feet. This equates to 226 ft² of filtration area. To connect the slipstream baghouse to the plant ducting, two separate 10-inch flanges were installed, one at the immediate exit of the wet scrubber and the other directly into the stack.

A variable-speed blower capable of drawing between 450 and 2700 acfm of flue gas (~300°F) through the baghouse was provided as part of the mobile unit. In this way, the filter face velocity could be varied between 2 and 12 ft/min. An 8-inch baghouse bypass line and an orifice meter were utilized to control and to maintain isokinetic flow at the inlet nozzle for all test conditions. In addition, pipe velocities were maintained near 75 ft/sec, preventing dropout of fly ash particles. The baghouse chamber and inlet piping runs were insulated and heat-traced.

Because the slipstream baghouse was located after a wet scrubber, the flue gas at the inlet was saturated at about 132°F. To avoid condensation and the resulting wetting of the bags and fan, an additional drip leg and heating elements were installed. This allowed the inlet flue gas temperature to be maintained at approximately 165°F. The baghouse chambers were heated to maintain a temperature of about 215°F at the baghouse outlet. For a full-scale unit, it would be expected that a portion of the flow (prior to the scrubber) would be routed to the baghouse to maintain a temperature above the water dew point.

Most of the parameters of the slipstream baghouse were controlled using an automated data acquisition system; however, the temperature of the inlet ducting and baghouse were maintained through manual inputs. The unit was designed so that the temperature of the bottom, middle, and top of the baghouse could be independently set. Cleaning of the bags was achieved by the use of medium-pressure pulse-jets that could be computer-controlled or operated manually. All baghouse operational parameters were recorded by the computer and later downloaded to a flash drive. Emptying of the baghouse hopper was achieved through a manual gate valve. Hopper ash was collected in barrels placed under the hopper. For this project, the baghouse hoppers were emptied at the end of each test. Ports were installed at both the inlet and outlet of the baghouse, so mercury measurements could be taken using continuous mercury monitors (CMMs) and carbon traps. A picture of the portable baghouse is shown in Figure 1.
For the Keetac project, the baghouse was operated at a nominal air-to-cloth ratio of 6 ft/min (ft³/min of gas at actual temperatures and pressures per ft² of cloth). The bags that were used for this test were Ryton® PPS (polyphenylene sulfide). These are relatively standard bags used in pulse-jet baghouse installations because of their chemical resistance. The gas flow rate averaged 584 scfm. The actual gas flow was based on the average temperature at the inlet to the baghouse (165°F) and at the outlet (215°F), or 190°F, resulting in an actual gas flow rate of 719 acfm. This would require between six and seven bags to provide an air-to-cloth ratio of 6 ft/min. For these tests, the more conservative approach was taken, and seven bags were installed, resulting in an actual air-to-cloth ratio of 5.45 ft/min. The bag layout is shown in Figure 2. Cleaning of the bags was computer-controlled and based on a set differential pressure. The calculations for air-to-cloth ratio are shown in Appendix A.

### 3.1.2 Activated Carbon Injection System

Activated carbon was injected into the slipstream baghouse using a K-Tron feed system. The K-Tron is a dual-screw feeder that has been used in a number of projects to continuously inject sorbents into flue gas entering the slipstream baghouse. From the feeder, the sorbent was introduced into baghouse inlet piping via an Air-Vac eductor driven by compressed air. The feeder was filled with activated carbon as needed; however, none of the tests required the feeder to be filled more than once a day. The feed rate was set using a controller and was also bucket-calibrated.
Figure 2. Bag layout of the EERC slipstream baghouse resulting in an air-to-cloth ratio of 5.45 ft/min (open circles are the bags).

### 3.1.3 Mercury Measurement Equipment

The CMMs used for these tests were Tekran instruments. A Tekran analyzes mercury using cold-vapor atomic fluorescence (CVAF) techniques and has gold traps that are used to capture and concentrate the mercury. The system consists of three parts. The first is the inertial separation probe (ISP), which is designed to remove particles with minimal contact with the flue gas. The second section is the pretreatment and conversion system. These instruments only measure elemental mercury, and the gold trap can be poisoned by some of the gases that are typically found in both utility and industrial processes. These include HCl, NO₂, and SO₂. Therefore, the pretreatment and conversion system must take out or greatly reduce these gases as well as convert all the mercury to elemental mercury. The Tekran uses dilution and thermal conversion to accomplish these tasks. The final section of the instrument is the CVAF mercury analyzer.

Mercury was also measured utilizing sorbent traps by pulling flue gas through the trap using a pump and then measuring the gas flow with a dry gas meter. The sorbent traps were then analyzed for mercury using an OhioLumex analyzer, which is a cold-vapor atomic adsorption analyzer that uses a thermal attachment to release the mercury captured on the sorbent trap. The mercury is then carried by a gas stream into the analyzer. All of the equipment for conducting sorbent trap mercury measurements was used in compliance with the protocols outlined in EPA Method 30B.

### 3.2 Project Test Plan

Once the slipstream baghouse and CMMs were installed and the temperatures set so that wetting of the bags/fan did not occur, actual testing began (June 17, 2011). The original test plan
is shown in Table 1. However, several problems were encountered that altered the overall test plan as originally proposed. It was planned that most, if not all, of the testing would occur when coal was fired, but the plant had difficulty operating its coal feed unit. As a result, more testing was conducted when natural gas was fired than was planned. In a taconite plant, the mercury emitted by the fuel is only a fraction of the total mercury, so the mercury control technology could still be evaluated. The second problem that occurred was a shutdown of the Minnesota state government on July 1, 2011. As a result, the project ended earlier than intended. Finally, the mercury removal was such that the tests using the higher rates of sorbents, 4 lb/Macf for the standard activated carbon and 2 and 4 lb/Macf for the bromine-treated activated carbon, were not necessary. As will be discussed later, much higher mercury removals than 75% were achieved at these lower ACI rates. The actual tests that were completed are shown in Table 2. Test 4 was intended to be overnight to reestablish the baseline conditions prior to beginning the tests using the treated activated carbon. However, as will be discussed in Section 4, this took substantially longer than was planned.

4.0 RESULTS AND DISCUSSION

4.1 Operation of the Slipstream Baghouse

The slipstream baghouse operated very well during the entire test period. There were no unplanned down periods. As discussed earlier, a major concern was the potential for wetting of the bags as a result of the saturated gas exiting the wet scrubber. However, by adding additional external heaters and extra insulation to prevent cold spots, the inlet temperature of the flue gas was increased such that no wetting took place. Figure 3 shows the baghouse inlet and outlet temperatures were relatively constant over the entire project.

In a full-scale installation of a baghouse to control mercury emissions, external heaters would not be possible. Therefore, a wet scrubber bypass would be required to provide additional heat to prevent water condensation on the bags. If the following assumptions are made:

- Total flue gas flow rate is 600,000 scfm.
- The temperature of the gas entering the wet scrubber is 300°F.

<table>
<thead>
<tr>
<th>Test</th>
<th>Carbon</th>
<th>Carbon Feed Rate, lb/Macf</th>
<th>Test Duration, days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Standard ACI</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Standard ACI</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Standard ACI</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Treated ACI</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Treated ACI</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Treated ACI</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Contingency tests</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

Table 1. Project Test Plan
Table 2. Actual Tests Conducted at Keetac

<table>
<thead>
<tr>
<th>Test</th>
<th>Date/Time Start</th>
<th>Date/Time End</th>
<th>Fuel</th>
<th>Sorbent</th>
<th>Add Rate, g/hr</th>
<th>Add Rate, lb/Macf</th>
<th>Run Time, hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6/17/11 17:30</td>
<td>6/19/11 12:05</td>
<td>Natural gas</td>
<td>Baseline</td>
<td>0</td>
<td>0</td>
<td>42.5</td>
</tr>
<tr>
<td>4</td>
<td>6/24/11 12:36</td>
<td>6/24/11 16:10</td>
<td>Natural gas</td>
<td>Standard</td>
<td>42.50</td>
<td>2.2</td>
<td>3.6</td>
</tr>
<tr>
<td>5</td>
<td>6/24/11 16:10</td>
<td>6/26/11 08:28</td>
<td>Natural gas</td>
<td>Baseline</td>
<td>0</td>
<td>0</td>
<td>40.7</td>
</tr>
<tr>
<td>6</td>
<td>6/26/11 09:05</td>
<td>6/27/11 10:59</td>
<td>Natural gas</td>
<td>Bromine-treated</td>
<td>12.11</td>
<td>0.6</td>
<td>25.9</td>
</tr>
<tr>
<td>7</td>
<td>6/27/11 10:59</td>
<td>6/27/11 18:31</td>
<td>PRB</td>
<td>Bromine-treated</td>
<td>12.11</td>
<td>0.6</td>
<td>7.5</td>
</tr>
<tr>
<td>8</td>
<td>6/27/11 18:31</td>
<td>6/28/11 16:00</td>
<td>Natural gas</td>
<td>Bromine-treated</td>
<td>12.11</td>
<td>0.6</td>
<td>21.3²</td>
</tr>
<tr>
<td>9</td>
<td>6/28/11 08:26</td>
<td>6/28/11 08:39</td>
<td>PRB</td>
<td>Bromine-treated</td>
<td>12.11</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>10</td>
<td>6/28/11 16:00</td>
<td>6/29/11 10:07</td>
<td>Natural gas</td>
<td>Bromine-treated</td>
<td>21.36</td>
<td>1.1</td>
<td>18.1</td>
</tr>
<tr>
<td>13</td>
<td>6/30/11 06:28</td>
<td>7/1/11 07:57</td>
<td>PRB</td>
<td>Bromine-treated</td>
<td>21.36</td>
<td>1.1</td>
<td>25.4</td>
</tr>
</tbody>
</table>

¹ Based on an actual gas flow rate of 720 acf.
² Powder River Basin coal.
³ Does not include the short time the coal was on (Test 9).

Figure 3. Slipstream baghouse operating temperatures.
• The temperature of the gas exiting the wet scrubber is saturated at 135°F.
• All water droplets are small, with little impact on the thermodynamics.
• The temperature of the gas entering the baghouse must be ≥155°F to ensure no wetting of the bags.

The amount of reheat that would be needed would require that 18.2% of the flow bypass the wet scrubber (calculations are shown in Appendix A). If relatively large water droplets exist, the percentage of bypass needed may be greater. Therefore, to minimize the amount of flue gas bypass, it will be important to minimize and reduce the size of any water droplets exiting the wet scrubber. This may necessitate using enhanced mist eliminators and/or adding a drip leg at the outlet of the scrubber.

Another important operational variable for any baghouse is the pressure drop across the bags. This impacts the needed fan capacity, the footprint (air-to-cloth ratio) of the baghouse, the particulate collection efficiency, bag life, and overall economics. This project was not designed to determine the final pressure drop that would be experienced under “normal” operation, as the tests were too short to reach any steady-state condition. Often this can take several months before a reasonable steady state is reached. These tests were designed simply to facilitate the mercury measurement, and therefore, the pulsing of the bags was done on a regular basis and at a reasonably low pressure drop set point. Between each test, the baghouse was pulsed off-line to facilitate cleaning. Figure 4 shows the baghouse pressure drop and gas flow rate over the length of the project. When Keetac was firing natural gas, the bags were pulsed when the pressure drop reached 3 in. W.C. However, a higher set point was used, first 4 and then 6 in. W.C. when a PRB coal was the fuel. It is clear that longer-term testing is needed to determine the ultimate pressure drop that will be experienced. This will obviously determine what air-to-cloth ratio is needed to maintain a reasonable pressure drop.

4.2 Particulate Control

Because the baghouse was installed following a particulate scrubber, it was expected that the inlet dust loading was going to be very low, and this was the case. Also, as expected, the baghouse inlet dust loading was higher when coal was fired. In either case, the dust loading at the outlet of the baghouse was exceedingly low and, therefore, would allow for flexibility in the use of fuel as well as flexibility in overall plant operations without greatly impacting particulate emissions. The results of EPA Method 5 particulate sampling is shown in Table 3. The calculations are shown in Appendix A, and the dust-loading data sheets are provided in Appendix B. As Table 3 shows, the actual particulate removal was somewhat higher when coal was fired. This may be the result of a dust cake forming on the bags. Because the baghouse inlet dust loadings are so low, especially for tests firing natural gas, the particulate removal efficiency is somewhat misleading. Very small changes in the outlet particulate concentration have a major effect on the particulate removal efficiency.
Table 3. Particulate Sampling Across the Slipstream BH at Keetac

<table>
<thead>
<tr>
<th>Date</th>
<th>Fuel</th>
<th>Time</th>
<th>Sample Pt</th>
<th>Sample Time, min</th>
<th>H₂O, %</th>
<th>Isokinetic, %</th>
<th>Dust Loading, grains/scf</th>
<th>Removal, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>06/16/11</td>
<td>Natural gas</td>
<td>14:10</td>
<td>BH in</td>
<td>40</td>
<td>15.6</td>
<td>105.6</td>
<td>0.0026</td>
<td>–</td>
</tr>
<tr>
<td>06/18/11</td>
<td>Natural gas</td>
<td>14:51</td>
<td>BH in</td>
<td>120</td>
<td>16.3</td>
<td>104.1</td>
<td>0.0027</td>
<td>80.8</td>
</tr>
<tr>
<td>06/18/11</td>
<td>Natural gas</td>
<td>14:47</td>
<td>BH out</td>
<td>120</td>
<td>16.2</td>
<td>104.2</td>
<td>0.0006</td>
<td></td>
</tr>
<tr>
<td>06/20/11</td>
<td>Natural gas</td>
<td>13:50</td>
<td>BH in</td>
<td>120</td>
<td>16.1</td>
<td>99.3</td>
<td>0.0022</td>
<td>59.1</td>
</tr>
<tr>
<td>06/20/11</td>
<td>Natural gas</td>
<td>13:41</td>
<td>BH out</td>
<td>120</td>
<td>16.0</td>
<td>100.5</td>
<td>0.0009</td>
<td></td>
</tr>
<tr>
<td>06/30/11</td>
<td>PRB coal</td>
<td>09:43</td>
<td>BH in</td>
<td>180</td>
<td>16.0</td>
<td>98.3</td>
<td>0.0040</td>
<td>90.0</td>
</tr>
<tr>
<td>06/30/11</td>
<td>PRB coal</td>
<td>09:35</td>
<td>BH out</td>
<td>180</td>
<td>16.1</td>
<td>103.3</td>
<td>0.0004</td>
<td></td>
</tr>
<tr>
<td>06/30/11</td>
<td>PRB coal</td>
<td>16:17</td>
<td>BH in</td>
<td>180</td>
<td>17.2</td>
<td>101.1</td>
<td>0.0045</td>
<td>93.3</td>
</tr>
<tr>
<td>06/30/11</td>
<td>PRB coal</td>
<td>16:08</td>
<td>BH out</td>
<td>180</td>
<td>17.2</td>
<td>103.9</td>
<td>0.0003</td>
<td></td>
</tr>
</tbody>
</table>

4.3 Mercury Control

The primary goal of this project was to provide a minimum of 75% reduction in mercury emissions utilizing a slipstream baghouse with both a standard and bromine-treated activated carbon. The mercury reductions achieved (see Equation 1 in Section 2.0) were evaluated by measuring the mercury at the inlet and the outlet of the slipstream baghouse utilizing CMMs and sorbent traps. The CMMs also provided the mercury speciation at each location. An example of the mercury calculations is provided in Appendix A.
4.3.1 Baseline Results

The baseline results are shown in Figure 5, which shows there was no mercury removal across the baghouse without activated carbon addition. In fact, the outlet mercury concentration was somewhat higher than at the inlet. Although new bags were used for this project, most likely there was some carbon attached to the walls of the baghouse from previous tests which resulted in a small amount of offgassing of mercury. Initially the inlet and outlet mercury concentrations were about the same, but then for a period of time, the outlet concentration was greater than the inlet. Near the end of the baseline test, the two concentrations again appeared to be about the same. This again supports the occurrence of mercury offgassing. The phenomenon of mercury offgassing was more prominent, as shown in Figure 6, when later in the project the carbon feed system was turned off prior to changing the type of carbon. The goal was to return to the baseline condition. Offgassing of mercury occurs when activated carbon becomes mercury-saturated and then other components in the flue gas, such as HCl, SO₂ and NO₂, replace the already-collected mercury (2). The sorbent trap samples that were taken during the initial baseline test support the CMM data indicating a higher mercury concentration at the outlet than at the inlet.

As would be expected following a wet scrubber, the mercury at the baghouse inlet was >80% elemental mercury. Under baseline conditions, at the outlet of the baghouse, the mercury speciation did not change.

The CMM mercury measurement results using the standard activated carbon are shown in Figure 7. Two ACI rates, 1.1 and 2.0 lb/Macf, were tested. Unfortunately, because the coal feeder was not operating properly at the plant and because of the state shutdown, we were unable...
Figure 6. Results showing mercury reemission after shutting off the ACI.

Figure 7. Mercury results utilizing standard activated carbon.
to test the standard activated carbon when coal was fired. Therefore, all of the tests were done firing natural gas.

### 4.3.2 Mercury Removal Using Standard Activated Carbon (DARCO Hg)

The CMM mercury measurement results using the standard activated carbon are shown in Figure 7. Two ACI rates, 1.1 and 2.0 lb/Macf, were tested. Unfortunately, because the coal feeder was not operating properly at the plant and because of the state shutdown, we were unable to test the standard activated carbon when coal was fired. Therefore, all of the tests were done with natural gas.

At an ACI rate of 1.1 lb/Macf, the mercury removal averaged 76.1% with a standard deviation of 6.3%. Therefore, the results were somewhat borderline as to whether the goal of 75% mercury removal was met. At an ACI rate of 2.0 lb/Macf, the mercury removal averaged 84.5% with a standard deviation of 8.5%. At this feed rate when natural gas was fired, the mercury removal goal was met. When the ACI rate was increased to 2.2 lb/Macf, mercury removal averaged 91.0%. A summary of the results is shown in Table 4.

Based on the mercury speciation measured by the CMM at the outlet of the baghouse, it appears that the activated carbon not only captured mercury but converted a percentage of the mercury not captured to oxidized mercury. At the outlet of the baghouse, the mercury being emitted was only about 35% elemental mercury. It is interesting to note that when the ACI rate was increased from 1.1 to 2.0 lb/Macf, the concentration of elemental mercury remained approximately the same. Therefore, the decrease in total mercury emissions is due to additional removal of the oxidized mercury.

### 4.3.3 Mercury Removal Using Bromine-Treated Activated Carbon (DARCO LH-Hg)

The CMM mercury measurement results using the bromine-treated activated carbon are shown in Figures 8 and 9. Figures 8 and 9 show the results when the ACI rate was 0.6 lb/Macf and 1.1 lb/Macf, respectively. During the time these tests were being conducted, both natural gas and PRB coal were fired. The results for these tests are summarized in Table 5.

As shown in Figure 8, once the bromine-treated ACI was started and natural gas was fired, there was a slow decrease in the mercury removal. This slow decrease may be related to the previous test when no activated carbon was injected and there was substantial offgassing of mercury (Figure 6). Because of this slow decrease in mercury, the mercury removal averaged only 74.2% with a very high standard deviation of 16.8%. It took almost 12 hours before the

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Feed Rate, lb/Macf</th>
<th>Inlet Hg Conc., µg/Nm³</th>
<th>Outlet Hg Conc., µg/Nm³</th>
<th>Mercury Removal, %</th>
<th>Std. Dev., %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>1.1</td>
<td>6.00</td>
<td>1.42</td>
<td>76.3</td>
<td>6.3</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>2</td>
<td>5.99</td>
<td>0.93</td>
<td>84.5</td>
<td>7.7</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>2.2</td>
<td>5.18</td>
<td>0.47</td>
<td>91.0</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Figure 8. Mercury results utilizing bromine-treated activated carbon at a feed rate of 0.6 lb/Macf.

Figure 9. Mercury results utilizing bromine-treated activated carbon at a feed rate of 1.1 lb/Macf.
Table 5. Mercury Removal Using a Slipstream Baghouse and Bromine-Treated Activated Carbon

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Feed Rate, lb/Macf</th>
<th>Inlet Hg Conc., µg/Nm³</th>
<th>Outlet Hg Conc., µg/Nm³</th>
<th>Mercury Removal, %</th>
<th>Std. Dev., %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas*</td>
<td>0.60</td>
<td>5.25</td>
<td>0.89</td>
<td>82.9</td>
<td>4.9</td>
</tr>
<tr>
<td>PRB Coal</td>
<td>0.60</td>
<td>5.25</td>
<td>0.60</td>
<td>88.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>1.1</td>
<td>4.55</td>
<td>0.55</td>
<td>88.1</td>
<td>4.8</td>
</tr>
<tr>
<td>PRB Coal</td>
<td>1.1</td>
<td>4.38</td>
<td>0.19</td>
<td>95.6</td>
<td>2.0</td>
</tr>
</tbody>
</table>

* Only the last 28 hours of the test was considered.

Mercury removal was >75%. For the remaining 28 hours of testing, the mercury removal was 82.9% with a standard deviation of only 4.9%. During this period, the goal of 75% mercury removal was met at a bromine-treated ACI rate of only 0.6 lb/Macf.

The mercury removal was higher when the PRB coal was fired compared to natural gas. Even at 0.6 lb/Macf of bromine-treated carbon, the mercury removal averaged 88.6% with a standard deviation of only 2.3%. Figure 9 shows the mercury results when the bromine-treated ACI rate was increased to 1.1 lb/Macf. With coal, a very high mercury removal of >95% was achieved. For the entire testing with bromine-treated activated carbon, the concentration of elemental mercury at the baghouse was very low at <0.5 µg/Nm³.

4.3.4 Comparison of the Mercury Removal Between the CMMs and Sorbent Traps

The results of the sorbent trap sampling, along with the CMM results, were provided in Figures 5–9. Table 6 shows a comparison of the mercury removal measured by the two different mercury measurement methods. As shown, there was very good agreement between the two, but the measured removal was somewhat greater when using the CMMs. This may be a result of how each of the methods measures mercury, as will be discussed in Section 6.0.

Table 6. Comparison of Sorbent Trap and CMM Results

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Type Activated Carbon</th>
<th>Injection Rate, lb/Macf</th>
<th>Sorbent Trap Averages</th>
<th>CMM Averages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>BH Inlet Hg Conc., µg/Nm³</td>
<td>BH Outlet Hg Conc., µg/Nm³</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>None</td>
<td>Baseline</td>
<td>6.042</td>
<td>7.038</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Standard</td>
<td>1.1</td>
<td>5.900</td>
<td>1.140</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Standard</td>
<td>1.1</td>
<td>6.896</td>
<td>1.536</td>
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<td>Standard</td>
<td>2.0</td>
<td>7.151</td>
<td>1.577</td>
</tr>
<tr>
<td>PRB Coal</td>
<td>Treated</td>
<td>0.6</td>
<td>5.936</td>
<td>0.808</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Treated</td>
<td>0.6</td>
<td>5.590</td>
<td>1.163</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>Treated</td>
<td>1.1</td>
<td>5.020</td>
<td>0.621</td>
</tr>
<tr>
<td>PRB Coal</td>
<td>Treated</td>
<td>1.1</td>
<td>4.930</td>
<td>0.441</td>
</tr>
<tr>
<td>PRB Coal</td>
<td>Treated</td>
<td>1.1</td>
<td>5.051</td>
<td>0.232</td>
</tr>
</tbody>
</table>
4.4 Preliminary Economic Evaluation

A very preliminary economic evaluation was done. The evaluation included the capital cost of purchasing and installing both a pulse-jet baghouse operating at an air-to-cloth ratio of 6 ft/min and an ACI system. All costs are based on 2011 dollars. Please note, the costs presented in this report were determined based on a model developed for the utility industry, and therefore, the economic information provided should be used for discussion purposes only. Site-specific cost information would need to be developed if a full-scale baghouse were to be installed.

4.4.1 Installation and Operating Costs for a Pulse-Jet Baghouse

The capital costs for purchasing and installing a baghouse at Keetac are shown in Table 7. The total capital cost would be between $10,000,000 and $12,000,000. The first-year operating cost for the baghouse is shown in Table 8. The estimated operating cost for the first year is $2,044,920.

<table>
<thead>
<tr>
<th>Table 7. Capital Cost for a Pulse-Jet Baghouse at Keetac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost Items</td>
</tr>
<tr>
<td>Purchased Equipment</td>
</tr>
<tr>
<td>Basic Fabric Filter</td>
</tr>
<tr>
<td>Insulation</td>
</tr>
<tr>
<td>Cages</td>
</tr>
<tr>
<td>Initial Bags (including spares)</td>
</tr>
<tr>
<td>Auxiliary Equipment (fan, ductwork, motor, starter, dampers, compressor, screw conveyor)</td>
</tr>
<tr>
<td>Instrument and Controls, %</td>
</tr>
<tr>
<td>Taxes, %</td>
</tr>
<tr>
<td>Freight, %</td>
</tr>
<tr>
<td>Total Purchased Equipment (TPE)</td>
</tr>
<tr>
<td>Installation Direct Costs (calculated as a % of TPE)</td>
</tr>
<tr>
<td>Foundations and Supports</td>
</tr>
<tr>
<td>Erection and Handling</td>
</tr>
<tr>
<td>Electrical, %</td>
</tr>
<tr>
<td>Piping, %</td>
</tr>
<tr>
<td>Insulation for Ductwork</td>
</tr>
<tr>
<td>Painting</td>
</tr>
<tr>
<td>Total Installation Direct Costs</td>
</tr>
<tr>
<td>Total Direct Costs for Purchased Equipment and Installation</td>
</tr>
<tr>
<td>Indirect Costs (calculated as a % of TPE)</td>
</tr>
<tr>
<td>Engineering and Supervision</td>
</tr>
<tr>
<td>Contingencies (project and process)</td>
</tr>
<tr>
<td>General Facilities</td>
</tr>
<tr>
<td>Total Indirect Costs</td>
</tr>
<tr>
<td>Total Capital Requirements</td>
</tr>
</tbody>
</table>
### Table 8. Baghouse Annual Operating and Maintenance Costs for Keetac

<table>
<thead>
<tr>
<th>Operating Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Annual Costs</td>
<td></td>
</tr>
<tr>
<td>Operating and Supervision Labor</td>
<td>$125,200</td>
</tr>
<tr>
<td>Replace Bags (labor and materials)</td>
<td>$97,210</td>
</tr>
<tr>
<td>Utilities (fan and cleaning bags)</td>
<td>$498,020</td>
</tr>
<tr>
<td><strong>Total Annual Direct Cost</strong></td>
<td><strong>$720,430</strong></td>
</tr>
<tr>
<td>Indirect Annual Costs</td>
<td></td>
</tr>
<tr>
<td>Taxes, Insurance and Administration</td>
<td>$382,530</td>
</tr>
<tr>
<td>Capital Recovery</td>
<td>$908,960</td>
</tr>
<tr>
<td><strong>Total Annual Indirect Cost</strong></td>
<td><strong>$1,291,490</strong></td>
</tr>
<tr>
<td><strong>Total Annual Cost</strong></td>
<td><strong>$2,011,920</strong></td>
</tr>
</tbody>
</table>

#### 4.4.2 Installation and Operating Costs for an ACI System

A price quote was obtained from Norit Americas Inc. to provide a complete powdered activated carbon (PAC) injection system. The total capital cost (FOB) is $1,220,410. Included in this price are the following items:

- PAC storage silo and all associated equipment
- Volumetric feeder, hopper, and associated equipment for two delivery lines
- Eductors and blowers
- All structural steel and piping
- Control panel and associated software and hardware
- Injection distribution system (injection lances) and flow/distribution modeling field support services. Norit would provide the services of a technician to support installation and start-up of the equipment.

In addition to capital equipment provided by a vendor, certain site preparation and infrastructure would be required by plant personnel. Based on information provided by Norit, an estimate of $125,000 would be required to provide the following:

- Concrete foundations for the silo, feeders, and blowers
- Unloading and assembly of vendor-supplied equipment with support from the Norit Americas on-site technician
- Piping to provide dry compressed air (100 psi) to the feeder and silo
- Drainage and containment as required by the site to collect and dispose of wash-down and any other wastes generated by the PAC system
- Electrical service including single-phase 120-volt and three-phase 480-volt power
- Communication wiring to the plant process and data control system
- General lighting
- Applicable permits

The total capital cost for the PAC system, including both the vendor-supplied process equipment and site preparation work is $1,345,410. The primary operating cost for the ACI system is the cost of the sorbent and the sorbent feed rate. Based on the results for this test, to ensure meeting the mercury reduction goal of 75%, the feed rate for standard activated carbon would be 2 lb/Macf and 1.1 lb/Macf if bromine-treated activated carbon were assumed. Table 9 presents the estimated sorbent costs at Keetac. These results also assume that the total gas flow rate for the plant is 600,000 scfm, the baghouse temperature at the ACI location is 155°F, and the plant has an operating factor of 0.90 (7884 hr/yr). Including maintenance costs and utilities for the ACI system, the total yearly operating cost would be $861,700 if standard activated carbon is used and $723,750 if the bromine-treated carbon is used. Again, operating cost of the ACI system are going to be very sensitive to sorbent costs.

5.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

Prior to beginning the project, a quality assurance plan was submitted and approved by MNDNR and EPA. This document was used as a guideline for the project. All project data from the baghouse operation, CMMs, and other sampling was either downloaded from the computers to a flash drive or recorded onto data sheets. The data sheets were properly labeled, and chain-of-custody procedures were followed for all samples and data sheets.

5.1 K-Tron Activated Carbon Feeder

Prior to beginning the project, the EERC K-Tron feeder was calibrated. The results are shown in Figure 10. As can be seen, the calibration curve is highly linear and correlates directly with the rpm set point. In addition to the development of the initial calibration curve, several

| Table 9. Estimated Sorbent Costs at Keetac with a Pulse-Jet Baghouse |
|-----------------------|-----------------|-----------------|
| Item                  | Standard Activated Carbon | Treated Activated Carbon |
| ACI Rate              | 2.0 lb/Macf      | 1.1 lb/Macf      |
| Yearly Consumption    | 788,400 lb       | 394,200 lb       |
| Cost per lb Delivered | $0.85            | $1.35            |
| Yearly Sorbent Costs  | $670,140         | $532,170         |
times during the project, the feeder was bucket-calibrated to ensure the feed rate had remained constant, which it had.

5.2 Particulate Samples (EPA Method 5)

All particulate sampling followed the procedures outlined in EPA Method 5. The only exception was that the piping was not traversed as it was a slipstream and the piping was only 10 in. in diameter so stratification was not a concern. All sampling boxes were calibrated prior to arriving on-site, and a meter constant ($C_m$) was calculated. The primary sampling QC criteria are that the sampling be conducted in an isokinetic manner so particles captured on the filter are representative of those in the gas stream. The requirement is that all samples be isokinetic within 10%. As can be seen in Table 10, all samples met this criteria.

The filters were preweighed to a constant temperature and stored in labeled petri dishes. Once the dust loading was completed as prescribed in EPA Method 5, the filters were carefully removed from the filter holders, and any remaining dust was brushed onto the filters. The filters and any dust brushed from the filter holder were once again placed in labeled petri dishes and desiccated prior to weighing. The filters were weighed on-site using a calibrated five-place balance.
Table 10. Particulate Sampling Isokinetic Determination

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Date</th>
<th>Fuel</th>
<th>Isokinetic, %</th>
</tr>
</thead>
<tbody>
<tr>
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<td>06/16/11</td>
<td>Natural gas</td>
<td>105.6</td>
</tr>
<tr>
<td>2</td>
<td>06/18/11</td>
<td>Natural gas</td>
<td>104.1</td>
</tr>
<tr>
<td>3</td>
<td>06/18/11</td>
<td>Natural gas</td>
<td>104.2</td>
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<tr>
<td>4</td>
<td>06/20/11</td>
<td>Natural gas</td>
<td>99.3</td>
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<td>5</td>
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<td>Natural gas</td>
<td>100.5</td>
</tr>
<tr>
<td>6</td>
<td>06/30/11</td>
<td>PRB coal</td>
<td>98.3</td>
</tr>
<tr>
<td>7</td>
<td>06/30/11</td>
<td>PRB coal</td>
<td>103.3</td>
</tr>
<tr>
<td>8</td>
<td>06/30/11</td>
<td>PRB coal</td>
<td>101.1</td>
</tr>
<tr>
<td>9</td>
<td>06/30/11</td>
<td>PRB coal</td>
<td>103.9</td>
</tr>
</tbody>
</table>

5.3 Mercury Measurements

Two different mercury measurements were made during the project. The primary measurements were provided by CMMs installed at the inlet and outlet of the baghouse. The second method used sorbent traps. These were taken for QA/QC purposes and to compare to the CMM results.

5.3.1 Calibration of the CMMs

The requirements for calibration, spanning, and zeroing of the CMMs are listed in Table 11. The leak check was <1% following installation of the two CMMs. The multipoint linearity checks are shown in Table 12. With the exception of the second check for the CMM located at the baghouse outlet, which was a bit high, they all were within 10% of the expected value. The daily zero and span results are shown in Tables 13 and 14.

In all cases, the span was within the required 90%–100% range, and the zero values were at or near zero. The internal calibration results are shown in Tables 15 and 16. The instrument was calibrated both at the probe tip and directly into the analyzer. Again, as was the case with the span data, all recoveries were within the 10% range.

5.3.2 QA/QC Requirements for the Sorbent Traps

An additional QA/QC for the CMMs was to compare the results to those obtained using sorbent traps. Sorbent traps are considered to be a reference method (EPA Method 30B). At least one paired sorbent trap sample was taken at the baghouse inlet and outlet for each test. The results were then compared to the CMM data taken over the same time period.

Table 11. CMM Calibration Requirements

<table>
<thead>
<tr>
<th>Test</th>
<th>Criteria</th>
<th>How Often</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leak Check</td>
<td>&gt;2% of total sample flow</td>
<td>Immediately after installation</td>
</tr>
<tr>
<td>Internal Zero and Span</td>
<td>Automatically adjusted by the instrument</td>
<td>Daily</td>
</tr>
<tr>
<td>Local and Probe Tip Calibration</td>
<td>90%–110% of anticipated value</td>
<td>Every other day or more as needed</td>
</tr>
<tr>
<td>Multipoint Span</td>
<td>Automatically adjusted by the instrument</td>
<td>Once a week</td>
</tr>
</tbody>
</table>
To measure the mercury adsorbed by the sorbent traps, an OhioLumex instrument was used. This instrument uses cold-vapor atomic absorption to measure the mercury that is desorbed from the traps using thermal techniques. This instrument is currently considered to be the standard for these types of measurements. Before beginning analysis of the samples, a five-point linear calibration curve is generated. This curve must have an R² of >99% before it is acceptable. Because the samples were taken back to the EERC for analysis, the samples were analyzed over two separate time periods. Therefore, two calibration curves were generated. Once a calibration curve has been generated, separate National Institute of Standards and Technology (NIST) traceable QC samples are used to check the calibration curve. The requirement is that the recovery of the QC standards be ±10%, or a new curve must be generated.

The two calibration curves for this project are shown in Table 17. As shown, both calibration curves were acceptable.

In addition to the development of the calibration curve, for every ten samples and at least once a day, check standards must be analyzed. These also have to have recoveries within 10% of the known value or a new calibration curve must be developed. Table 18 presents the check standards that were completed for this project. All QA/QC check standards were within the acceptable range.

### 5.3.3 Comparison of CMMs to Sorbent Trap Mercury Measurements

For each test, at least one paired set of sorbent trap samples was taken at the baghouse inlet and outlet. These results were then compared to the results obtained using the CMMs. The
Table 13. Baghouse Inlet CMM Zero and Span Data

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Side</th>
<th>Probe Zero, µg/Nm³</th>
<th>Probe Tip, µg/Nm³</th>
<th>Date/Time</th>
<th>Side</th>
<th>Probe Zero, µg/Nm³</th>
<th>Probe Tip, µg/Nm³</th>
</tr>
</thead>
<tbody>
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<td>0.000</td>
<td></td>
<td>6/23/11 1:12</td>
<td>A</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.065</td>
<td></td>
<td></td>
<td>B</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>6/17/11 7:27</td>
<td>A</td>
<td>0.000</td>
<td>98.06</td>
<td>6/23/11 1:32</td>
<td>A</td>
<td>0.000</td>
<td>100.17</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.000</td>
<td>98.11</td>
<td></td>
<td>B</td>
<td>0.075</td>
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<tr>
<td>6/17/11 18:07</td>
<td>A</td>
<td>0.571</td>
<td>102.39</td>
<td>6/24/11 1:12</td>
<td>A</td>
<td>0.000</td>
<td>99.87</td>
</tr>
<tr>
<td></td>
<td>B</td>
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<td>100.81</td>
<td></td>
<td>B</td>
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<td>99.19</td>
</tr>
<tr>
<td>6/18/11 1:10</td>
<td>A</td>
<td>0.234</td>
<td>97.40</td>
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<td>A</td>
<td>0.000</td>
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</tr>
<tr>
<td></td>
<td>B</td>
<td>0.097</td>
<td>97.40</td>
<td></td>
<td>A</td>
<td>0.000</td>
<td>97.96</td>
</tr>
<tr>
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<td>98.63</td>
<td>6/26/11 1:12</td>
<td>A</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.000</td>
<td>98.63</td>
<td></td>
<td>B</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
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<td>6/28/11 1:15</td>
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<tr>
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</tr>
<tr>
<td></td>
<td>B</td>
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<tr>
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<td>A</td>
<td>0.061</td>
<td>99.17</td>
<td>6/30/11 1:12</td>
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<td>0.000</td>
<td></td>
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<tr>
<td></td>
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<tr>
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<td>A</td>
<td>102.60</td>
<td>7/1/11 1:12</td>
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<td>7/1/11 1:32</td>
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<td>B</td>
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</tr>
</tbody>
</table>

Comparison was shown previously in Section 4.3, Figures 5–9. This section discusses the QA/QC associated with those comparisons.
### Table 14. Baghouse Outlet CMM Zero and Span Data

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Side</th>
<th>Probe Zero, µg/Nm³</th>
<th>Probe Tip, µg/Nm³</th>
<th>Date/Time</th>
<th>Side</th>
<th>Probe Zero, µg/Nm³</th>
<th>Probe Tip, µg/Nm³</th>
</tr>
</thead>
<tbody>
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</tr>
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</tr>
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<td>A</td>
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<td>B</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
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<td>0.000</td>
<td>100.03</td>
<td>6/30/2011</td>
<td>A</td>
<td>0.000</td>
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</tr>
<tr>
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<td>B</td>
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<td>103.33</td>
<td>6/30/2011</td>
<td>A</td>
<td>0.000</td>
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</tbody>
</table>
Table 15. Baghouse Inlet CMM Calibration Data

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Recovery, %</th>
<th>Date/Time</th>
<th>Recovery, %</th>
<th>Date/Time</th>
<th>Recovery, %</th>
<th>Date/Time</th>
<th>Recovery, %</th>
</tr>
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<tbody>
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<td>6/19/11 3:00</td>
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<td>6/27/11 3:00</td>
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</tr>
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<td>100.72</td>
<td>6/19/11 3:05</td>
<td>100.72</td>
<td>6/27/11 3:05</td>
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<td>6/27/11 3:37</td>
<td>101.02</td>
</tr>
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<td>6/19/11 3:12</td>
<td>100.01</td>
<td>6/27/11 3:15</td>
<td>102.30</td>
<td>6/27/11 3:45</td>
<td>101.81</td>
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<td>6/25/11 3:02</td>
<td>99.34</td>
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<td>104.17</td>
</tr>
<tr>
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<td>6/25/11 3:05</td>
<td>100.34</td>
<td>7/1/11 3:02</td>
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<td>102.41</td>
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<td>6/25/11 3:10</td>
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<td>102.39</td>
<td>7/1/11 3:40</td>
<td>102.94</td>
</tr>
</tbody>
</table>

To be a valid paired sample, the paired sorbent traps must have a relative standard difference (RSD) of ≤ 20%, where the RSD is defined by:

\[ RSD = \frac{|C_a - C_b|}{C_b + C_b} \times 100\% \quad \text{[Eq. 2]} \]

where \( C_a \) and \( C_b \) are the mercury concentration measured by the paired sorbent traps.

As shown in Table 19, all the sorbent trap paired sample RSD values were substantially less than the requirements of <20% outlined in EPA Method 30B. In addition, to be a valid sample, the amount of mercury captured in the back half (breakthrough) cannot be >5% of the total mercury captured by the sorbent trap. With the exception of one sample that was 3.6% in the second half, all samples had a breakthrough that was <1%.

The comparison between the sorbent trap samples and the CMMs is also provided in Table 19. With the exception of the last three baghouse outlet samples, a comparison between the mercury concentrations measured using the sorbent traps and those measured using the CMMs had an RSD of <15%. The last three mercury concentrations measured at the baghouse outlet were very low, and very small differences in concentrations result in higher RSDs, but in terms of mercury removal across the baghouse, these differences have little meaning.
### Table 16. Baghouse Outlet CMM Calibration Data

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Recovery, %</th>
<th>Date/Time</th>
<th>Recovery, %</th>
<th>Date/Time</th>
<th>Recovery, %</th>
<th>Date/Time</th>
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</tr>
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<tbody>
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<td>6/17/11 10:22</td>
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<td>6/25/11 3:27</td>
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<td>6/18/11 18:25</td>
<td>100.38</td>
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<td>101.96</td>
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<td>7/1/11 3:27</td>
<td>102.50</td>
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### Table 17. OhioLumex Calibration Results

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<th>Known Mass, ng</th>
<th>Calculated Mass, ng</th>
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| R²             | 0.9993              | R²             | 1.00                |
Table 18. QC Check Standard Results for the OhioLumex

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</table>

Table 19. QA/QC Comparison of CMMs to Sorbent Traps

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Location</th>
<th>Ca, µg/Nm³</th>
<th>Cb, µg/Nm³</th>
<th>Paired Trap RSD, %</th>
<th>Sorbent Trap Average, µg/Nm³</th>
<th>CMM Average, µg/Nm³</th>
<th>RSD, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/18/11</td>
<td>BH inlet</td>
<td>6.033</td>
<td>6.050</td>
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<td>6.042</td>
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</tr>
<tr>
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<td>BH outlet</td>
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<td>7.036</td>
<td>0.04</td>
<td>7.038</td>
<td>5.669</td>
<td>10.77</td>
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<td>BH inlet</td>
<td>5.784</td>
<td>6.017</td>
<td>1.98</td>
<td>5.900</td>
<td>5.341</td>
<td>4.98</td>
</tr>
<tr>
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<td>BH outlet</td>
<td>1.166</td>
<td>1.115</td>
<td>2.20</td>
<td>1.140</td>
<td>0.908</td>
<td>11.36</td>
</tr>
<tr>
<td>6/21/11</td>
<td>BH inlet</td>
<td>6.946</td>
<td>6.846</td>
<td>0.73</td>
<td>6.896</td>
<td>6.306</td>
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</tr>
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<td>BH outlet</td>
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<td>1.529</td>
<td>0.51</td>
<td>1.536</td>
<td>1.185</td>
<td>12.90</td>
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<td>BH outlet</td>
<td>1.568</td>
<td>1.587</td>
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<td>1.577</td>
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<td>BH inlet</td>
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<td>1.45</td>
<td>5.936</td>
<td>5.300</td>
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<td>6/27/11</td>
<td>BH outlet</td>
<td>0.814</td>
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<td>0.75</td>
<td>0.808</td>
<td>0.629</td>
<td>12.46</td>
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<td>BH inlet</td>
<td>5.598</td>
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<td>5.590</td>
<td>4.701</td>
<td>8.64</td>
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<td>BH outlet</td>
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<td>BH outlet</td>
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<td>0.25</td>
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<td>0.51</td>
<td>0.232</td>
<td>0.093</td>
<td>43.04</td>
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</tbody>
</table>
Although small, there appears to be a bias in the measurements. The sorbent trap mercury measurements were in all cases greater than the CMM results. This almost certainly is a result of differences in how the two measurement methods deal with particulate matter. The sorbent trap samples have a quartz wool plug prior to the mercury sorbent. When the analysis is done, the quartz wool is analyzed with the first sorbent section. Therefore, any mercury captured by the particulate matter on the quartz plug is considered to be part of the overall measured concentration. However, with a CMM, the ISP helps ensure only gas-phase mercury is measured. The fact that the bias is greater at the baghouse inlet where the particulate concentration is the greatest supports this. Based on previous testing done at taconite plants, it has been found that the high iron content of the dust results in mercury capture (3).

The complete sorbent trap data along with the CMM comparison information is presented in Appendix C.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the testing conducted using a slipstream baghouse at Keetac, the following conclusions can be made:

- Mercury removal of >75% can be achieved at Keetac with either standard or bromine-treated activated carbon.
- To ensure >75% removal when natural gas is fired, 2.0 lb/Macf is needed when using standard activated carbon.
- To ensure >75% removal when natural gas is fired, 1.1 lb/Macf is needed when using bromine-treated activated carbon.
- To ensure >75% removal when a PRB coal is fired, only 0.6 lb/Macf of bromine-treated activated carbon is needed.
- Very low particulate emissions can be achieved.
- Because of the relatively high cost of installing a fabric filter, the most economical installation would be for those taconite facilities that require fuel flexibility and/or where particulate emissions are a concern.
- If a baghouse is to be installed at Keetac, 18%–20% flue would need to bypass the wet particulate scrubber to prevent wetting of the bags.
- As expected, the mercury at the outlet of the scrubber is ~80% elemental mercury.
- It appears that if the ACI is turned off, there is the potential of high mercury emissions as a result of reemission.
• Overall, the slipstream baghouse and CMMs operated well during the test period.

If this is to be a viable technology, the following recommendations are made for future testing.

• Longer-term testing is needed to determine the resultant steady-state pressure drop across the baghouse as a function of air-to-cloth ratio.

• Longer-term tests are also needed to ensure that required mercury control will be maintained.

• It appeared that the bromine-treated activated carbon worked better when firing coal compared to natural gas. The same may be true using standard activated carbon. Therefore, additional coal tests are needed.

• The economic evaluation presented in this report is based on the utility requirements and may or may not be the same for a taconite plant. Therefore, more specific economic data are needed.

• There may be a need to evaluate or update the existing wet scrubber mist eliminators.

7.0 REFERENCES


APPENDIX A

SAMPLE CALCULATIONS
SAMPLE CALCULATIONS

1.0 AIR-TO-CLOTH RATIO

Gas flow rate = 584 scfm
Pressure = 1 atm.
Temperature at baghouse inlet = 165°F
Temperature at baghouse outlet = 215°F
Average temperature = (165+215)/2 = 190°F
Standard temperature = 68°F
Actual gas flow rate = (584)*(190+460)/(68+460) = 719 acfm
Bag diameter = 6 in
Bag length = 12 ft
No. of bags = 7
Total bag surface area = \( \pi \times (6/12) \times 12 \times 7 = 131.95 \) ft²
Air-to-cloth ratio = 719/131.95 = 5.45 ft/min

2.0 ACTIVATED CARBON FEED RATE IN lb/Macf

Activated carbon feed rate = 42.5 g/hr
Actual gas flow rate = 719 acfm
Activated carbon feed rate = 42.5/(454*719*60)*10⁶ = 2.17 lb/Macf

3.0 FLUE GAS BYPASS CALCULATION FOR REHEAT

Saturated gas temperature = 135°F = 57.22°C
Gas flow rate = 600,000 scfm (68°F) = 15,830.4 scm/min (0°C) = 19,148.4 m³/min (actual)
Desired gas temperature to prevent bag wetting = 155°F = 68.33°C
Temperature of flue gas prior to wet scrubber = 300°F = 148.89°C
Flue gas molecular weight = 30.4 kg-moles/m³
Molecular weight of water = 18.01 kg-moles/m³
Ideal gas law = 1kg-mole/22.4 m³ at standard pressure (1 atm.) and temp. (0°C)
Pressure = 1 atm. = 1*101.325 = 101.325 kPa
From steam table the moisture vapor pressure at 135°F = 17.49 kPa
Gas vapor pressure = 101.325-17.49 = 83.83 kPa
Gas flow rate (mass basis) = 15,830.4*(30.4/22.4)*(83.83/100) = 18,010.1 kg/min
Moisture flow rate (mass basis) = 15,830.4*(18.01/22.4)* (17.50/100) = 2227.4 kg/min
Flue gas heat capacity = 1.01 kJ/kg/°K
Moisture heat capacity = 1.87 kJ/kg/°K
Energy needed to heat gas to desired temp. = 18,010.1*1.01*(68.33-57.22) = 202,093.1 kJ/min
Energy needed to heat moisture = 2227.4*1.87*(68.33-57.22) = 46,275.8 kJ/min
High temperature dilution gas needed = (202,093.1+46,275.8)/1.01/(148.89-68.33) = 3052.5 kg/min
Dilution gas volume flow rate = 3052.5*(22.4/30.4)*(148.89+273)/273=3475.9 m³/min (actual)
% bypass needed of high-temperature gas = 3475.9/19148.4 *100 = 18.2%

4.0 PARTICULATE-SAMPLING CALCULATIONS

4.1 Volume of Gas Sample

\[ V_m (\text{std}) = V_m (\text{measured by dry gas meter, connected to standard conditions, dscf}) \]

\[ V_m (\text{std}) (\text{dscf}) = \frac{K_1 \times V_m \times C_m \times P_m}{T_m + 460} \]

\[ V_m (\text{std}) = \frac{17.64 \times 81.588 \times 1.010 \times 28.15}{70 + 460} = 77.207 \text{ dscf} \]

Where:
- \( K_1 = 17.64 \text{ R/in. Hg} \)
- \( V_m = \) Volume of gas sample as measured by dry gas meter corrected for Cm = meter calibration coefficient (dcf)
- \( P_m = \) Meter pressure (in. Hg)
- \( T_m = \) Meter temperature (°F)

4.2 Volume of Water Vapor

\[ V_w (\text{std}) = V_w (\text{water vapor in the gas sample, corrected to standard conditions, scf}) \]

\[ V_w (\text{std}) (\text{scf}) = K_2 \times H_2O(g) \]

\[ V_w (\text{std}) = 0.04715 \times 314.7 = 14.813 \text{ scf} \]

Where:
- \( K_2 = 0.04715 \text{ ft}^3/\text{g} \)
- \( H_2O \text{ (g)} = \) Mass of liquid collected in impingers and silica gel (g)

4.3 Water Vapor in the Gas Stream

\[ B_{ws} = \text{Water vapor in the gas stream, proportion by volume} \]

\[ B_{ws} = \frac{V_w(\text{std})}{V_m(\text{std}) + V_w(\text{std})} \]

\[ B_{ws} = \frac{14.813}{77.207 + 14.813} = 0.1613 \]

4.4 Molecular Weight

\[ M_w = 30 \times (1-B_{ws}) + 18 \times B_{ws} = 30 \times (1 - 0.1613) + 0.1613 = 28.06 \]
4.5 Average Stack Gas Velocity

\[ V_s = \text{Average stack gas velocity, ft/sec} \]

\[ V_s (\text{ft/sec}) = K_3 \times C_p \times (\Delta p)^{1/2} (\text{avg}) \times \left[ \frac{T_s + 460}{P_s \times M_s} \right]^{1/2} \]

\[ V_s = 85.49 \times 0.84 \times 0.40 \times \left[ \frac{165 + 460}{28.09 \times 28.06} \right]^{1/2} = 25.58 \text{ ft/sec} \]

Where:

\[ K_3 = 85.49 \text{ ft/sec} \times \left[ \frac{lb}{lb \text{- mole} \times in. Hg} \times 
\frac{R \times in. H_2O}{\text{sec}} \right]^{1/2} \]

\[ C_p = \text{Pitot tube coefficient, dimensionless} \]

\[ \Delta p = \text{Velocity head of stack gas (in. Hg)} \]

\[ (\Delta p)^{1/2} (\text{avg}) = \text{Average of the square root of } \Delta p \text{ values} \]

\[ T_s = \text{Stack gas temperature (°F)} \]

\[ P_s = \text{Stack pressure (in. Hg)} \]

4.6 Isokinetic Sampling Rate

\[ I = \% \text{ of isokinetic sampling, } \% \]

\[ I (\%) = \frac{K_4 \times (T_s + 460) \times Vm(\text{std}) \times 144}{P_s \times V_s \times An \times \theta \times (1 - BWS)} \]

\[ I = \frac{0.09450 \times (165 + 460) \times 77.207 \times 144}{28.07 \times 25.58 \times 0.06158 \times 180 \times (1 - 0.1613)} = 98.3\% \]

Where:

\[ K_4 = \frac{0.09450 \% (\text{in.Hg})(\text{min})}{R \times \text{sec}} \]

\[ An = \text{Cross-sectional area of nozzle (in.}^2\text{)} \]

\[ \theta = \text{Total sampling time (min)} \]

4.7 Dust Loading

Filter tare weight = 0.23651 g
Final filter weight = 0.25662 g
Net weight on filter = 0.25662 - 0.23651 = 0.02011 g
Petri dish tare weight = 0.74168 g
Petri dish and probe dust = 0.74182 g
Net weight on petri dish = 0.74182 - 0.74168 = 0.00014 g
Total dust collected = 0.02011 + 0.00014 = 0.02025 g = 0.02025 * 15.43 = 0.31246 grains
Gas volume sampled = 77.207 dscf
Dust loading = 0.31246 / 77.027 = 0.0041 grains/dscf

5.0 MERCURY SAMPLING

5.1 Mercury Concentration in Flue Gas Based on Sorbent Traps (Sample 7A)

Volume of gas sampled = 50.277 L (dry)
Moisture in flue gas = 16.2% (from dust loading sample)
Volume of moisture sampled = 50.277 * (1 - 0.162) = 9.719 L
Total gas sampled = 50.277 + 9.719 = 59.996 L (wet)
Tm = 65°F
Pb (barometric) = 28.35 in Hg
Elevation = 20 ft
Cm N (normal conditions) = 68°F and 29.92 in Hg
Vt (corrected) = 59.996 * 1.015 * (29.92 / [28.35 - 20/1000]) * 528 / (65 + 460) = 57.990 NL (wet)

Section 1 Hg = 288 ng
Section 2 Hg = 0 ng
Back plug = 0 ng
Total Hg collected = 288 ng
Breakthrough = 0/288 * 100 = 0%
Total Hg conc. in gas stream = 288 / 57.990 = 4.966 ng/NL = 4.966 µg/Nm³

5.2 Paired Sorbent Trap Calculations (7A and 7B)

Hg concentration from Trap 7A = 4.966 µg/Nm³
Hg concentration from Trap 7B = 5.074 µg/Nm³
Relative standard difference = ABS[(5.074 - 4.966) / (5.074 + 4.966) * 100 = 1.07%]

5.3 Mercury Removal Across Slipstream Baghouse (Sample 7 sorbent trap and CMM average over the time the sorbent trap sample was taken)

Sorbent trap avg. Hg at the BH inlet = (4.966 + 5.074) / 2 = 5.020 µg/Nm³
Sorbent trap avg. Hg at the BH outlet = (0.619 + 0.623) / 2 = 0.621 µg/Nm³
CMM avg. Hg at the BH inlet = 4.52 µg/Nm³
CMM avg. Hg at the BH outlet = 0.451 µg/Nm³
Hg removal based on sorbent traps = (5.020 - 0.621) / 5.020 * 100 = 87.6%
Hg removal based on CMMs = (4.52 - 0.451) / 4.52 * 100 = 90.0%
APPENDIX B

DUST-LOADING DATA SHEETS
<table>
<thead>
<tr>
<th>OPERATORS</th>
<th>RS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>KEETAC-BHIN-M5-1</td>
</tr>
<tr>
<td>RUN #</td>
<td>Vvstd 0.697 SCF</td>
</tr>
<tr>
<td>DATE</td>
<td>Vmstd 6.297 SCF</td>
</tr>
<tr>
<td>TIME</td>
<td>Vtstd 6.994 SCF</td>
</tr>
<tr>
<td>FUND #</td>
<td>% H2O 10.0 %</td>
</tr>
<tr>
<td></td>
<td>% Isokin 38.3 %</td>
</tr>
<tr>
<td></td>
<td>DUST LOADING DATA SHEET</td>
</tr>
<tr>
<td>Sample Pt.</td>
<td>DWN LEG BH IN</td>
</tr>
<tr>
<td>Traverse Pt.</td>
<td>3' IN</td>
</tr>
<tr>
<td>Pb (Barometric Press.)</td>
<td>28.97 in Hg</td>
</tr>
<tr>
<td>Ps = 28.87 in Hg Abs.</td>
<td>Ts = 608 °R</td>
</tr>
<tr>
<td>Elevation correction</td>
<td>20 ft (1 in Hg / 1000 ft)</td>
</tr>
<tr>
<td>Ps (Stack Pressure)</td>
<td>-1.1 in H2O</td>
</tr>
<tr>
<td>VS (Stack Velocity)</td>
<td>1706 ft/min</td>
</tr>
<tr>
<td>Dn (Nozzle Diam.)</td>
<td>0.280 in</td>
</tr>
<tr>
<td>QN (Nozzle Flow Rate)</td>
<td>0.7296 ACFM</td>
</tr>
<tr>
<td>Est. ∆P (Pitot)</td>
<td>0.21 in H2O</td>
</tr>
<tr>
<td>QM (Meter Flow Rate)</td>
<td>0.5227 ACFM</td>
</tr>
<tr>
<td>Cm</td>
<td>1.010</td>
</tr>
<tr>
<td>∆H (orifice)</td>
<td>0.70 in H2O</td>
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<tr>
<td>Cp</td>
<td>0.84 (Type S=.84, Std=.99)</td>
</tr>
<tr>
<td>Est. Ts (Stack Temp)</td>
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<tr>
<td>Est. % H2O</td>
<td>15</td>
</tr>
<tr>
<td>∆H@</td>
<td>1.46</td>
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<tr>
<td>CO ppm</td>
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<tr>
<td>Tm (Est)</td>
<td>60 °F</td>
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<td>NO ppm</td>
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<tr>
<td>∆H (Est)</td>
<td>0.80 in Hg</td>
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<tr>
<td>NO2 ppm</td>
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<tr>
<td>SO2 ppm</td>
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</tr>
<tr>
<td>CO2 %</td>
<td></td>
</tr>
<tr>
<td>coal CO2=18.6*(21-02%)/21</td>
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Note: Standard Temperature and Pressure are 68 °F and 29.92 in. Hg

<table>
<thead>
<tr>
<th>Time (min.)</th>
<th>Temp stack</th>
<th>Gas Meter (R3)</th>
<th>Tm Inlet</th>
<th>Tm Outlet</th>
<th>∆H</th>
<th>∆P Pilot</th>
<th>Pump Vac in Hg</th>
<th>Temp Probe</th>
<th>Temp Box</th>
<th>Temp Impinger</th>
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<tr>
<td>0</td>
<td>140</td>
<td>65.091</td>
<td>50</td>
<td>50</td>
<td>0.80</td>
<td>0.21</td>
<td>3.0</td>
<td>250</td>
<td>OK</td>
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<tr>
<td>30</td>
<td>140</td>
<td>71.331</td>
<td>54</td>
<td>54</td>
<td>0.80</td>
<td>0.21</td>
<td>5.0</td>
<td>250</td>
<td>OK</td>
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<td>30</td>
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<td>0.50</td>
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<tr>
<td>Averages:</td>
<td>140</td>
<td>6.240</td>
<td>52</td>
<td></td>
<td>0.70</td>
<td>0.21</td>
<td>4.0</td>
<td>250</td>
<td>#DIV/0!</td>
<td>#DIV/0!</td>
</tr>
<tr>
<td>Comment</td>
<td></td>
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</tr>
<tr>
<td>Sample Pt.</td>
<td>DWN LEG BH IN</td>
<td>Date</td>
<td>6/15/2011</td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Train Type</td>
<td>Fund #</td>
<td>15726</td>
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</tr>
<tr>
<td></td>
<td>Cost Center #</td>
<td></td>
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<table>
<thead>
<tr>
<th>STOPPER TYPE</th>
<th>TYPE OF SOLUTION</th>
<th>INITIAL WT. (g)</th>
<th>FINAL WT. (g)</th>
<th>NET WT. (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight</td>
<td>DI</td>
<td>645.3</td>
<td>655.3</td>
<td>10.0</td>
</tr>
<tr>
<td>Straight</td>
<td>DI</td>
<td>614.3</td>
<td>616.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Impinger</td>
<td>DRY</td>
<td>637.7</td>
<td>638.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Straight</td>
<td>SIL GEL</td>
<td>958.7</td>
<td>960.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Straight</td>
<td></td>
<td>616.2</td>
<td>616.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Straight</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impinger</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FILTER</td>
<td>wet</td>
<td>wet</td>
<td>#VALUE!</td>
<td>14.8</td>
</tr>
<tr>
<td>Additional Dust</td>
<td></td>
<td></td>
<td>0.00000</td>
<td>0.00000</td>
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</table>

**TOTAL DUST (g)** #VALUE!

<table>
<thead>
<tr>
<th></th>
<th>Vwstd</th>
<th>0.697 SCF</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vmstd</td>
<td>6.297 SCF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vtstd</td>
<td>6.994 SCF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>% H2O</td>
<td>10.0</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>% Isokinetic</td>
<td>38.3</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>DCL</td>
<td>#VALUE!</td>
<td>grains/SCF</td>
</tr>
<tr>
<td></td>
<td>DCL - Metric</td>
<td>#VALUE!</td>
<td>grams/SCM = grains/SCF*2.288</td>
</tr>
</tbody>
</table>

**DUST LOADING CALCULATIONS (Concentration Basis)**

<table>
<thead>
<tr>
<th></th>
<th>Inlet DCL</th>
<th>grains/SCF</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>% Efficiency</td>
<td>(Inlet DCL - Outlet DCL) * 100</td>
<td>#VALUE!</td>
<td>%</td>
</tr>
<tr>
<td>Inlet DCL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pipe Area</td>
<td>ft²</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ACFM = VS * Pipe Area (ft²)</td>
<td>0.0000 ACFM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SCFM = ACFM * PS/TS * 17.64</td>
<td>0.0 SCFM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>lbs/hour = grains/scf * 0.000143 * SCFM * 60</td>
<td>#VALUE!</td>
<td>lbs/hour</td>
</tr>
</tbody>
</table>
### Equations

**Page 1**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS (Stack Pressure)</td>
<td>(PB + (PS \text{ in } H_2O / 13.6) - \text{ elevation} / 1000) in. Hg Abs.</td>
</tr>
<tr>
<td>TS (Stack Temperature)</td>
<td>(\text{average TS of} + 460) oR</td>
</tr>
<tr>
<td>VS (Stack Velocity) ft/min</td>
<td>(60\times 85.49 \times Cp \times \sqrt{(P \times \text{TS oR} / \text{PS in Hg Abs / MS})}) ft/min</td>
</tr>
<tr>
<td>MS</td>
<td>(30 \times (1-%H_2O/100) + 18 \times %H_2O/100) g/mol</td>
</tr>
<tr>
<td>QN (Nozzle Flow Rate)</td>
<td>(\text{QM} \times P_{\text{in Hg Abs}} / (Cm \times \text{TS oR} \times (1/13.6)) - (1-%H_2O/100)) ACFM</td>
</tr>
<tr>
<td>QM (Meter Flow Rate)</td>
<td>(\text{H} @ (\text{pid} + \text{HM}/13.6)/(0.03175 \times (\text{TM} + 460))) in H2O</td>
</tr>
<tr>
<td>Seconds/Rev</td>
<td>(1 / (\text{QM} / 0.1 / 60))</td>
</tr>
</tbody>
</table>

**Page 2**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VWstd</td>
<td>(0.04707 \times (H_2O \text{ g})) SCF</td>
</tr>
<tr>
<td>VMstd</td>
<td>(17.64 \times \text{VWstd} \times \text{Cm} \times (PB + \text{HM} / 13.6 - \text{Elevation} / 1000)) SCF</td>
</tr>
<tr>
<td>VTstd</td>
<td>(\text{VWstd} + \text{VMstd}) SCF</td>
</tr>
<tr>
<td>% H2O</td>
<td>(\text{VWstd} / 100) %</td>
</tr>
<tr>
<td>% Isokinetic</td>
<td>(0.0945 \times \text{TS oR} \times \text{VMstd} \times 60 \text{ sec/min} \times 144 \text{ in}^2/\text{ft}^2) (\text{PS in Hg Abs} \times \text{VS} \times (\text{DN} / 4 \times \text{pi}) \times \text{time min} \times (1-%H_2O/100)) %</td>
</tr>
<tr>
<td>DCL</td>
<td>(15.43 \times \text{(dust g)} / \text{VMstd}) grains/SCF</td>
</tr>
<tr>
<td>% Efficiency</td>
<td>((\text{Inlet DCL} - \text{Outlet DCL}) / \text{Inlet DCL} \times 100) %</td>
</tr>
<tr>
<td>ACFM</td>
<td>(\text{VS} \times \text{Pipe Area (ft}^2)) ACFM</td>
</tr>
<tr>
<td>SCFM</td>
<td>(\text{ACFM} \times \text{PS} / \text{TS} \times 17.64) SCFM</td>
</tr>
<tr>
<td>lbs/hour</td>
<td>(\text{grains/SCF} \times 0.000143 \times \text{SCFM} \times 60 \text{ min/hr}) lbs/hour</td>
</tr>
</tbody>
</table>

**PPM Calculation**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPM</td>
<td>(\text{Conc mg/L} \times \text{Vol mL} \times L/1000 \text{ mL} \times 2.205e-6 \text{ lb/mg} \times 387 \text{ ft}^3/\text{mol} / \text{VTstd} \times e6)</td>
</tr>
<tr>
<td>Stack Vel ft/sec.</td>
<td>(V_{s}=85.49 \times Cp \times \text{SQRT(Dp} \times \text{SQRT(Ts/Ps/Mw))})</td>
</tr>
<tr>
<td>Mol Wt. Wet</td>
<td>(M_w=30 \times (1-B_{ws})+18 \times B_{ws})</td>
</tr>
<tr>
<td>ID</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Run #</td>
<td></td>
</tr>
<tr>
<td>Start Time</td>
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</tr>
<tr>
<td>Fund #</td>
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<table>
<thead>
<tr>
<th>VT Std</th>
<th>ft^3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of Sample</td>
<td>mL</td>
</tr>
<tr>
<td>Concentration</td>
<td>mg/L or ppm</td>
</tr>
<tr>
<td>Molecular Weight</td>
<td>g/mole</td>
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</table>

**Molecular Weights (g/mole)**

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<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
<tr>
<td>SO3</td>
<td>80.06</td>
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<tr>
<td>SO2</td>
<td>64.06</td>
</tr>
<tr>
<td>NH3</td>
<td>17.04</td>
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<tr>
<td>Cl2</td>
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<td>HCl</td>
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<tr>
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<td>HF</td>
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</tr>
<tr>
<td>Hg</td>
<td>200.59</td>
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</table>

#DIV/0! ppm in flue gas

387 ft^3/mol at 68oF
<table>
<thead>
<tr>
<th>DATE</th>
<th>ID</th>
<th>SAMPLE PORT</th>
<th>SAMPLER</th>
<th>START TIME</th>
<th>TEST TIME</th>
<th>PRESSURE (in Hg)</th>
<th>BARO PRESSURE (in H2O)</th>
<th>TEMP</th>
<th>STACK TEMP</th>
<th>GAS NOZ</th>
<th>METER DIA</th>
<th>VOL (cf)</th>
<th>TOTAL H2O</th>
<th>DUST VMSTD (SCF)</th>
<th>VTSTD</th>
<th>% METER</th>
<th>% DLC</th>
<th>% GRAINS/SCF</th>
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<tbody>
<tr>
<td>041522011</td>
<td>KEETAC-BHN-MS-1-DWN-LSS-BH-R</td>
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<td>19:28</td>
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<td>28.97</td>
<td>-1.1</td>
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<td>6.440</td>
<td>54.9 VALUE</td>
<td>5.937</td>
<td>6.904</td>
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<td>54</td>
<td>5.70</td>
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</table>
### OPERATORS
- RS

### RUN #
- KEETAC-BHOUT-M5-6-2

### DATE
- 6/30/2011

### TIME
- 16:08

### FUND #
- 15726

### DUST LOADING DATA SHEET
- DCL 0.0003 grains/SCF

### Sample Pt.
- BH OUT DWN LG

### Traverse Pt.
- 3' BIN

### Pb (Barometric Press.)
- 28.05 in Hg

### Ps (Stack Pressure)
- -7.2 in H2O

### Vs (Stack Velocity)
- 1613 ft/min

### Dn (Nozzle Diam.)
- 0.280 in

### QN (Nozzle Flow Rate)
- 0.6896 ACFM

### Est. AP (Pilot)
- 0.16 in H2O

### QM (Meter Flow Rate)
- 0.4390 ACFM

### Cm
- 1.040

### ΔH (orifice)
- 0.49 in H2O

### Cp
- 0.84 (Type S=.84, Std=.99)

### Est. Ts (Stack Temp)
- 216 °F

### Est. % H2O
- 16

### ΔTz
- 1.57

### O2 %
- 16.9

### CO ppm
- 3

### NO ppm
- 83

### NO2 ppm
- 2

### SO2 ppm
- 12

### CO2 %
- 18.6°(21-02%)21

### Note: Standard Temperature and Pressure are 68 °F and 29.92 in. Hg

<table>
<thead>
<tr>
<th>Time (min.)</th>
<th>Temp stack</th>
<th>Gas Meter (ft³)</th>
<th>Tm Inlet</th>
<th>Tm Outlet</th>
<th>ΔH</th>
<th>ΔP Pilot</th>
<th>Pump Vac in Hg</th>
<th>MUFF</th>
<th>Temp Box</th>
<th>Temp Impinger</th>
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Averages: 216 80.427 79 0.53 0.16 2.1 251 #DIV/0! #DIV/0!

Comments: Leak ck OK
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<thead>
<tr>
<th>Sample Pt.</th>
<th>BH OUT DWN LG</th>
<th>Date</th>
<th>6/30/2011</th>
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<tbody>
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<td>Run #</td>
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<td>Run #</td>
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</tr>
<tr>
<td>Fund #</td>
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<td>15726</td>
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<tr>
<td>Cost Center #</td>
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<td>Cost Center #</td>
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</table>

<table>
<thead>
<tr>
<th>STOPPER TYPE</th>
<th>TYPE OF SOLUTION</th>
<th>INITIAL WT. (g)</th>
<th>FINAL WT. (g)</th>
<th>NET WT. (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight DI</td>
<td>DI</td>
<td>799.7</td>
<td>999.6</td>
<td>199.9</td>
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<tr>
<td>Straight DI</td>
<td>DI</td>
<td>641.6</td>
<td>756.8</td>
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<td>Impinger</td>
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<td>668.3</td>
<td>673.8</td>
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<tr>
<td>Straight</td>
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<td>0.0</td>
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<tr>
<td>Impinger</td>
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<tr>
<td>Straight</td>
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<tr>
<td>TOTAL H2O (g)</td>
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<td>339.3</td>
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<tr>
<td>Additional Dust</td>
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<tr>
<td>TOTAL DUST (g)</td>
<td></td>
<td>0.00140</td>
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<td></td>
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</tbody>
</table>

| Vwstd        | 15.971 SCF       |
| Vmstd        | 76.845 SCF       |
| Vtstd        | 92.816 SCF       |
| % H2O        | 17.2 %           |
| % Isokinetic | #VALUE! %        |
| DCL          | 0.0003 grains/SCF|
| DCL - Metric | 0.0006 grams/SCM = grains/SCF * 2.288 |

**DUST LOADING CALCULATIONS (Concentration Basis)**

| Inlet DCL    | 0.0045 grains/SCF|
| % Efficiency | (Inlet DCL - Outlet DCL) * 100 | 93.7531 % |

**Pipe Area**

<table>
<thead>
<tr>
<th>Pipe Area</th>
<th>( \text{ft}^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACFM</td>
<td>0.0000 ACFM</td>
</tr>
<tr>
<td>SCFM</td>
<td>0.0 SCFM</td>
</tr>
<tr>
<td>lbs/hour</td>
<td>0.0000 lbs/hour</td>
</tr>
</tbody>
</table>

| lbs/scf * 0.000143 * SCFM * 60 | 0.0000 lbs/hour |
### Equations

**Page 1**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS (Stack Pressure)</td>
<td>( \text{PB} + (\text{PS in H}_2\text{O} / 13.6) - \text{elevation/1000} )</td>
</tr>
<tr>
<td>TS (Stack Temperature)</td>
<td>( \text{average TS of F} + 460 )</td>
</tr>
<tr>
<td>VS (Stack Velocity) ft/min</td>
<td>( 60 \times 85.49 \times C_p \times \text{sort} \left( \frac{P \times \text{TS of R}}{\text{PS in H}_2\text{O}} / \text{MS} \right) )</td>
</tr>
<tr>
<td>MS</td>
<td>( 30 \times (1-%\text{H}_2\text{O}/100) + 18 \times %\text{H}_2\text{O}/100 )</td>
</tr>
<tr>
<td>QN (Nozzle Flow Rate)</td>
<td>( \text{VS} \times \pi \times \text{DN}^2 / 576 )</td>
</tr>
<tr>
<td>QM (Meter Flow Rate)</td>
<td>( \text{QN} \times \text{T} \times \text{PS in H}_2\text{O} / (\text{Cm} \times \text{TS of R} \times (\text{HM }/ 13.6)) - (1-%\text{H}_2\text{O}/100) )</td>
</tr>
<tr>
<td>H (orifice)</td>
<td>( \text{QM}^2 \times \text{H_at} \times (\text{PB} + \text{HM}/13.6) \times (0.03175 \times (\text{TM} + 460)) )</td>
</tr>
<tr>
<td>Seconds/Rev</td>
<td>( 1 / (\text{QM} / 0.1 / 60) )</td>
</tr>
</tbody>
</table>

**Page 2**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Formula</th>
<th>Unit(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{VWstd} )</td>
<td>( 0.04707 \times (\text{H}_2\text{O g}) )</td>
<td>SCF</td>
</tr>
<tr>
<td>( \text{VMstd} )</td>
<td>( 17.64 \times \text{VWstd} \times \text{Cm} \times (\text{PB} + \text{HM}/13.6 - \text{Elevation/1000}) )</td>
<td>SCF</td>
</tr>
<tr>
<td>( \text{VTstd} )</td>
<td>( \text{VWstd} + \text{VMstd} )</td>
<td>SCF</td>
</tr>
<tr>
<td>( % \text{H}_2\text{O} )</td>
<td>( % \text{H}_2\text{O} )</td>
<td>%</td>
</tr>
<tr>
<td>( % \text{Isokinetic} )</td>
<td>( 0.0945 \times \text{TS of R} \times \text{VMstd} \times 60 \text{ sec/min} \times 144 \text{ in}^2/\text{ft}^2 )</td>
<td>%</td>
</tr>
<tr>
<td>( \text{DCL} )</td>
<td>( 15.43 \times (\text{dust g}) / \text{VMstd} )</td>
<td>grains/SCF</td>
</tr>
<tr>
<td>( % \text{Efficiency} )</td>
<td>( (\text{Inlet DCL} - \text{Outlet DCL}) / \text{Inlet DCL} \times 100 )</td>
<td>%</td>
</tr>
<tr>
<td>( \text{ACFM} )</td>
<td>( \text{VS} \times \text{Pipe Area (ft}^2) )</td>
<td>ACFM</td>
</tr>
<tr>
<td>( \text{SCFM} )</td>
<td>( \text{ACFM} \times \text{PS} / \text{TS} \times 17.64 )</td>
<td>SCFM</td>
</tr>
<tr>
<td>( \text{lbs/hour} )</td>
<td>( \text{grains/SCF} \times 0.000143 \times \text{SCFM} \times 60 \text{ min/hr} )</td>
<td>lbs/hour</td>
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</table>

**PPM Calculation**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Formula</th>
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</thead>
<tbody>
<tr>
<td>( \text{PPM} )</td>
<td>( \text{Conc mg/L} \times \text{Vol mL} / \text{L}/1000 \text{ mL} \times 2.205e-6 \text{ lb/mg} \times 387 \text{ ft}^3/\text{mol} / \text{VTstd} \times e6 )</td>
</tr>
<tr>
<td>( \text{Stack Vel ft./sec.} )</td>
<td>( V_s = 85.49 \times C_p \times \text{SQRT(Dp} \times \text{SQRT(Ts/Ps/Mw)}) )</td>
</tr>
<tr>
<td>( \text{Mol Wt. Wet} )</td>
<td>( \text{Mw} = 30 \times (1-\text{Bws}) + 18 \times \text{Bws} )</td>
</tr>
<tr>
<td>ID</td>
<td>Run #</td>
</tr>
<tr>
<td>----</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td></td>
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</tbody>
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<table>
<thead>
<tr>
<th>Vt Std</th>
<th>Volume of Sample</th>
<th>Concentration</th>
<th>Molecular Weight</th>
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<tr>
<td>ft^3</td>
<td>mL</td>
<td>mg/L or ppm</td>
<td>g/mole</td>
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</table>

<table>
<thead>
<tr>
<th>Molecular Weights (g/mole)</th>
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<td>NH\textsubscript{3}</td>
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<td>Cl\textsubscript{2}</td>
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</tr>
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<td>F\textsubscript{2}</td>
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<tr>
<td>HF</td>
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<tr>
<td>Hg</td>
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#DI/V0! ppm in flue gas

387 ft\textsuperscript{3}/mol at 68°F
<table>
<thead>
<tr>
<th>DATE</th>
<th>ID</th>
<th>SAMPLE PORT</th>
<th>SAMPLER</th>
<th>TIME</th>
<th>TIME</th>
<th>(in Hg)</th>
<th>(in H2O)</th>
<th>(F)</th>
<th>O2%</th>
<th>ΔP</th>
<th>DIA</th>
<th>VOL (cf)</th>
<th>H2O</th>
<th>DUST</th>
<th>VMSTD (SCF)</th>
<th>H2O</th>
<th>TEMP</th>
<th>ΔH</th>
<th>ISO</th>
<th>SCF</th>
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<tr>
<td>6/30/2011</td>
<td>KEE2AC</td>
<td>BH OUT</td>
<td>WASH OUT DNW L0</td>
<td>RS</td>
<td>16:08</td>
<td>180</td>
<td>26.05</td>
<td>-7.3</td>
<td>216</td>
<td>48.6</td>
<td>0.16</td>
<td>0.985</td>
<td>305.2</td>
<td>355.3</td>
<td>0.0014</td>
<td>79.845</td>
<td>6.2616</td>
<td>17.2</td>
<td>79</td>
<td>0.83 #VALUE!</td>
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**BARO**: Barometric pressure. **STACK**: Static pressure. **STANDARD**: Static temperature. **GAS**: Gas meter. **TOTAL**: Total meter. **%**: Percentage meter. **DLC**: Dust load concentration.
<table>
<thead>
<tr>
<th>OPERATORS</th>
<th>RS</th>
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<tbody>
<tr>
<td>ID</td>
<td>KEETAC-BHOUT-M5-5</td>
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<tr>
<td>RUN #</td>
<td>Vwstd 14,629 SCF</td>
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<tr>
<td>DATE</td>
<td>Vmstd 76,326 SCF</td>
</tr>
<tr>
<td>TIME</td>
<td>Vtstd 90,955 SCF</td>
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<tr>
<td>FUND #</td>
<td>% H2O 16.1%</td>
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<td>% Isokin 103.3%</td>
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**DUST LOADING DATA SHEET**

<table>
<thead>
<tr>
<th>Sample Pt.</th>
<th>BH OUT DWN LG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traverse Pt.</td>
<td>3' BIN</td>
</tr>
<tr>
<td>Ps = 27.59 in. Hg Abs.</td>
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<tr>
<td>Ts = 676 °R</td>
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<tr>
<td>Pb (Barometric Press.)</td>
<td>28.11 in Hg</td>
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<tr>
<td>Elevation correction</td>
<td>5 ft (1 in Hg / 1000 ft)</td>
</tr>
<tr>
<td>Ps (Stack Pressure)</td>
<td>-7.0 in H2O</td>
</tr>
<tr>
<td>Dn (Nozzle Diam.)</td>
<td>0.280 in</td>
</tr>
<tr>
<td>Est. AP (Pilot)</td>
<td>0.16 in H2O</td>
</tr>
<tr>
<td>QM (Meter Flow Rate)</td>
<td>0.4264 ACFM</td>
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<tr>
<td>QM (Nozzle Flow Rate)</td>
<td>0.6887 ACFM</td>
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<tr>
<td>Cp</td>
<td>0.84 (Type S=.84, Std=.99)</td>
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<tr>
<td>Est. Ts (Stack Temp)</td>
<td>216 °F</td>
</tr>
<tr>
<td>Est. % H2O</td>
<td>16</td>
</tr>
<tr>
<td>∆H@</td>
<td>1.57</td>
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<tr>
<td>Tm (Est)</td>
<td>70 °F</td>
</tr>
<tr>
<td>∆H (Est)</td>
<td>0.60 in Hg</td>
</tr>
<tr>
<td>O2 %</td>
<td>17.2</td>
</tr>
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<td>CO ppm</td>
<td>3</td>
</tr>
<tr>
<td>NO ppm</td>
<td>101</td>
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<tr>
<td>NO2 ppm</td>
<td>0</td>
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<tr>
<td>SO2 ppm</td>
<td>7</td>
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<tr>
<td>CO2 %</td>
<td>coal CO2=18.6*(21-02%)/21</td>
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*Note: Standard Temperature and Pressure are 68 °F and 29.92 in. Hg*

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| Vwstd       | 14.629 SCF       |
| Vmstd       | 76.326 SCF       |
| Vtstd       | 90.955 SCF       |
| % H2O       | 16.1 %           |
| % Isokinetic| 103.3 %          |
| DCL         | 0.0004 grains/SCF|
| DCL - Metric| 0.0010 grams/SCM = grains/SCF * 2.288 |

**DUST LOADING CALCULATIONS (Concentration Basis)**

| Inlet DCL | 0.0040 grains/SCF |
| % Efficiency = (Inlet DCL - Outlet DCL) * 100 | 88.8307 % |
| Inlet DCL |                |
| Pipe Area | ft²            |
| ACFM = VS * Pipe Area (ft²) | 0.0000 ACFM |
| SCFM = ACFM * PS/TS * 17.64 | 0.0 SCFM |
| lbs/hour = grains/scf * 0.000143 * SCFM * 60 | 0.0000 lbs/hour |
### Equations

**Page 1**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
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<tbody>
<tr>
<td>PS (Stack Pressure)</td>
<td>$= PB + \frac{(PS \text{ in } H_2O) \times 13.6}{1000} \text{ - elevation/1000}$</td>
</tr>
<tr>
<td>TS (Stack Temperature)</td>
<td>$= \frac{\text{average TS oR + 460}}{\text{oR}}$</td>
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<tr>
<td>VS (Stack Velocity) ft/min</td>
<td>$= 60 \times 85.49 \times CP \times \sqrt{\left(\frac{P \times TS \text{ oR}}{PS \text{ in Hg Abs} / MS}\right)}$</td>
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<tr>
<td>MS</td>
<td>$= 30 \times (1% \text{H}_2\text{O}/100) + 18 \times % \text{H}_2\text{O}/100$</td>
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<tr>
<td>QN (Nozzle Flow Rate)</td>
<td>$= 12 \times \pi \times DN2 / 576$</td>
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<tr>
<td>QM (Meter Flow Rate)</td>
<td>$= \text{QN} \times TM \times \text{PS in Hg Abs} / (Cm \times \text{TS oR} \times \left(\frac{HM}{13.6}\right) - (1% \text{H}_2\text{O}/100))$</td>
</tr>
<tr>
<td>H (orifice)</td>
<td>$= \text{QM} \times H \times (\text{PB + HM}/13.6)/(0.03175 \times (TM + 460))$</td>
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<tr>
<td>Seconds/Rev</td>
<td>$= 1 / \left(\text{QM} / 0.1 / 60\right)$</td>
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**Page 2**

<table>
<thead>
<tr>
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<tr>
<td>VWstd</td>
<td>$= 0.04707 \times (H_2O \text{ g})$</td>
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<td>VMstd</td>
<td>$= 17.64 \times VWstd \times Cm \times (PB + \text{HM}/13.6 - \text{Elevation}/1000)$</td>
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<td>VTstd</td>
<td>$= VWstd + VMstd$</td>
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<tr>
<td>% H2O</td>
<td>$= \frac{(VWstd / VTstd) \times 100}{\text{%}}$</td>
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<tr>
<td>% Isokinetic</td>
<td>$= 0.0945 \times \text{TS oR} \times VMstd \times 60 \text{ sec/min} \times 144 \text{ in}^2 / \text{ft}^2$</td>
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<td>(PS in Hg Abs \times VS \times (DN2/4\pi) \times \text{time min} \times (1% \text{H}_2\text{O}/100)$</td>
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<td>DCL</td>
<td>$= 15.43 \times \text{(dust g) / VMstd}$</td>
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<tr>
<td>% Efficiency</td>
<td>$= \left(\text{Inlet DCL - Outlet DCL}\right) / \text{Inlet DCL} \times 100 %$</td>
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<td>ACFM</td>
<td>$= \text{VS \times Pipe Area (ft}^2\text{)}$</td>
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<td>SCFM</td>
<td>$= \text{ACFM} \times PS / TS \times 17.64$</td>
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<tr>
<td>lbs/hour</td>
<td>$= \text{grains/SCF} \times 0.000143 \times \text{SCFM} \times 60 \text{ min/hr}$</td>
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**PPM Calculation**

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<td>PPM</td>
<td>$= \text{Conc mg/L \times Vol mL \times L/1000 mL \times 2.205e-6 lb/mg \times 387 ft}^3 / \text{mol} / \text{VTstd \times e6}$</td>
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<td>Stack Vel ft/sec</td>
<td>$V_{s} = 85.49 \times CP \times \text{SQRT(Dp \times \text{SQRT(Ts/Ps/Mw))}}$</td>
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<td>Mol Wt. Wet</td>
<td>$M_w = 30 \times (1 - \text{Bws}) + 18 \times \text{Bws}$</td>
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#DIV/0! ppm in flue gas

387 ft^3/mol at 680F
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<td>Note: Standard Temperature and Pressure are 68 °F and 29.92 in. Hg</td>
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<th>Tm Outlet</th>
<th>ΔH</th>
<th>ΔP Pilot</th>
<th>Pump Vac in Hg</th>
<th>251</th>
<th>Temp Box</th>
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Averages: 224 50.824 65 0.49 0.16 1.8 250 #DIV/0! #DIV/0! Comments
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<th>Sample Pt.</th>
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<th>6/20/2011</th>
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<td>TYPE OF SOLUTION</td>
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<td>FINAL WT. (g)</td>
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<td>801.1</td>
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<td>TOTAL H2O (g)</td>
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<td>Vwstd</td>
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<td>% H2O</td>
<td>16.0 %</td>
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<tr>
<td>% Isokinetic</td>
<td>100.5 %</td>
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<tr>
<td>DCL</td>
<td>0.0009 grains/SCF</td>
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<tr>
<td>DCL - Metric</td>
<td>0.0022 grams/SCM = grains/SCF * 2.288</td>
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**DUST LOADING CALCULATIONS (Concentration Basis)**

- **Inlet DCL**

- **% Efficiency** = \( \frac{(\text{Inlet DCL} - \text{Outlet DCL}) \times 100}{\text{Inlet DCL}} \) %

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<tr>
<th>Pipe Area</th>
<th>ft^2</th>
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<td>ACFM = VS * Pipe Area (ft^2)</td>
<td>0.0000 ACFM</td>
</tr>
<tr>
<td>SCFM = ACFM * PS/TS * 17.64</td>
<td>0.0 SCFM</td>
</tr>
<tr>
<td>lbs/hour = grains/scf * 0.000143 * SCFM * 60</td>
<td>0.0000 lbs/hour</td>
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<td>Equations</td>
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<td>--------------------------------------------------------------------------</td>
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<tr>
<td>PS (Stack Pressure) =PB + (PS in H2O / 13.6) - elevation/1000</td>
<td>in. Hg Abs.</td>
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<tr>
<td>TS (Stack Temperature) =average TS oF + 460</td>
<td>oR</td>
</tr>
<tr>
<td>VS (Stack Velocity) ft/min =60*85.49 * Cp * sqrt( P * TS oF / PS in Hg Abs / MS)</td>
<td>ft/min</td>
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<tr>
<td>MS =30 * (1-%H2O/100) + 18 * %H2O/100</td>
<td>g/mol</td>
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<tr>
<td>QN (Nozzle Flow Rate) =VS * pi * DN2 / 576</td>
<td>ACFM</td>
</tr>
<tr>
<td>QM (Meter Flow Rate) =QN * TM * PS in Hg Abs/(Cm * TS oF * ( HM /13.6)) - (1-%H2O/100)</td>
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<td>H (orifice) =QM2 * H@ * (PB + HM /13.6)/(0.03175 * (TM + 460))</td>
<td>in H2O</td>
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<td>Seconds/Rev =1/(QM / 0.1 / 60)</td>
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<td><strong>Page 2</strong></td>
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<tr>
<td>VWstd =0.04707 * (H2O g)</td>
<td>SCF</td>
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<tr>
<td>VMstd =17.64 * VWstd * Cm * (PB+ HM/13.6 - Elevation/1000)</td>
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<td>VTstd =VWstd + VMstd</td>
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<tr>
<td>% H2O = (VWstd / VTstd) * 100</td>
<td>%</td>
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<tr>
<td>% Isokinetic = 0.0945 * TS oR * VMstd * 60 sec/min * 144 in2/ft2</td>
<td>%</td>
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<tr>
<td>(PS in Hg Abs * VS * (DN2/4*pi) * time min * (1-%H2O/100)</td>
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<td>DCL =15.43 * (dust g) / VMstd</td>
<td>grains/SCF</td>
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<tr>
<td>% Efficiency =(Inlet DCL - Outlet DCL) / Inlet DCL * 100</td>
<td>%</td>
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<tr>
<td>ACMF =VS * Pipe Area (ft2)</td>
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<tr>
<td>SCFM =ACFM * PS / TS * 17.64</td>
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<tr>
<td>lbs/hour =grains/SCF * 0.000143 * SCFM * 60 min/hr</td>
<td>lbs/hour</td>
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<td><strong>PPM Calculation</strong></td>
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<tr>
<td>PPM =Conc mg/L * Vol mL * L/1000 mL * 2.205e-6 lb/mg * 387 ft3/mol / VTstd * e6</td>
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<td>Stack Vel ft/sec. Vs=65.49<em>Cp</em>SQRT Dp*SQRT(Ts/Ps/Mw)</td>
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<td>Mol Wt. Wet Mw=30*(1-Bws)+18*Bws</td>
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<td>Run #</td>
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<td>VT Std</td>
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<td>% H2O 16.2 %</td>
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<td>% Isokin 104.2 %</td>
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**DUST LOADING DATA SHEET**

| Sample Pt. | BH OUT DWN LG |
| Travers Pt. | 3' Bin |
| Pb (Baromet start) | 28.20 in Hg |
| Ps (Stack Pressure) | 187.97 in. Hg Abs. |
| Ts (Elevation correction) | 684.2 R |
| Ps (Stack Pressure) | -3.0 in H2O |
| Vs (Stack Velocity) | 1607 ft/min |
| Dn (Nozzle Diam.) | 0.280 in |
| Qn (Nozzle Flow Rate) | 0.6871 ACFM |
| Est. AP (Pilot) | 0.16 in H2O |
| Qm (Meter Flow Rate) | 0.4400 ACFM |
| Cm | 1.040 |
| H (orifice) | 0.50 in H2O |
| Cp | 0.84 (Type S=.84, Std=.99) |
| S (Stack Temp) | 224.9 F |
| Est. % H2O | 16 |
| O2 % | 17.9 |
| CO ppm | 4 |
| NO ppm | 228 |
| NO2 ppm | 2 |
| SO2 ppm | 0 |
| CO2 % | 18.6% |

**Note:** Standard Temperature and Pressure are 68°F and 29.92 in. Hg.

<table>
<thead>
<tr>
<th>Time (min.)</th>
<th>Temp stack</th>
<th>Gas Meter (ft³)</th>
<th>Tm Inlet</th>
<th>Tm Outlet</th>
<th>ΔH</th>
<th>ΔP Pilot</th>
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| Averages:   | 224        | 53.300         | 71       | 0.53      | 0.16 | 1.5     | 250 #DIV/0! | #DIV/0!   |         |               |

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**DUST LOADING CALCULATIONS (Concentration Basis)**

\[
\text{Inlet DCL} = \frac{0.0027 \text{ grains/SCF}}{0.0006 \text{ grains/SCF}}
\]

\[
\% \text{ Efficiency} = \left(\frac{\text{Inlet DCL} - \text{Outlet DCL}}{\text{Inlet DCL}}\right) \times 100 = 77.4670 \%
\]

\[
\frac{\text{Pipe Area}}{\text{ft}^2} = 0.0000 \text{ ACFM}
\]

\[
\text{SCFM} = \text{ACFM} \times \frac{\text{PS/TS}}{17.64} = 0.0 \text{ SCFM}
\]

\[
\text{lbs/hour} = \text{grains/scf} \times 0.000143 \times \text{SCFM} \times 60 = 0.0000 \text{ lbs/hour}
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| VT Std | ft^3 |
| Volume of Sample | mL |
| Concentration | mg/L or ppm |
| Molecular Weight | g/mole |

**Molecular Weights (g/mole)**

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#DIV/0! ppm in flue gas

387 ft³/mol at 680°F
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**DUST LOADING DATA SHEET**

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Est. ΔH (Stack Temp) 166 °F

Est. % H2O 16%

ΔH@ 1.46

ΔH (Est) 0.60 in Hg

Note: Standard Temperature and Pressure are 68 °F and 29.92 in. Hg

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<td>% Efficiency</td>
<td>= (Inlet DCL - Outlet DCL) * 100</td>
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<td>ACFM = VS * Pipe Area (ft2)</td>
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<td>SCFM = ACFM * PS/TS * 17.64</td>
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<td>lbs/hour = grains/scf * 0.000143 * SCFM * 60</td>
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<td>PS (Stack Pressure) &amp;= PB + (PS in H2O / 13.6) - elevation/1000 in. Hg Abs.</td>
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<td>TS (Stack Temperature) &amp;= average TS °F + 460 oR</td>
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<td>VS (Stack Velocity) &amp;= 60 * 85.49 * Cp * sqrt(P * TS oR / PS in Hg Abs / MS) ft/min</td>
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<td>MS &amp;= 30 * (1-%H2O/100) + 18 * %H2O/100 g/mol</td>
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<td>QN (Nozzle Flow Rate) &amp;= VS * pi * DN2 / 576 ACFM</td>
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<td>QM (Meter Flow Rate) &amp;= QN * TM * PS in Hg Abs/(Cm * TS oR * (HM/13.6)) - (1-%H2O/100) ACFM</td>
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<tr>
<td>H (orifice) &amp;= QM2 * H@ * (PB + HM/13.6)/(0.03175 * (TM + 460)) in H2O</td>
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<tr>
<td>Seconds/Rev &amp;= 1/(QM / 0.1 / 60)</td>
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<td>VWstd &amp;= 0.04707 * (H2O g) SCF</td>
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<td>VMstd &amp;= 17.64 * VWstd * Cm * (PB+HM/13.6 - Elevation/1000) SCF</td>
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<td>VTstd &amp;= VWstd + VMstd SCF</td>
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<td>% H2O &amp;= (VWstd / VTstd) * 100 %</td>
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<td>% Isokinetic &amp;= 0.0945 * TS oR * VMstd * 60 sec/min * 144 in2/ft2 %</td>
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<td>(PS in Hg Abs * VS * (DN2/4*pi) * time min * (1-%H2O/100)</td>
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<td>DCL &amp;= 15.43 * (dust g) / VMstd grains/SCF</td>
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<td>% Efficiency &amp;= (Inlet DCL - Outlet DCL) / Inlet DCL * 100 %</td>
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<tr>
<td>ACFM &amp;= VS * Pipe Area (ft2) ACFM</td>
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<tr>
<td>SCFM &amp;= ACFM * PS / TS * 17.64 SCFM</td>
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<tr>
<td>lbs/hour &amp;= grains/SCF * 0.000143 * SCFM * 60 min/hr lbs/hour</td>
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<td><strong>PPM Calculation</strong></td>
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<tr>
<td>PPM &amp;= Conc mg/L * Vol mL * L/1000 mL * 2.205e-6 lb/mg * 387 ft3/mol / VTstd * e6</td>
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<tr>
<td>Stack Vel ft./sec. &amp;= 85.49<em>Cp</em>SORT Dp*SORT(Ts/Ps/Mw)</td>
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<td>Mol Wt. Wet &amp;= Mw = 30*(1-Bws) + 18*Bws</td>
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<td>Vt Std</td>
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<td>Molecular Weight</td>
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**Molecular Weights (g/mole)**

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<td>F₂</td>
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<td>HF</td>
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<td>Hg</td>
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#DIV/0! ppm in flue gas

387 ft³/mol at 680°F
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<th>SAMPLER</th>
<th>TIME</th>
<th>TIME</th>
<th>PRESS</th>
<th>PRESS</th>
<th>TEMP</th>
<th>NOZ</th>
<th>METER</th>
<th>TOTAL</th>
<th>TOTAL</th>
<th>VTSTD</th>
<th>% METER</th>
<th>% GRAINS/</th>
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<td>KEETAC-BHN-MS-5/BHN-DWN LG</td>
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<td>Vmstd 77.207 SCF</td>
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<td>TIME</td>
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<tr>
<td>FUND #</td>
<td>% H2O 16.1 %</td>
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<td>% Isokin 88.3 %</td>
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**DUST LOADING DATA SHEET**

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<th>Sample Pt.</th>
<th>DCL 0.0040 grains/SCF</th>
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<td>Traverse Pt.</td>
<td>3' IN</td>
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<tr>
<td>Pb (Barometric Press.)</td>
<td>28.11 in Hg</td>
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<td>Ts = 28.07 in Hg Abs.</td>
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<tr>
<td>Elevation correction</td>
<td>20 ft (1 in Hg / 1000 ft)</td>
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<tr>
<td>Ps (Stack Pressure)</td>
<td>-0.3 in H2O</td>
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<tr>
<td>VS (Stack Velocity)</td>
<td>1535 ft/min</td>
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<tr>
<td>Dn (Nozzle Diam.)</td>
<td>0.280 in</td>
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<tr>
<td>QN (Nozzle Flow Rate)</td>
<td>0.6565 ACFM</td>
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<tr>
<td>Est. ∆P (Pilot)</td>
<td>0.16 in H2O</td>
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<td>QM (Meter Flow Rate)</td>
<td>0.4565 ACFM</td>
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<tr>
<td>Cp</td>
<td>1.010</td>
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<td>ΔH (orifice)</td>
<td>0.51 in H2O</td>
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<td>(Type S=.84, Std=.99)</td>
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<tr>
<td>Seconds/Rev</td>
<td>13.1</td>
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<td>Est. Ts (Stack Temp)</td>
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<td>Est. % H2O</td>
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<td>O2 %</td>
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<td>CO ppm</td>
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<td>NO2 ppm</td>
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<td>SO2 ppm</td>
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<td>CO2 %</td>
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<tr>
<td>coal CO2=18.6*(21-02%)/21</td>
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*Note: Standard Temperature and Pressure are 68°F and 29.92 in. Hg*

<table>
<thead>
<tr>
<th>Time (min.)</th>
<th>Temp stack</th>
<th>Gas Meter (ft³)</th>
<th>Tm Inlet</th>
<th>Tm Outlet</th>
<th>ΔH</th>
<th>ΔP Pilot</th>
<th>Pump Vac in Hg</th>
<th>Temp Probe</th>
<th>Temp Box</th>
<th>Temp Impinger</th>
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<tr>
<td>0</td>
<td>165</td>
<td>206.629</td>
<td>64</td>
<td>65</td>
<td>0.51</td>
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<td>DCL</td>
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<td>DCL - Metric</td>
<td>0.0093 grams/SCM = grains/SCF*2.288</td>
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**DUST LOADING CALCULATIONS (Concentration Basis)**

\[
\text{Inlet DCL} = \frac{(\text{Inlet DCL} - \text{Outlet DCL}) \times 100}{\text{Inlet DCL}} \]

\[
\% \text{ Efficiency} = \left(\frac{\text{Inlet DCL} - \text{Outlet DCL}}{\text{Inlet DCL}}\right) \times 100
\]

\[
\text{Pipe Area} = \frac{\text{ACFM} \times \text{Pipe Area (ft}^2\text{)}}{0.0000 \text{ ACFM}}
\]

\[
\text{SCFM} = \frac{\text{ACFM} \times \text{PS/TS} \times 17.64}{0.0 \text{ SCFM}}
\]

\[
\text{lbs/hour} = \frac{\text{grains/scf} \times 0.000143 \times \text{SCFM} \times 60}{0.0000 \text{ lbs/hour}}
\]
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<td><strong>Page 1</strong></td>
</tr>
<tr>
<td>PS (Stack Pressure) &amp; =PB + (PS in H2O / 13.6) - elevation/1000</td>
</tr>
<tr>
<td>TS (Stack Temperature) &amp; =average TS oR + 460</td>
</tr>
<tr>
<td>VS (Stack Velocity) ft/min &amp; =60 * 85.49 * Cp * sqrt( P * TS oR / PS in Hg Abs / MS)</td>
</tr>
<tr>
<td>MS &amp; =30 * (1-%H2O/100) + 18 * %H2O/100</td>
</tr>
<tr>
<td>QN (Nozzle Flow Rate) &amp; =VS * pi * DN2 / 576</td>
</tr>
<tr>
<td>QM (Meter Flow Rate) &amp; =QN * TM * PS in Hg Abs / (Cm * TS oR * (HM /13.6)) - (1-%H2O/100)</td>
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<tr>
<td>H (orifice) &amp; =QM2 * H (PB + HM /13.6)/ (0.03175 * (TM + 460))</td>
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<tr>
<td>Seconds/Rev &amp; =1/(QM / 0.1 / 60)</td>
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<tr>
<td><strong>Page 2</strong></td>
</tr>
<tr>
<td>VWstd &amp; =0.04707 * (H2O g)</td>
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<tr>
<td>VMstd &amp; =17.64 * VWstd * Cm * (PB+ HM /13.6 - Elevation/1000)</td>
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<tr>
<td>VTstd &amp; =VWstd + VMstd</td>
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<tr>
<td>% H2O &amp; = (VWstd / VTstd) * 100</td>
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<tr>
<td>% Isokinetic &amp; =0.0945 * TS oR * VMstd * 60 sec/min * 144 in2/ft2</td>
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<tr>
<td>(PS in Hg Abs * VS * (DN2/4*pi) * time min * (1-%H2O/100)</td>
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<td>DCL &amp; =15.43 * (dust g) / VMstd</td>
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<tr>
<td>% Efficiency &amp; =(Inlet DCL - Outlet DCL) / Inlet DCL * 100</td>
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<tr>
<td>ACMF &amp; =VS * Pipe Area (ft2)</td>
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<tr>
<td>SCFM &amp; =ACFM * PS / TS * 17.64</td>
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<tr>
<td>lbs/hour &amp; =grains/SCF * 0.000143 * SCFM * 60 min/hr</td>
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<tr>
<td><strong>PPM Calculation</strong></td>
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<td>PPM &amp; =Conc mg/L * Vol mL * L/1000 mL * 2.205e-6 lb/mg * 387 ft3/mol / VTstd * e6</td>
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<td>Stack Vel ft/sec. &amp; Vs=85.49 * Cp * SQR Dp * SQR(Ts/Ps/Mw)</td>
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<td>Mol Wt. Wet &amp; Mw=30*(1-Bws)+18*Bws</td>
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#DIV/0! ppm in flue gas

387 ft^3/mol at 68oF
| ID | BARO STICK STACK | DATE | TIME | SAMPLE PORT | SAMPLER | SAMPLE | SMC | SPC | GRAMS | % | METER | % | WEIGH | % | WEIGHT | % | WEIGHT | % | TOTAL | % | WEIGHT | % | WEIGH | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | WEIGHT | % | W
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<td>Elevation correction</td>
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<td>ΔH (Est)</td>
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Note: Standard Temperature and Pressure are 68° F and 29.92 in. Hg.

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<th>ΔH</th>
<th>ΔP Pilot</th>
<th>Pump Vac in Hg</th>
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<td>179.430</td>
<td>66</td>
<td>62</td>
<td>0.50</td>
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<td>186.170</td>
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<td>1.3</td>
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<td>#DIV/0!</td>
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coal CO2=18.6(21-02%)/21
<table>
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<table>
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<tr>
<th>STOPPER TYPE</th>
<th>TYPE OF SOLUTION</th>
<th>INITIAL WT. (g)</th>
<th>FINAL WT. (g)</th>
<th>NET WT. (g)</th>
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<tr>
<td>Straight</td>
<td>DI</td>
<td>811.1</td>
<td>980.1</td>
<td>169.0</td>
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<td>Straight</td>
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<td>25.8</td>
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<td>Impinger</td>
<td>DRY</td>
<td>618.2</td>
<td>623.8</td>
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<tr>
<td>Straight</td>
<td>SIL GEL</td>
<td>969.3</td>
<td>980.7</td>
<td>11.4</td>
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<td>Straight</td>
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<td>0.0</td>
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<tr>
<td>Straight</td>
<td></td>
<td>0.0</td>
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<tr>
<td>Impinger</td>
<td></td>
<td>0.0</td>
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<tr>
<td>Straight</td>
<td>Silica Gel</td>
<td>0.0</td>
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TOTAL H2O (g) 211.8

FILTER

<table>
<thead>
<tr>
<th>INITIAL WT. (g)</th>
<th>FINAL WT. (g)</th>
<th>NET WT. (g)</th>
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<td>0.23076</td>
<td>0.23762</td>
<td>0.00686</td>
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<tr>
<td>0.74072</td>
<td>0.74139</td>
<td>0.00067</td>
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</table>

TOTAL DUST (g) 0.00000

Vwstd 9.969 SCF

Vrstd 52.138 SCF

Vtstd 62.107 SCF

% H2O 16.1%

% Isokinetic 99.3%

DCL 0.0022 grains/SCF

DCL-Metric 0.0051 grams/SCM = grains/SCF*2.288

**DUST LOADING CALCULATIONS (Concentration Basis)**

Inlet DCL

% Efficiency = (Inlet DCL - Outlet DCL) * 100

#DIV/0! %

Inlet DCL

Pipe Area ft²

ACFM = VS * Pipe Area (ft²) 0.0000 ACFM

SCFM = ACFM * PS/TS * 17.64 0.0 SCFM

lbs/hour = grains/scf * 0.000143 * SCFM * 60 0.0000 lbs/hour
### Equations

#### Page 1

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS (Stack Pressure)</td>
<td>( = \text{PB} + \left( \text{PS in H}_2\text{O} / 13.6 \right) - \text{elevation/1000} ) in. Hg Abs.</td>
</tr>
<tr>
<td>TS (Stack Temperature)</td>
<td>( = \text{average TS ofF} + 460 ) ofR</td>
</tr>
<tr>
<td>VS (Stack Velocity)/ft/min</td>
<td>( = 60 \times 85.49 \times \text{Cp} \times \text{sort} \times \left( \text{P} \times \text{TS ofR} / \text{PS in H}_2\text{O} \right) / \text{MS in Hg Abs} / \text{MS} ) ft/min</td>
</tr>
<tr>
<td>MS</td>
<td>( = 30 \times \left( 1 - % \text{H}_2\text{O}/100 \right) + 18 \times % \text{H}_2\text{O}/100 ) g/mol</td>
</tr>
<tr>
<td>QN (Nozzle Flow Rate)</td>
<td>( = \text{VS} \times \text{pi} \times \text{DN2} / 576 ) ACFM</td>
</tr>
<tr>
<td>QM (Meter Flow Rate)</td>
<td>( = \text{QN} \times \text{TM} \times \text{PS in H}_2\text{O}/\left( \text{Cm} \times \text{TS ofR} \times \left( \text{HM} / 13.6 \right) \right) - \left( 1 - % \text{H}_2\text{O}/100 \right) ) ACFM</td>
</tr>
<tr>
<td>H (orifice)</td>
<td>( = \text{QM2} \times \text{H@} \times \left( \text{PB} + \text{HM} / 13.6 \right) / \left( 0.03175 \times \left( \text{TM} + 460 \right) \right) ) in Hg</td>
</tr>
<tr>
<td>Seconds/Rev</td>
<td>( = 1 / \left( \text{QM} / 0.1 / 60 \right) )</td>
</tr>
</tbody>
</table>

#### Page 2

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VWstd</td>
<td>( = 0.04709 \times \left( \text{H}_2\text{O} \right) ) SCF</td>
</tr>
<tr>
<td>VMstd</td>
<td>( = 17.64 \times \text{VWstd} \times \text{Cm} \times \left( \text{PB} + \text{HM} / 13.6 \right) - \text{Elevation/1000} ) SCF</td>
</tr>
<tr>
<td>VT std</td>
<td>( = \text{VWstd} + \text{VMstd} ) SCF</td>
</tr>
<tr>
<td>% H2O</td>
<td>( = \left( \text{VWstd} / \text{VTstd} \right) \times 100 ) %</td>
</tr>
<tr>
<td>% Isokinetic</td>
<td>( = 0.09145 \times \text{TS ofR} \times \text{VMstd} \times 60 \text{ sec/min} \times 144 \text{ in}^2/\text{ft}^2 \times \left( \text{PS in H}_2\text{O} \right) \times \text{VS} \times \left( \text{DN2/4*pi} \right) \times 60 \text{ min} \times \left( 1 - % \text{H}_2\text{O}/100 \right) )</td>
</tr>
<tr>
<td>DCL</td>
<td>( = 15.43 \times \left( \text{dust g} \right) / \text{VMstd} ) grains/SCF</td>
</tr>
<tr>
<td>% Efficiency</td>
<td>( = \left( \text{Inlet DCL} - \text{Outlet DCL} \right) / \text{Inlet DCL} \times 100 ) %</td>
</tr>
<tr>
<td>ACFM</td>
<td>( = \text{VS} \times \text{Pipe Area (ft2)} ) ACFM</td>
</tr>
<tr>
<td>SCFM</td>
<td>( = \text{ACFM} \times \text{PS} / \text{TS} \times 17.64 ) SCFM</td>
</tr>
<tr>
<td>lbs/hour</td>
<td>( = \text{grains/SCF} \times 0.000143 \times \text{SCFM} \times 60 \text{ min/hr} ) lbs/hour</td>
</tr>
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</table>

### PPM Calculation

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPM</td>
<td>( = \text{Conc mg/L} \times \text{Vol mL} \times \text{L/1000 mL} \times 2.205e-6 \text{ lb/mg} \times 387 \text{ ft3/mol} / \text{VTstd} \times e6 )</td>
</tr>
</tbody>
</table>

| Stack Vel ft/sec.               | \( = 85.49 \times \text{Cp} \times \text{SORT Dp} \times \text{SORT(Ts/Ps/Mw)} \) |

<p>| Mol Wt. Wet                     | ( = 30 \times (1 - \text{Bws}) + 18 \times \text{Bws} ) |</p>
<table>
<thead>
<tr>
<th>ID</th>
<th>Run #</th>
<th>Start Time</th>
<th>Fund #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vt Std</td>
<td>ft³</td>
<td>Volume of Sample</td>
<td>mL</td>
</tr>
<tr>
<td>Concentration</td>
<td>mg/L or ppm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Weight</td>
<td>g/mole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Molecular Weights (g/mole)</th>
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<tbody>
<tr>
<td>SO₃</td>
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<tr>
<td>SO₂</td>
</tr>
<tr>
<td>NH₃</td>
</tr>
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<td>Cl₂</td>
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<tr>
<td>HCl</td>
</tr>
<tr>
<td>F₂</td>
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<tr>
<td>HF</td>
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<tr>
<td>Hg</td>
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**ppm in flue gas**

387 ft³/mol at 68°F
<table>
<thead>
<tr>
<th>DATE</th>
<th>ID</th>
<th>SAMPLE PORT</th>
<th>SAMPLER</th>
<th>TIME</th>
<th>TIME</th>
<th>PRESS (in Hg)</th>
<th>PRESS (in H2O)</th>
<th>TEMP (F)</th>
<th>O2%</th>
<th>ΔP</th>
<th>DIA</th>
<th>VOL (cf)</th>
<th>H2O</th>
<th>DUST</th>
<th>VMSTD (SCF)</th>
<th>H2O</th>
<th>TEMP</th>
<th>ΔH</th>
<th>ISO</th>
<th>SCF</th>
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<td>02022011</td>
<td>KEP-AC-RHIN-M6</td>
<td>4</td>
<td>DWP LSG RHIN</td>
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<td>120</td>
<td>28.17</td>
<td>-0.15</td>
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<td>211.8</td>
<td>0.007531</td>
<td>57.138</td>
<td>62.167</td>
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<td>83</td>
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<td>99.3</td>
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**Operators**: RS

**ID**: KEETAC-BHIN-M5-3

**Run #:** Vmstd 10,770 SCF

**Date**: 6/18/2011

**Time**: 14.51

**FUND #:** 15726

**Dust Loading Data Sheet**: DCL 0.0027 grains/SCF

**Sample Pt.**: BH IN DWN LG

**Traverse Pt.**: 3' IN

**Ps**: 28.17 in. Hg Abs.

**Ts**: 605 °F

**Elevation correction**: 20 ft (1 in Hg / 1000 ft)

**Ps (Stack Pressure)**: -0.2 in H2O

**Vs (Stack Velocity)**: 1506 ft/min

**Dn (Nozzle Diam.)**: 0.280 in

**Qn (Nozzle Flow Rate)**: 0.6440 ACFM

**Est AP (Pitot)**: 0.16 in H2O

**Qm (Meter Flow Rate)**: 0.4614 ACFM

**Cm**: 1.010

**AH (Orifice)**: 0.53 in H2O

**Cp**: 0.84 (Type S=.84, Std=.99)

**S**: Seconds/Rev

**Est. Ts (Stack Temp)**: 145 °F

**Est. % H2O**: 16

**O2 %**: 17.8

**CO ppm**: 4

**Tm (Est)**: 60 °F

**NO ppm**: 233

**AH (Est)**: 0.80 in Hg

**NO2 ppm**: 2

**SO2 ppm**: 0

**CO2 %**: 

coal CO2=18.6*(21-0%) / 21

**Note**: Standard Temperature and Pressure are 68°F and 29.92 in. Hg

<table>
<thead>
<tr>
<th>Time (min.)</th>
<th>Temp stack</th>
<th>Gas Meter (R3)</th>
<th>Tm Inlet</th>
<th>Tm Outlet</th>
<th>ΔH</th>
<th>ΔP Pitot</th>
<th>Pump Vac in Hg</th>
<th>Temp Probe</th>
<th>Temp Box</th>
<th>Temp Impinger</th>
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<td>#DIV/0!</td>
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**Averages: 145**

**58.838**

**74**

**0.60**

**0.16**

**3.6**

**249 #DIV/0! #DIV/0!**

**Comments**
<table>
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<tr>
<th>Sample Pt.</th>
<th>BH IN DWN LG</th>
<th>Date</th>
<th>6/18/2011</th>
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<tr>
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<table>
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<tr>
<th>STOPPER TYPE</th>
<th>TYPE OF SOLUTION</th>
<th>INITIAL WT. (g)</th>
<th>FINAL WT. (g)</th>
<th>NET WT. (g)</th>
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<tbody>
<tr>
<td>Straight</td>
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<td>854.5</td>
<td>1016.3</td>
<td>161.8</td>
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<tr>
<td>Straight</td>
<td>KCl</td>
<td>636.1</td>
<td>681.8</td>
<td>45.7</td>
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<tr>
<td>Impinger</td>
<td>KCl</td>
<td>641.3</td>
<td>647.9</td>
<td>6.6</td>
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<tr>
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<tr>
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<td>KMnO4</td>
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<td></td>
<td>0.0</td>
</tr>
<tr>
<td>Impinger</td>
<td>KMnO4</td>
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<td>0.0</td>
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<tr>
<td>Straight</td>
<td>Silica Gel</td>
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TOTAL H2O (g) | 228.8 |

FILTER |

<table>
<thead>
<tr>
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<th>INITIAL WT. (g)</th>
<th>FINAL WT. (g)</th>
<th>NET WT. (g)</th>
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<tbody>
<tr>
<td>0.23647</td>
<td>0.24528</td>
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<tr>
<td>0.74021</td>
<td>0.74072</td>
<td>0.00051</td>
<td></td>
</tr>
</tbody>
</table>

TOTAL DUST (g) | 0.00983 |

Vwstd | 10.770 SCF |
Vmstd | 55.416 SCF |
Vlstd | 66.186 SCF |
% H2O | 16.3 %    |
% Isokinetic | 104.1 % |
DCL | 0.0027 grains/SCF |
DCL - Metric | 0.0063 grams/SCM = grains/SCF*2.288 |

**DUST LOADING CALCULATIONS (Concentration Basis)**

| Inlet DCL | 0.0060 grains/SCF |
| % Efficiency = (Inlet DCL - Outlet DCL) * 100 | 54.3678 % |
| Inlet DCL | 76.60% |
| Pipe Area | ft² |
| ACFM = VS * Pipe Area (ft²) | 0.0000 ACFM |
| SCFM = ACFM * PS/TS * 17.64 | 0.0 SCFM |
| lbs/hour = grains/scf * 0.000143 * SCFM * 60 | 0.0000 lbs/hour |
### Equations

#### Page 1

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS (Stack Pressure) = PB + (PS in H2O / 13.6) - elevation / 1000</td>
<td>in. Hg Abs.</td>
</tr>
<tr>
<td>TS (Stack Temperature) = average TS of T + 460</td>
<td>oR</td>
</tr>
<tr>
<td>VS (Stack Velocity) ft/min = 60 * 85.49 * Cp * sqrt( P * TS of T / PS in Hg Abs / MS )</td>
<td>ft/min</td>
</tr>
<tr>
<td>MS = 30 * (1-%H2O/100) + 18 * %H2O/100</td>
<td>g/mol</td>
</tr>
<tr>
<td>QN (Nozzle Flow Rate) = VS * pi * DN2 / 576</td>
<td>ACFM</td>
</tr>
<tr>
<td>QM (Meter Flow Rate) = QN * TM * PS in Hg Abs / (Cm * TS of T / (HM / 13.6) - (1-%H2O/100) )</td>
<td>ACFM</td>
</tr>
<tr>
<td>H (orifice) = QM2 * H@2 * (PB + HM / 13.6) / (0.03175 * (TM + 460))</td>
<td>in H2O</td>
</tr>
<tr>
<td>Seconds/Rev = 1 / (QM / 0.1 / 60)</td>
<td></td>
</tr>
</tbody>
</table>

#### Page 2

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VWstd = 0.04707 * (H2O g)</td>
<td>SCF</td>
</tr>
<tr>
<td>VMstd = 17.64 * VWstd * Cm * (PB + HM / 13.6 - Elevation / 1000)</td>
<td>SCF</td>
</tr>
<tr>
<td>VTstd = VWstd + VMstd</td>
<td>SCF</td>
</tr>
<tr>
<td>% H2O = (VWstd / VTstd) * 100</td>
<td>%</td>
</tr>
<tr>
<td>% Isokinetic = (0.0945 * TS of T * VMstd * 60 sec/min * 144 in2/ft2) * (PS in Hg Abs * VS * (DN2/4*pi) * time min * (1-%H2O/100) )</td>
<td>%</td>
</tr>
<tr>
<td>DCL = 15.43 * (dust g) / VMstd</td>
<td>grains/SCF</td>
</tr>
<tr>
<td>% Efficiency = (Inlet DCL - Outlet DCL) / Inlet DCL * 100</td>
<td>%</td>
</tr>
<tr>
<td>ACMF = VS * Pipe Area (ft2)</td>
<td>ACFM</td>
</tr>
<tr>
<td>SCFM = ACMF * PS / TS * 17.64</td>
<td>SCFM</td>
</tr>
<tr>
<td>lbs/hour = grains/SCF * 0.000143 * SCFM * 60 min/hr</td>
<td>lbs/hour</td>
</tr>
</tbody>
</table>

#### PPM Calculation

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPM = Conc mg/L * Vol mL * L/1000 mL * 2.205e-6 lb/mg * 387 ft3/mol / VTstd * e6</td>
<td></td>
</tr>
<tr>
<td>Stack Vel ft/sec. Vs = 85.49 * Cp * SQRT Dp * SQRT(Ts/Ps/Mw)</td>
<td></td>
</tr>
<tr>
<td>Mol Wt. Wet Mw = 30 * (1-Bws) + 18 * Bws</td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Run #</td>
</tr>
<tr>
<td>----</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vt Std</th>
<th>Volume of Sample</th>
<th>Concentration</th>
<th>Molecular Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ft^3$</td>
<td>mL</td>
<td>mg/L or ppm</td>
<td>g/mole</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Molecular Weights (g/mole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO3</td>
</tr>
<tr>
<td>SO2</td>
</tr>
<tr>
<td>NH3</td>
</tr>
<tr>
<td>Cl2</td>
</tr>
<tr>
<td>HCl</td>
</tr>
<tr>
<td>F2</td>
</tr>
<tr>
<td>HF</td>
</tr>
<tr>
<td>Hg</td>
</tr>
</tbody>
</table>

#DIV/0! ppm in flue gas

387 ft3/moI at 68oF
<table>
<thead>
<tr>
<th>DATE</th>
<th>ID</th>
<th>SAMPLE PORT</th>
<th>SAMPLER</th>
<th>START TIME</th>
<th>TEST TIME</th>
<th>PRESS (in Hg)</th>
<th>PRESS (in H2O)</th>
<th>TEMP (F)</th>
<th>O2%</th>
<th>% DIA</th>
<th>VCL (cf)</th>
<th>H2O</th>
<th>DUST</th>
<th>VMSTD (SCF)</th>
<th>H2O</th>
<th>TEMP</th>
<th>ΔH</th>
<th>ISO</th>
<th>SCF</th>
<th>% GRAINS/</th>
<th>DLC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1011</td>
<td>KESTAD-1/10</td>
<td>RS</td>
<td>14.51</td>
<td>120</td>
<td>20.20</td>
<td>-0.18</td>
<td>145</td>
<td>17</td>
<td>6.16</td>
<td>0.260</td>
<td>59.038</td>
<td>223.6</td>
<td>2.00483</td>
<td>155.16</td>
<td>66.196</td>
<td>16.3</td>
<td>74</td>
<td>0.60</td>
<td>104.61</td>
<td>0.0039</td>
</tr>
</tbody>
</table>
**OPERATORS** RS

**ID** KEETAC-BHIN-M5-2

**RUN #**

**DATE** 6/16/2011

**TIME** 14:10

**FUND #** 15726

**DUST LOADING DATA SHEET**

<table>
<thead>
<tr>
<th>Sample Pt.</th>
<th>DWN LEG BH IN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traverse Pt.</td>
<td>3' IN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pb (Barometric Press.)</th>
<th>29.00 in Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation correction</td>
<td>20 ft (1 in Hg / 1000 ft)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ps (Stack Pressure)</th>
<th>-1.1 in H2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dn (Nozzle Diam.)</td>
<td>0.280 in</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Est. ΔP (Pilot)</th>
<th>0.21 in H2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cm</td>
<td>1.010</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cp</th>
<th>0.84 (Type S=.84, Std=.99)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Est. Ts (Stack Temp)</td>
<td>148 °F</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Est. % H2O</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔH@</td>
<td>1.46</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tm (Est)</th>
<th>62 °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔH (Est)</td>
<td>0.50 in Hg</td>
</tr>
</tbody>
</table>

Note: Standard Temperature and Pressure are 68 oF and 29.92 in. Hg

Coal CO2 = 18.6 * (21 - 0.02%) / 21

<table>
<thead>
<tr>
<th>Time (min.)</th>
<th>Temp stack</th>
<th>Gas Meter (ft³)</th>
<th>Tm Inlet</th>
<th>Tm Outlet</th>
<th>ΔH</th>
<th>ΔP Pilot</th>
<th>Pump Vac in Hg</th>
<th>Temp Probe</th>
<th>Temp Box</th>
<th>Temp Impinger</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>148</td>
<td>71.320</td>
<td>59</td>
<td>59</td>
<td>0.80</td>
<td>0.21</td>
<td>3.0</td>
<td>250</td>
<td>OK</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>148</td>
<td>93.385</td>
<td>68</td>
<td>61</td>
<td>0.70</td>
<td>0.21</td>
<td>4.0</td>
<td>250</td>
<td>OK</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>148</td>
<td>93.385</td>
<td>68</td>
<td>62</td>
<td>0.60</td>
<td>0.21</td>
<td>4.5</td>
<td>250</td>
<td>OK</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Averages: 148 22.065 63 0.65 0.21 3.8 250 #DIV/0! #DIV/0!
<table>
<thead>
<tr>
<th>Sample Pt.</th>
<th>DWN LEG BH IN</th>
<th>Date</th>
<th>6/16/2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run #</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fund #</td>
<td>15726</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Center #</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STOPPER TYPE</th>
<th>TYPE OF SOLUTION</th>
<th>INITIAL WT. (g)</th>
<th>FINAL WT. (g)</th>
<th>NET WT. (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight</td>
<td>DI</td>
<td>654.8</td>
<td>702.5</td>
<td>47.7</td>
</tr>
<tr>
<td>Straight</td>
<td>DI</td>
<td>615.8</td>
<td>636.3</td>
<td>20.5</td>
</tr>
<tr>
<td>Impinger</td>
<td>DRY</td>
<td>639.0</td>
<td>645.2</td>
<td>6.2</td>
</tr>
<tr>
<td>Straight</td>
<td>SIL GEL</td>
<td>960.5</td>
<td>971.6</td>
<td>11.1</td>
</tr>
<tr>
<td>Straight</td>
<td></td>
<td>0.0</td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>Straight</td>
<td></td>
<td>0.0</td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>Impinger</td>
<td></td>
<td>0.0</td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>Straight</td>
<td></td>
<td>0.0</td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>TOTAL H2O (g)</td>
<td></td>
<td>85.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| FILTER       |                 | 0.21974         | 0.22343       | 0.00369     |
| Additional Dust |             |                 |               | 0.00000     |
| TOTAL DUST (g) |                 |                 |               | 0.00369     |

| Vwstd        | 4.024 SCF       |                 |               |             |
| Vmstd        | 21.826 SCF      |                 |               |             |
| Vtstd        | 25.851 SCF      |                 |               |             |
| % H2O        | 15.6 %          |                 |               |             |
| % Isokinetic | 105.6 %         |                 |               |             |
| DCL          | 0.0026 grains/SCF |               |               |             |
| DCL - Metric | 0.0060 grams/SCM = grains/SCF*2.288 | | | |

**DUST LOADING CALCULATIONS (Concentration Basis)**

<table>
<thead>
<tr>
<th>Inlet DCL</th>
<th>grains/SCF</th>
<th>% Efficiency = (Inlet DCL - Outlet DCL) * 100</th>
<th>#DIV/0!</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Area</td>
<td>ft²</td>
<td>ACFM = VS * Pipe Area (ft²)</td>
<td>0.0000</td>
<td>ACFM</td>
</tr>
<tr>
<td>SCFM</td>
<td>SCFM = ACFM * PS/TS * 17.64</td>
<td>0.0</td>
<td>SCFM</td>
<td></td>
</tr>
<tr>
<td>lbs/hour</td>
<td>lbs/hour = grains/scf * 0.000143 * SCFM * 60</td>
<td>0.0000</td>
<td>lbs/hour</td>
<td></td>
</tr>
<tr>
<td>Equations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>---------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Page 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PS (Stack Pressure)</td>
<td>(=PB + (PS \text{ in } H_2O / 13.6) - \text{elevation}/1000) in. Hg Abs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS (Stack Temperature)</td>
<td>(=\text{average TS oF} + 460) oR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VS (Stack Velocity) ft/min</td>
<td>(=60<em>85.49</em> C_p* \text{sort}(P*TS \text{ oR} / PS \text{ in Hg Abs} / \text{MS})) ft/min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MS</td>
<td>(=30* (1-%H_2O/100) + 18* %H_2O/100) g/mol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QN (Nozzle Flow Rate)</td>
<td>(=\text{VS} \times \text{pi} \times \text{DN2} / 576) ACFM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QM (Meter Flow Rate)</td>
<td>(=\text{QM} \times \text{TM} \times \text{PS in Hg Abs}/(\text{Cm} \times \text{TS oR} \times (\text{HM}/13.6)) - (1-%H_2O/100)) ACFM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H (orifice)</td>
<td>(=\text{H} = \frac{\text{QM} \times \text{H@}}{(\text{PB} + \text{HM}/13.6)/(0.03175 \times (\text{TM} + 460))}) in H2O</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seconds/Rev</td>
<td>(=\frac{1}{(\text{QM} / 0.1 / 60)})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Page 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VWstd</td>
<td>(=0.04707 \times (H_2O \text{ g})) SCF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VMstd</td>
<td>(=17.64 \times \text{VWstd} \times \text{Cm} \times (\text{PB}+\text{HM}/13.6 - \text{Elevation}/1000)) SCF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VTstd</td>
<td>(=\text{VWstd} + \text{VMstd}) SCF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% H2O</td>
<td>(= (\text{VWstd} / \text{VTstd}) \times 100) %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Isokinetic</td>
<td>(=0.0945 \times \text{TS oR} \times \text{VMstd} \times 60 \text{sec/min} \times 144 \text{in2/ft2}) %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(=\left(\text{PS in Hg Abs} \times \text{VS} \times (\text{DN2/4*pi}) \times \text{time min} \times (1-%H_2O/100)\right))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCL</td>
<td>(=15.43 \times (\text{dust g}) / \text{VMstd}) grains/SCF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Efficiency</td>
<td>(=((\text{Inlet DCL} - \text{Outlet DCL}) / \text{Inlet DCL}) \times 100) %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACMF</td>
<td>(=\text{VS} \times \text{Pipe Area (ft2)}) ACFM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCFM</td>
<td>(=\text{ACFM} \times \text{PS} / \text{TS} \times 17.64) SCFM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lbs/hour</td>
<td>(=\frac{\text{grains/SCF} \times 0.000143 \times \text{SCFM} \times 60 \text{min/hr}}) lbs/hour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PPM Calculation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPM</td>
<td>(=\text{Conc mg/L} \times \text{Vol mL} / \text{L/1000 mL} \times 2.205e-6 \text{lb/mg} \times 387 \text{ft3/mol} / \text{VTstd} \times e6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stack Vel ft/sec.</td>
<td>(=85.49 \times C_P \times \text{SQRT Dp} \times \text{SQRT(Ts/Ps/Mw)})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOL Wt. Wet</td>
<td>(=30 \times (1-Bws) + 18 \times Bws)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Run #</td>
<td>Start Time</td>
<td>Fund #</td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>-------</td>
<td>------------</td>
<td>--------</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vt Std</td>
<td>ft^3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume of Sample</td>
<td>mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentration</td>
<td>mg/L or ppm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Weight</td>
<td>g/mole</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Molecular Weights (g/mole)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SO3</td>
<td>80.06</td>
</tr>
<tr>
<td>SO2</td>
<td>64.06</td>
</tr>
<tr>
<td>NH3</td>
<td>17.04</td>
</tr>
<tr>
<td>Cl2</td>
<td>70.90</td>
</tr>
<tr>
<td>HCl</td>
<td>36.46</td>
</tr>
<tr>
<td>F2</td>
<td>38.00</td>
</tr>
<tr>
<td>HF</td>
<td>20.02</td>
</tr>
<tr>
<td>Hg</td>
<td>200.59</td>
</tr>
</tbody>
</table>

#DIV/0! ppm in flue gas

387 ft^3/mol at 68oF
<table>
<thead>
<tr>
<th>DATE</th>
<th>ID</th>
<th>SAMPLE PORT</th>
<th>SAMPLER</th>
<th>START TIME</th>
<th>TEST TIME</th>
<th>PRESSURE (in Hg)</th>
<th>PRESSURE (in H2O)</th>
<th>TEMP (F)</th>
<th>NOZ</th>
<th>METER VOL (cf)</th>
<th>H2O</th>
<th>DUST</th>
<th>VMSTD (SCF)</th>
<th>H2O</th>
<th>TEMP</th>
<th>ΔH</th>
<th>ISO</th>
<th>SCF</th>
</tr>
</thead>
<tbody>
<tr>
<td>06/18/2011</td>
<td>SBT60074-M5-2</td>
<td>DOWN LEG B+ IN</td>
<td>RS</td>
<td>1:41:05</td>
<td>0:45:00</td>
<td>29.00</td>
<td>-1.1</td>
<td>448</td>
<td>0.00</td>
<td>0.21</td>
<td>22.065</td>
<td>85.5</td>
<td>0.00369</td>
<td>21.826</td>
<td>28.88</td>
<td>15.6</td>
<td>0.03</td>
<td>155.8</td>
</tr>
</tbody>
</table>
APPENDIX C

COMPLETE SORBENT TRAP AND CMM COMPARISON DATA

(Copies of the original sorbent trap data sheets and the CMM data are available upon request.)
<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Units</th>
<th>1A</th>
<th>1B</th>
<th>1A</th>
<th>1B</th>
<th>2A</th>
<th>2B</th>
<th>2A</th>
<th>2B</th>
<th>3A</th>
<th>3B</th>
<th>3A</th>
<th>3B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trap ID</td>
<td></td>
<td>88413</td>
<td>88410</td>
<td>88425</td>
<td>88419</td>
<td>88443</td>
<td>88406</td>
<td>88423</td>
<td>88376</td>
<td>88402</td>
<td>88417</td>
<td>88420</td>
<td>88385</td>
</tr>
<tr>
<td>Duration</td>
<td>min</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
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**Removal (sorbent trap)**

| %      |        | 77.9  | 86.4  | 79.2  |

**Removal (CMM)**

| %      |        | 82.0  | 88.1  | 80.2  |

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<td></td>
<td>4.52</td>
<td>0.451</td>
<td>4.21</td>
<td>0.290</td>
<td>4.30</td>
<td>0.093</td>
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<tr>
<td>Std. Dev. µg/Nm³</td>
<td></td>
<td>0.076</td>
<td>0.078</td>
<td>0.123268</td>
<td>0.055</td>
<td>0.066525</td>
<td>0.056</td>
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<tr>
<td>RSD (sorbent trap to CMM) %</td>
<td></td>
<td>5.231</td>
<td>15.846</td>
<td>7.847127</td>
<td>20.594</td>
<td>8.049454</td>
<td>43.042</td>
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<tr>
<td>Removal (CMM) %</td>
<td></td>
<td>90.0</td>
<td>93.1</td>
<td>97.8</td>
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