



**NTH Consultants, Ltd.**

Infrastructure Engineering  
and Environmental Services

608 S. Washington Avenue  
Lansing, MI 48933  
517.484.6900  
517.485.8323 Fax

Ms. Mary Ann Dolehanty  
Unit Supervisor, Permit Section  
Michigan Department of Natural Resources & Environment  
Air Quality Division  
P.O. Box 30473  
Lansing, MI 48909

May 3, 2010  
NTH Project No. 16-060556

**RE: Response to Request for Information  
Holland Board of Public Works  
Application 25-07**

**RECEIVED**

**MAY 03 2010**

**AIR QUALITY DIV.**

Dear Ms. Dolehanty:

In response to your letter dated March 10, 2010 and as a result of comments received during the open public comment period, the Holland Board of Public Works (HBPW) is providing information regarding why the use of the PM<sub>10</sub> surrogacy policy is technically and legally justified for the proposed project and how the proposed project will meet the requirements of best available control technology (BACT) for PM<sub>2.5</sub>. An ambient impact analysis demonstrating that the proposed project will meet the national ambient air quality standard (NAAQS) for emissions of PM<sub>2.5</sub> in response to item number 2 of your March 10, 2010 letter will be submitted under separate cover.

Attachment A to this letter provides a detailed analysis of the technical and legal justifications for use of the PM<sub>10</sub> surrogacy policy. Appendix I attached to this letter updates the existing application and provides a detailed BACT analysis for emissions of PM<sub>2.5</sub> from the proposed project and demonstrates that the selection of BACT for PM<sub>10</sub> satisfies the requirement for BACT for PM<sub>2.5</sub>.

If you have any further questions, please feel free to contact us at (517) 484-6900.

Sincerely,

NTH Consultants, Ltd.

  
Jeffrey P. Jaros  
Project Manager

  
Delbert Rector, P.E.  
Senior Vice President

Enclosure

cc: Mr. Vrajesh Patel, Michigan Department of Environmental Quality  
Mr. David Koster, Holland Board of Public Works  
Charles Denton, Esquire, Barnes & Thornburg LLP  
Mr. Daniel Mitas, HDR|CB

JPJ/DR/mjb



## **1.0 PM<sub>10</sub> IS A REASONABLE SURROGATE FOR PM<sub>2.5</sub> BECAUSE IT IS IMPOSSIBLE TO SATISFY PSD REQUIREMENTS FOR PM<sub>2.5</sub>**

U.S. EPA did not establish the PM<sub>10</sub> Surrogate Policy as a matter of convenience; the policy was established because U.S. EPA determined that it was administratively impracticable to require sources or permitting agencies to implement the Prevention of Significant Deterioration (PSD) program for PM<sub>2.5</sub> because of significant technical difficulties. U.S. EPA explicitly identified the following difficulties: (1) lack of availability of necessary data for calculating direct PM<sub>2.5</sub> emissions; (2) lack of a modeling system designed to include precursor emissions and account for secondary fine particle formation that would incorporate a method for assessing local impacts from individual point sources; and (3) lack of PM<sub>2.5</sub> ambient air monitoring. In the Trimble order, U.S. EPA cites the 2008 implementation rule for the proposition that “these difficulties have largely been resolved.” Trimble Order at 44. However, neither the 2008 implementation rule nor the Trimble order itself provides any explanation as to how U.S. EPA arrived at this conclusion. When examined more closely, it quickly becomes apparent that these “difficulties” have not, in fact, been resolved.<sup>1</sup>

### **A. Test Methods/Emission Factors**

Fundamental problems still exist with U.S. EPA’s reference test methods for PM<sub>2.5</sub> emissions and, as a result, with the available emissions factors. Most notably, no generally accepted method has yet been established for accurately determining the condensable fraction of direct PM<sub>2.5</sub> emissions. U.S. EPA also has not promulgated a test method for filterable PM<sub>2.5</sub>.

It is well recognized that there are serious issues with the current condensable PM test method (Method 202).<sup>2</sup> Primarily, there is the potential for artifact formation leading to unpredictable variations in measured emissions and results that are biased high. U.S. EPA has recently proposed changes to Method 202 to address these issues. While the proposed revision may be an improvement, the existing condensable PM emissions data that could be used in a PM<sub>2.5</sub> analysis is based on the existing Method 202 and, thus suffers from the same serious issues related to accuracy.

For filterable PM, U.S. EPA has promulgated two test methods that are typically used to demonstrate compliance with permit limits; Method 5 and Method 201A. Method 5 does not

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<sup>1</sup> See, e.g., UARG Comments, Proposed Rule to Extend the Administrative Stay of the Permit “Grandfathering” Provision of the New Source Review Implementation Rules for the PM<sub>2.5</sub> National Ambient Air Quality Standards, EPA Docket No. EPA-HQ-OAR-2003-0062 (Aug. 24, 2009) (Attachment 1).

<sup>2</sup> 74 Fed. Reg. 12970 (Mar. 25, 2009); see also, UARG Comments, Methods for Measurement of Filterable PM<sub>10</sub> and PM<sub>2.5</sub> and Measurement of Condensable Particulate Matter Emissions From Stationary Sources, EPA Docket EPA-HQ-OAR-2008-0348 (May 26, 2009) (Attachment 2).



address particle size while Method 201A currently only addresses  $PM_{10}$ . U.S. EPA recently proposed changes to Method 201A to allow for the collection of filterable  $PM_{2.5}$  as well as  $PM_{10}$ . Method 201A, including the revised version, cannot be used in wet stacks, stacks with a diameter of 18 inches or less, or stacks with a temperature greater than  $260^{\circ}C$ .<sup>3</sup> The limitations of the method are one of the reasons why Method 5 is often used for  $PM_{10}$  compliance demonstrations with the assumption that all of the PM collected is  $PM_{10}$ . As with  $PM_{10}$ , U.S. EPA recommends the use of Method 5 for  $PM_{2.5}$  testing in such situations with the assumption that all the PM collected is  $PM_{2.5}$ . While that has been accepted for  $PM_{10}$ ,  $PM_{2.5}$  is presumed to be a much smaller fraction of the filterable PM emissions and assuming all the PM is  $PM_{2.5}$  will lead to significant overestimation of emissions and ambient impacts. U.S. EPA, in the context of emission inventories, even cautions against assuming that Method 5 data provide a reasonable estimate for  $PM_{10}$  emissions, much less  $PM_{2.5}$ , which will result in greater inaccuracies.<sup>4</sup>

Because of the test method issues described above, there is a paucity of reliable and accurate information available on  $PM_{2.5}$  emissions or the capability of air pollution control devices to control  $PM_{2.5}$  emissions.<sup>5</sup> U.S. EPA acknowledged that it was proposing the revised test methods for primary  $PM_{2.5}$  because of questions about the accuracy of existing emissions data, particularly for condensable emissions.<sup>6</sup> The  $PM_{2.5}$  specific data that do exist should be viewed with skepticism, particularly when comparing data to estimate emissions or control technology capability, because of the lack of reliable uniform test methods.

Thus, despite U.S. EPA's claims that the technical difficulties identified in the Surrogate Policy have been resolved, sufficient reliable and accurate data still do not exist to compare and contrast emissions control alternatives for  $PM_{2.5}$  or to reliably establish a  $PM_{2.5}$  emission limit.

## **B. Modeling System**

The New Source Review (NSR) regulations were promulgated primarily to address the local and near-scale impacts (i.e., less than 50 km from source) of criteria pollutants from certain emission sources. As such, models were specifically developed to aid regulators and applicants in determining these local impacts for permitting purposes. Appendix W to 40 CFR Part 51 provides the regulatory approvals and protocols for performing the ambient impact analyses required by NSR. The currently approved and accepted dispersion model for NAAQS and PSD Increment analyses as required by the NSR regulations is AERMOD.

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<sup>3</sup> 74 Fed. Reg. at 12974.

<sup>4</sup> 74 Fed. Reg. at 12976.

<sup>5</sup> See Standards of Performance for Coal Preparation Plants, 40 C.F.R. 60, Subpart Y, 73 Fed. Reg. 22901, 22906, (Apr. 28, 2008) (acknowledging the lack of sufficient performance test data to establish a  $PM_{10}$  or  $PM_{2.5}$  limit for coal processing and conveying equipment, coal storage systems, and transfer and loading system).

<sup>6</sup> 74 Fed. Reg. at 12972.



AERMOD is a steady-state Gaussian plume dispersion model that treats all pollutant emissions as aerosols, or gases, and was developed to predict impacts from the direct emission of pollutants from stationary sources. When run in the Regulatory DFAULT mode, as prescribed by U.S. EPA for regulatory applications, AERMOD does not account for particle size or mass. With the exception of simple exponential decay for sulfur dioxide (non-DFAULT option), AERMOD does not have the ability to perform chemical transformations. Consequently, AERMOD cannot handle the complex chemical reactions that occur between pollutants to produce secondary pollutants known to contribute to  $PM_{2.5}$ .

$PM_{2.5}$  can either be emitted directly from an emission source as a solid (filterable) or condensable, and it can form in the atmosphere as a result of the chemical interaction between pollutants. AERMOD has been developed to primarily predict local and near-scale impacts from the direct emission of the filterable fraction of  $PM_{2.5}$ ; although, most regulatory modeling applications assume that the condensable fraction of  $PM_{2.5}$  acts exactly as the filterable fraction when emitted from a stack and include these emissions when performing the ambient impact analysis.

The current guidance for handling the secondary particulate formed as a result of chemical transformation is contained in the U.S. EPA document titled “Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone,  $PM_{2.5}$ , and Regional Haze” (EPA-454/B-07-002, April 2002), and is for states and tribes to use in SIP development. This guidance prescribes states and tribes to use CAMx, CMAQ, or UAM-V, or other approved Lagrangian photochemical grid model.

These Lagrangian models are regional-scale models intended to assist states and regional planning organizations in developing regulations and control requirements for attainment demonstrations. These models do not have the ability to resolve small or local-scale impacts from one or only a few sources. Typically, the grid resolution of these models is 12-36 km, but can be as little as 4 km, and cover modeling domains several hundred kilometers on a side. Because of the intensive computation requirements necessary to develop appropriate input data (emissions, meteorological), these models must be run on extremely fast computers with specialized operating systems and take days and even weeks to run.

Since U.S. EPA has not promulgated a modeling system that appropriately accounts for the local-scale phenomenon and impacts required under NSR, HBPW has appropriately relied on the  $PM_{10}$  NAAQS compliance demonstration as a surrogate for demonstrating compliance with the  $PM_{2.5}$  NAAQS.

### **C. PSD Increments for $PM_{2.5}$**

As its name suggests, the core requirement of the PSD program is to prevent significant deterioration of air quality. The way this is accomplished is by using computer dispersion models



to predict the contribution to ambient levels from the project itself and to determine whether this contribution together with the contributions of other relevant projects exceed the allowable air quality increment. This core requirement cannot be met for PM<sub>2.5</sub> because U.S. EPA has not established an increment for PM<sub>2.5</sub>. Letter from Gregg Worley, U.S. EPA Region IV to Sean Alteri, Kentucky Division of Air Quality (October 2, 2009). No case-by-case “reasonableness” determination will change this fact. It is simply not possible to meet this core PSD requirement for PM<sub>2.5</sub>.

The bottom line is that neither key PSD requirement – the technology analysis or the air quality analysis – can be completely implemented for PM<sub>2.5</sub> and no “reasonableness” inquiry will change that fact.

## **II. PM<sub>10</sub> IS A REASONABLE SURROGATE FOR PM<sub>2.5</sub> AT HBPW**

HBPW carefully reviewed the surrogate case law identified by U.S. EPA in the Trimble Order and concluded that in each of the cases cited by U.S. EPA, the agency sought to use a surrogate as a matter of convenience as compared to the scientific and technical necessity that led the issuance of the Surrogate Policy back in 1997. Even if a case-specific reasonableness determination were required, the facts overwhelmingly support the conclusion that PM<sub>10</sub> is a reasonable surrogate for PM<sub>2.5</sub> at the CFB Unit 10 project. While U.S. EPA failed in the Trimble Order to provide an explanation of what a permittee or a permitting authority must actually do to satisfy the new case-by-case demonstration requirement, the Agency did make a few suggestions as to what might be needed. U.S. EPA concluded that a PM<sub>10</sub> reasonableness determination would need to assess (1) the effectiveness of the emission controls with regard to PM<sub>2.5</sub> as compared with PM<sub>10</sub> and (2) the differences in atmospheric dispersion properties of PM<sub>2.5</sub> as compared to PM<sub>10</sub>. Trimble Order at 44. U.S. EPA suggested two steps as a possible approach to demonstrating that PM<sub>10</sub> is a reasonable surrogate for PM<sub>2.5</sub>. First, U.S. EPA suggests that the source or permitting authority should establish in the record “a strong statistical relationship between PM<sub>10</sub> and PM<sub>2.5</sub> emissions from the proposed unit, both with and without the proposed control technology in operation.” Trimble Order at 45. This appears to suggest that there should be a known relationship between PM<sub>2.5</sub> emissions levels and PM<sub>10</sub> emissions levels, such that an increase or reduction in PM<sub>2.5</sub> emissions necessarily would be reflected in a predictable way in the level of PM<sub>10</sub> emissions. U.S. EPA cautions that a simple ratio of AP-42 emissions factors or a ratio derived from a single stack test would not provide a sufficient correlation. Instead, an engineering analysis or a review of existing testing data from similar sources over a range of conditions would be needed. This is a curious criterion since surely U.S. EPA must know that since they have not promulgated a test method for PM<sub>2.5</sub>, there can be no confident comparison between of emission tests, even if tests based on some trial protocol are available. U.S. EPA has



already considered in establishing emission factors in AP-42 the then available data to suggest that there is a ratio between  $PM_{10}$  and  $PM_{2.5}$  for some tested sources.

Second, the permittee or permitting authority should show “that the degree of control of  $PM_{2.5}$  by the control technology selected in the  $PM_{10}$  BACT analysis will be at least as effective as the technology that would have been selected if a BACT analysis specific to  $PM_{2.5}$  emissions had been conducted.” *Id.* When applied to the CFB Unit 10 project, these factors strongly support the use of  $PM_{10}$  as a surrogate for  $PM_{2.5}$ . Through this analysis, HBPW demonstrates that for each emission unit at the proposed site 1) the available data show a consistent relationship between  $PM_{2.5}$  and  $PM_{10}$  emissions, and 2) the pollution control technologies that establish BACT for  $PM_{10}$  are also the best technologies for controlling direct  $PM_{2.5}$ . Following the emission unit specific organization of the BACT analysis presented in the previously submitted permit application for the ASCPC project, technical information justifying the reasonableness of the  $PM_{10}$  Surrogate Policy is presented below. Each position is supported by the detailed  $PM_{2.5}$  BACT analysis in Appendix I.

#### A. CFB Boiler

This unit is reviewed relative to the relationship between  $PM_{10}$  and  $PM_{2.5}$  emissions and the control technology.

##### 1. Relationship Between $PM_{10}$ and $PM_{2.5}$ Emissions

It is not possible to establish a strong statistical relationship between  $PM_{10}$  and  $PM_{2.5}$  for CFB multiple fuel fired boiler based on a comparison of test data since there is no test data available which is based on an approved test protocol. Consideration of both  $PM_{10}$  and  $PM_{2.5}$  must take into account the filterable and condensable portions of the emission. It is generally regarded that all of the condensable portion of emissions from a coal fired boiler will be  $PM_{2.5}$ . AP-42 lists condensable particulate from a coal fired boiler as being all less than 0.1 micron.<sup>7</sup>

The condensable component, 0.013 lb/MMBtu, is the same for  $PM_{10}$  and  $PM_{2.5}$ , and this is over 50 percent of the total  $PM_{10}$ , and therefore the control technology for condensable  $PM_{10}$  and  $PM_{2.5}$  would be identical.

For filterable particulate, AP-42, does not show the cumulative particle size distribution and size specific emission factors from a CFB coal fired boiler. The data presented in AP-42 Table 1.1-6 for a pulverized coal fired boiler indicates that  $PM_{2.5}$  is approximately 58% of  $PM_{10}$ . Table 1.1-9 for a stoker fired boiler indicates that  $PM_{2.5}$  is approximately

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<sup>7</sup> AP-42 Chapter 1.1 Table 1.1-5, footnote a



43% of  $PM_{10}$ . While a CFB boiler would be expected to be in between these two methods of firing, the information is not relied on because the data is relatively old, last updated in 1998, and would not necessarily apply to a modern fabric filter with much lower guaranteed (BACT) emission rates than were achieved 11 years ago.

2. Technologies for  $PM_{2.5}$

The BACT and MACT analysis previously performed for this unit clearly demonstrated that fabric filter control technology was the best proven control technology for  $PM_{10}$ . To obtain the very low filterable emission rate for  $PM_{10}$  required by BACT and MACT analysis for this unit (0.012 lb/MMBtu and 0.011 lb/MMBtu, respectively), a highly efficient filtering media must be used. Since these are truly technology forcing emission limits, there are very few  $PM_{10}$  tests that have been conducted, and no published  $PM_{2.5}$  test data. Appendix I demonstrates that BACT for  $PM_{2.5}$  is the same as for  $PM_{10}$ .

Therefore, use of the Surrogate policy is appropriate for this source.

**B. Material Handling Equipment**

Potential PM,  $PM_{10}$  and  $PM_{2.5}$  emissions from the material handling sources were included in Section 3 of the application, with example calculations, and details were provided in Appendix B.

1. Unenclosed Fugitive Emission Sources

These sources include the ship (barge) unloading pile, active and long term storage piles, bulldozing on the piles, reclaim hoppers, and paved roads. These sources exist to receive, convey and provide long term storage of coal. The overall emissions from coal handling are minimized through the implementation of a fugitive dust control plan.

The emission calculations for ship unloading were made using the emission factors from the drop point equation in AP-42 Chapter 13.2.4 for Aggregate Handling and Storage Piles. AP-42, Chapter 13.2.4 provides multipliers for PM particles with various aerodynamic diameters including  $PM_{10}$  and  $PM_{2.5}$ . The  $PM_{2.5}$  multiplier was updated in 2006 based on a study conducted by the Midwest Research Institute (MRI).<sup>8</sup> The emissions from the ship unloading, active and long term storage piles have been estimated using Section 13.2.5, Industrial Wind Erosion, from the AP-42. Chapter 13.2.5 also

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<sup>8</sup> Midwest Research Institute, Background Document for Revisions to Fine Fractions Ratios Used for AP-42 Fugitive Dust Emission Factors, November 1, 2006. The testing was conducted using federal reference method (FRM) samplers instead of the cyclone/impactor method that previously had been used to develop the AP-42 emission factors. The reason for conducting this study highlights the concerns with the lack of promulgated test methods and the unavailability of comparable data to perform any sort of meaningful statistical analysis.



provides multipliers for PM particles with various aerodynamic diameters including PM<sub>10</sub> and PM<sub>2.5</sub>. The PM<sub>2.5</sub> factor is based on another MRI study from 2006.<sup>9</sup>

The emission calculations for the bulldozing activities were made using the emission factors from AP-42 Chapter 13.2.2 for Unpaved Roads. AP-42, Chapter 13.2.2 provides multipliers for PM particles with various aerodynamic diameters including PM<sub>10</sub> and PM<sub>2.5</sub>. The PM<sub>2.5</sub> factor is based on the same MRI study cited in reference 3.

The emission calculations for the paved roads were made using the emission factors from AP-42 Chapter 13.2.1 for Paved Roads. AP-42, Chapter 13.2.1 provides algorithms for PM particles with various aerodynamic diameters including PM<sub>10</sub> and PM<sub>2.5</sub>. The PM<sub>2.5</sub> algorithm is based on the same MRI study cited in reference 3.

BACT for the fugitive emissions from the transfer of coal from the ship to the stockout pile is the use of dust palliatives to reduce drop height.

BACT for the active coal pile is the implementation of the fugitive dust control plan. BACT for the inactive coal pile is compaction and the implementation of the fugitive dust control plan. Once compacted, the inactive portion of the pile will be encrusted with a dust palliative.

BACT for the bulldozing activity is the use of wet suppression. The outdoor reclaim hoppers are generally overflowing with coal, so there are no “drop” emissions to the outdoors.

As the BACT analysis for PM<sub>2.5</sub> demonstrates, HBPW is unable to identify any additional control options that could provide PM<sub>2.5</sub> control for these material handling activities at the CFB Unit 10 Project beyond those that were already evaluated in the PM<sub>10</sub> BACT analysis. Applying minimum drop heights and wet dust suppression to material transfer points increases moisture content in the material and results in a reduction in emissions. AP-42 does not distinguish any differences in control effectiveness of increasing moisture content among different particle sizes. It is therefore reasonable to assume that wet suppression results in the same control efficiency for PM<sub>10</sub> and PM<sub>2.5</sub>. EPA’s recent rulemaking, the actual data from the MRI study, and the empirical relationship expressed

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<sup>9</sup> C. Cowherd, Background Document for Revisions to Fine Fraction Ratios Used for AP-42 Fugitive Dust Emission Factors. Prepared by Midwest Research Institute for Western Governors Association, Western Regional Air Partnership, Denver, CO, February 1, 2006.



in the emission factor AP-42 algorithm all support the conclusion that wet dust suppression controls both  $PM_{10}$  and  $PM_{2.5}$  with equal effectiveness for both PM species.

The BACT control measures for paved haul roads will be included in the updated fugitive dust control plan that will include the new roads. The silt loading and the potential to become entrained in the vehicle wake will be controlled by a plant-wide speed limit, road sweeping with fabric filter control and road wetting. The speed limit, which reduces the generation of the dust, will be equally effective for both  $PM_{10}$  and  $PM_{2.5}$ . Also the capture efficiency and the control efficiency of the road sweepers or wetting should be equally effective for both  $PM_{10}$  and  $PM_{2.5}$ .

With a consistent relationship between  $PM_{10}$  and  $PM_{2.5}$  emissions, an identical list of available control options for reducing both  $PM_{10}$  and  $PM_{2.5}$  emissions from material transfer points, paved roads and storage piles, and the BACT demonstrations that the selected  $PM_{10}$  control option is expected to have equivalent control effectiveness for  $PM_{10}$  and  $PM_{2.5}$ , use of  $PM_{10}$  as a surrogate for  $PM_{2.5}$  is reasonable for the PSD review of the open fugitive sources at the CFB Unit 10 project site.

## 2. Material Handling Sources Controlled with Fabric Filters

These sources include: the limestone storage silo, the ash silo, the coal transfer house and crusher and the crushed coal storage silos.

These material handling sources result in the same estimation of uncontrolled emissions as do the unenclosed sources discussed above. Therefore the same constant relationship between the uncontrolled  $PM_{10}$  and  $PM_{2.5}$  emissions is expected.

The short-term maximum emissions were based on a  $PM_{10}$  BACT emission limit of 0.004 grains per dry standard cubic foot (gr/dscf).

In the proposed revision to NSPS Subpart Y, U.S. EPA “concluded that there are insignificant condensable PM emissions from coal processing and conveying equipment, coal storage systems, and transfer and loading systems and, therefore, decided not to establish a separate PM limit for condensable PM emissions. We also concluded that it was not appropriate to establish separate  $PM_{2.5}$  or  $PM_{10}$  limits. Based on AP-42 emission factors,  $PM_{10}$  accounts for approximately half of the total PM emissions from coal handling operations and  $PM_{2.5}$  accounts for approximately 7 percent. We have concluded that both fabric filters and chemical dust suppressants control PM equally across the size



distribution, and setting an overall PM limit is sufficient to control both PM<sub>10</sub> and PM<sub>2.5</sub>.”  
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The small percentage of PM<sub>2.5</sub> in material handling emission, the effectiveness of fabric filters in controlling PM equally across the size distributions and the fact that U.S. EPA concluded in the proposed revision to Subpart Y that there was insufficient performance test data to establish a PM<sub>2.5</sub> limit for these types of activities, and the PM<sub>2.5</sub> BACT analysis supports the continued use of the Surrogate Policy for these material handling activities.

### C. Cooling Towers

The cooling towers will reject heat picked up from the condenser circulating water to the outdoor air, primarily through evaporation of a portion of the circulated cooling water. This evaporated cooling water will be released to the environment as a vapor. A very small portion of the circulating water flow is released in the form of water droplets. These droplets, referred to as “drift”, may contain dissolved mineral compounds. As the water droplets evaporate into the air, the mineral compounds will precipitate as a solid, in the form of a particulate emission. To control the amount of drift, the cooling tower will be equipped with mist eliminators designed to limit drift to 0.0005% of the circulating water flow.

The original estimate of these particulate emissions was made according to AP-42 Section 13.4. According to this document “a *conservatively high* PM<sub>10</sub> emission factor can be obtained by (a) multiplying the total liquid drift factor by the total dissolved solids (TDS) fraction in the circulating water and (b) assuming that, once the water evaporates, all remaining solid particles are within the PM<sub>10</sub>size range.”

The application did not distinguish between PM, PM<sub>10</sub> and PM<sub>2.5</sub> emissions (i.e., assumed that they were equal). However, a paper entitled “*Calculating Realistic PM<sub>10</sub> emissions from Cooling Towers*”<sup>11</sup>, by Joel Reisman and Gordon Frisbie, provides a method for determining all size fractions of PM from a cooling tower. Using the research data and techniques from this paper, the emissions of PM<sub>10</sub> and PM<sub>2.5</sub> have been calculated.

Since both the PM<sub>10</sub> and PM<sub>2.5</sub> fractions of the cooling tower PM can be calculated using the same methodology, and the BACT analysis demonstrates that the use of the same control mechanism the continued use of the Surrogate Policy is appropriate for the cooling towers.

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<sup>10</sup> *Standards of Performance for Coal Preparation Plants: Proposed Rule*, 73 Fed. Reg. at 22906.

<sup>11</sup> Paper included as attachment to this submittal.



## APPENDIX I

### 1.0 CONTROL TECHNOLOGY REVIEW

The proposed project is considered a “major modification” at a “major stationary source” as defined in the PSD regulations at 40 CFR 52.21 because there will be a significant increase in at least one regulated NSR pollutant; specifically PM, PM<sub>10</sub>/PM<sub>2.5</sub>, and CO emissions as a result of installing the new CFB boiler. Therefore, the requirements for best available control technology (BACT) found in 40 CFR 52.21(j) will be applicable to control emissions of PM, PM<sub>10</sub>/PM<sub>2.5</sub>, and CO from the proposed modifications presented in the previous sections. While U.S. EPA has failed to promulgate a formal procedure for determining BACT limits, the BACT analyses contained in this application were performed in accordance with the definition of BACT as set forth in Section 165(a)(4) of the federal CAA, the implementing regulations at 40 CFR 52.21(b)(12), and U.S. EPA’s recommended top-down procedure outlined in the New Source Review Workshop Manual (Draft 1990). Unless noted otherwise, all BACT limits established in this application represent emissions under normal operating conditions.

### 1.1 BEST AVAILABLE CONTROL TECHNOLOGY (BACT)

Any new major source or major modification to an existing major source is required to perform an evaluation of control technologies to ensure that emissions of each regulated NSR pollutant subject to review is minimized based on the maximum degree of reduction taking into consideration several factors. In addition, BACT is preferably defined as an emission limit, not a specific control technology as identified in the definition (40 CFR 52.21(b)(12)). Only if such an emission limit is infeasible (e.g., non-measurable and thus unenforceable) is BACT a technique, design, equipment or work practice.

*Best Available Control Technology means an emissions limitation (including a visible emission standard) based on the maximum degree of reduction for each pollutant subject to regulation under the Act which would be emitted from any proposed major stationary source or major modification which the Administrator, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such source or modification through application of production processes or available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of such pollutant. In no event shall application of best available control*



## APPENDIX I

*technology result in emissions of any pollutant, which would exceed the emissions allowed by any applicable standard under 40 CFR Parts 60 and 61. If the Administrator determines that technological or economic limitations on the application of measurement methodology to a particular emissions unit would make the imposition of an emissions standard infeasible, a design, equipment, work practice, operational standard, or combination thereof, may be prescribed instead to satisfy the requirement for the application of best available control technology. Such standard shall, to the degree possible, set forth the emissions reduction achievable by implementation of such design, equipment, work practice or operation, and shall provide for compliance by means which achieve equivalent results.*

Several relevant concepts deserve additional attention.

### **1.1.1 BACT is Determined “on a case-by-case basis.”**

The permitting agency determines BACT on a “case-by-case basis,” taking into account site-specific and source-specific characteristics. *Alaska Dep’t of Env’tl. Conservation v. EPA*, 540 U.S. 461, 488 (2004). These characteristics may include, among other things, the type of fuel that will be used (*e.g.*, bituminous coal versus Powder River Basin coal), and the type (*e.g.*, CFB versus pulverized coal boiler) and size of the source (*e.g.*, 300 megawatt versus 45 megawatt). A high degree of technical judgment must also be exercised in any BACT analysis for coal-fired plants because of the wide variety of coals and coal-fired facilities. *See, e.g., In re BP Cherry Point*, 12 E.A.D. 209, 223 n.37 (EAB 2005); *In re Prairie State Generating Co.*, PSD Appeal No. 05-05 *slip op.* at 71 (EAB August 24, 2006), *aff’d sub nom. Sierra Club v. EPA*, 499 F.3d 653 (7th Cir. 2007).

### **1.1.2 BACT must be “achievable.”**

The Environmental Appeals Board (EAB) has recently stated that, while BACT is forward looking, “the word ‘achievable’... constrains the permit issuer’s discretion by prohibiting BACT limits that would require pollution reductions greater than what can be achieved with available methods.” *In re Newmont Nevada Energy Investment, LLC*, 12 E.A.D. 429, 441 (EAB 2005); *accord Prairie State*, *slip op.* at 70. The EAB concluded that “the permit issuer may take into account the absence of long-term data, or the unproven long-term effectiveness of the technology, in setting the emissions limitation that is BACT for the facility.” *Newmont*, 12 E.A.D. at 442; *see also In re Cardinal FG Co.*, 12 E.A.D. 153, 170 (EAB 2005). The EAB stated that the BACT



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analysis “must be solidly grounded on what is presently known about the selected technology’s effectiveness” and that “emissions limitations achieved by other facilities and corresponding control technologies used at other facilities are an important source of information in determining” BACT. *Newmont*, 12 E.A.D. at 441.

### **1.1.3 Technology Must Be Available.**

A control technology also must be “available” to be considered BACT. According to EPA’s draft NSR manual “[a]vailable” means that the method’s systems and techniques are commercially available. *Prairie State*, slip op. at 45 (holding that to be commercially available, a technology must be offered for sale through commercial channels). BACT also does not require the applicant to participate in a research and development project to determine if the technology is “available” for a particular use.

### **1.1.4 Technology Must Be “feasible” for the Facility.**

"Feasible" technology means technology that is commercially available and has been demonstrated on the type of source being permitted. *See Cardinal*, 12 E.A.D. at 163-64. This means that the technology has progressed beyond the conceptual stage and beyond the pilot testing phase. *Id.* at 166 ("technologies in the testing stage generally are not considered technically feasible"). The technology must have been demonstrated successfully on full-scale operations for a sufficient time to be considered proven. *Id.* at 166 (upholding permitting agency's rationale that 2 to 3 years operating history of a technology "is insufficient to satisfy the concept of demonstrated technology").

### **1.1.5 BACT Does Not Require Technologies That Are Not Proven**

Theoretical, experimental or developing technologies are not “available” under BACT. Technologies with questionable or dubious reliability are likewise not considered "available" under BACT, and the applicant is not required to use them. *See Cardinal*, 12 E.A.D. at 166-67 (finding the unpredictable effect that a technology would have on the process is a rational basis for concluding technology was infeasible). BACT does not require an applicant to speculate as to whether an undemonstrated technology will effectively control the pollutant in question on the



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proposed source. Applicants are not required to accept the risk that a theoretically feasible, but unproven, technology will actually work on the proposed source.

A control technology applicable to one source (*e.g.*, a pulverized coal boiler) may not be applicable to a different source (*e.g.*, a CFB). *Id.*; *see also Groce v. Pa. Dept. of Env'tl. Prot.*, No. 2005-246-R, slip op. at 48 (Pa. Env'tl. Hearing Bd. Nov. 22, 2006) (holding that SCR is not feasible for CFB), *aff'd*, 921 A.2d 567 (Pa. Commw. Ct. 2007), *appeal denied* 944 A. 2d 759 (Pa. 2008).

### 1.1.6 BACT Does Not Require a Fuel Other Than That Proposed

Congress added the reference to “clean fuels” to the BACT definition in 1990, with the intent that the “cleanliness” of the fuel proposed by the applicant be considered in the BACT analysis. Congress did not intend the BACT analysis to require a fuel other than that proposed by the applicant. The Senate Committee Report explained,

*Subsection (d) amends section 169(3) of the Act to insert the words "clean fuels," after "including fuel cleaning" as part of the Best Available Control Technology (BACT) determination under Prevention of Significant Deterioration provisions. The intent of this amendment is to continue the requirements for case-by-case determinations of BACT as in current law. The Committee intends that the amendment will not result in an increase in the level of emission rates found to meet BACT, when compared on a case-by-case basis to BACT determinations under current law. **The Administrator may consider the use of clean fuels to meet BACT requirements if a permit applicant proposes to meet such requirements by using clean fuel.***

***In no case is the Administrator compelled to require mandatory use of clean fuels by a permit applicant.***

*S. Rep. No. 101-228, at 338 (1989); reprinted in 5 A Legislative History of the Clean Air Act Amendments of 1990, 103<sup>rd</sup> Cong., 1<sup>st</sup> Sess., S. Prt. No. 103-38, at 8678 (1993) (emphasis added) (ISJA85).*

Compelling use of clean fuels may require an “adjustment” to the source that is outside of the scope of a BACT analysis. When that “adjustment” is more than a simple switch (*e.g.*, low sulfur coal over high sulfur coal), the “adjustment” may become a change that “redefines the source,”



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which is outside of the scope of a BACT analysis. *In Re Northern Michigan University Ripley Plant, 2009 EPA App. LEXIS 5,51.*

### 1.1.7 BACT Does Not Redefine the Proposed Facility

EPA’s long-standing interpretation of the statute, articulated for more than 18 years in guidance and in a myriad of formal permit appeal decisions by the Administrator and EAB, is that BACT does not redefine the source. *In re Prairie State* slip op at 23, 27, 29-30 (discussing guidance and decisions) Based on the statutory language requiring application of BACT to the “proposed facility,” EPA has recognized in a long line of adjudicatory precedent and guidance that the BACT process is “not a means to redefine the design of the source when considering available control alternatives.” *See, e.g.,* New Source Review Workshop Manual at B.13 (Oct. 1990) (draft) (“NSR Manual”), JA62. EPA has repeatedly stated the policy in the context of PSD permit appeals:

*Permit conditions are imposed for the purpose of ensuring that the proposed source ... uses emission control systems that represent BACT.... These control systems, as stated in the definition of BACT, may require application of “production processes and available methods, systems, and techniques...” to control the emissions.... The permit conditions that define these systems are imposed on the source as the applicant has defined it.... [T]he conditions themselves are not intended to redefine the source....*

*In re Pennsauken County, NJ Res. Recovery Facility*, 2 E.A.D. 667, 673 (Adm’r 1988) (emphasis added) (upholding agency refusal to require a coal-fueled power plant be built when a municipal waste/coal-fueled facility was proposed); *see also In re Spokane Reg’l Waste-to-Energy*, 2 E.A.D. 809, 811 (Adm’r 1989) (acknowledging EPA will not require a PSD applicant to “change the fundamental scope of its project” in reviewing BACT); *In re Hawaiian Commercial & Sugar Co.*, 4 E.A.D. 95, 99-100 (EAB 1992) (rejecting argument that BACT requires applicant to install fuel-oil fired facility instead of the proposed coal-fired facility because requiring petitioner’s “preference as to the type of boiler **and fuel to be used** ... would in effect redefine the source”) (emphasis added); *cf. In re Hibbing Taconite Co.*, 2 E.A.D. 838, 842-43 (Adm’r 1989) (finding that requiring an applicant to **continue** using natural gas instead of allowing it to switch to residual petroleum coke would not redefine the source).



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Pursuant to the EPA’s long-standing interpretation, a BACT analysis goes too far if it requires a source to change or redefine its basic purpose and design. In re: Knauf Fiber Glass, GmbH, 8 E.A.D. 121, 136 (EAB 1999), and see, e.g. Hibbing Taconite, 2 E.A.D. at 843 & n.12; Pennsauken County, 2 E.A.D. at 673. Specifically, “certain [design] aspects” of the proposed facility are beyond the reach of BACT; “other [design] aspects are within it.” *Prairie State*, slip op. at 26. If the imposition of a control technology will alter certain design aspects to the extent to “redefine the source” that control technology is beyond the scope of BACT. The test to determine if the control technology “redefines the source” is to

- (1) look to the permit applicant’s definition of the proposed facility’s purpose or basic design, and
- (2) put the applicant’s case to a “hard look.”

*Prairie State*, slip op. at 28, n23.

With respect to the first element of the test, the term “design” means “[a]s a practical matter... a schematic drawing showing the means to an end, and ‘design’ used to identify the end, object, or purpose, are inherently intertwined.” *Prairie State*, slip op. at 28. Using EPA regulations for direction, a design indicates if the source is a “‘steel mill,’ ‘municipal incineration,’ ‘taconite ore processing plant.’” *Hibbing Taconite*, 2 E.A.D. at 842 (citing 40 C.F.R. sect. 52.21(b)(1)).

Once the purpose of the facility has been defined, the next step in determining if a control technology will redefine the source requires the permitting authority to take a “hard look” at the applicant’s definition of the source. The “hard look” determines the design elements “inherent” to the stated purpose and the design elements that “may be changed to achieve pollutant emissions reductions without disrupting the applicant’s basic business purpose for the proposed facility.” *Prairie State*, slip op. at 33-34. Because BACT does not regulate the applicant’s purpose or objective for the proposed facility, design elements that would disrupt the applicant’s business object for the proposed facility cannot be “redesigned.” The inherent design elements include those elements that are part of the “fundamental purpose” of the proposed facility, including those elements that if changed would “call into question [the facility’s] existence.” *Prairie State*, slip op. at 30. Specifically, BACT review may not consider fuel choices found



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“integral” to the basic design. In re Northern Michigan University Ripley Heating Plant, 2009 EPA App. LEXIS 5, 49.

One of the “classic” projects often referred to as an example of redefining a source involves a BACT analysis for a coal-fired power plant that seeks to require consideration of alternative fuel, such as natural gas. *Knauf*, 8 E.A.D. at 137 (citing *In re Birchwood, Inc.*, 5 E.A.D. 779, 793 (Adm’r 1992)). The BACT review of a coal-fired power plant does not need to consider alternative fuel, such as a natural gas-fired unit, “even though a natural gas unit would be inherently less polluting than the coal-fired unit.” *Id.* Substitution of a gas-fired power plant for a planned coal-fired plant, other type of fuel powered plant, would amount to redefining the source. *Id.*

### 1.1.8 Top-Down BACT Analysis

The U.S. EPA has established a five-step procedure for determining the appropriate BACT limit for each subject pollutant that starts with the most stringent emission limit and lists all control technologies. This is referred to as “Top-Down” BACT and includes the following 5 steps as outlined in the Draft New Source Review Manual, dated 1990:

- 1) Identify All Control Technologies
- 2) Evaluation of All Control Technologies and Eliminating All Infeasible Options
- 3) Rank Remaining Control Technologies by Control Effectiveness
- 4) Evaluate Remaining Control Technologies Based on Energy, Environmental, and Economic Impacts of Control Options
- 5) Select BACT Based upon Consideration of Impacts

#### STEP 1 – Identify All Control Technologies

The first step in the top down procedure is to identify all control technologies and emission reduction options for each subject pollutant. Available control technologies are those with a practical potential for application to the emission unit. HBPW is employing CFB technology for the new boiler. In order to identify the appropriate control technologies, the following sources of information were referenced:



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- U.S. EPA RACT/BACT/LAER Clearinghouse (RBLC)
- U.S. EPA Control Technology Center (CTC)
- Recent Permit Actions by MDEQ and other States
- Vendor Information
- Project Experience from all parties associated with this project, including NTH Consultants, Ltd., HDR|Cummins & Barnard, Inc., and the Holland Board of Public Works
- U.S. EPA Region 7 National Coal-Fired Utility Projects Spreadsheet

### **STEP 2 – Eliminate Technically Infeasible Control Technologies**

The second step in performing the top-down BACT analysis is to eliminate all technically infeasible options. The determination that a control technology is technically infeasible is source-specific and based upon physical, chemical, and engineering principles. Two key concepts in determining whether an undemonstrated technology is feasible are: availability and applicability. A technology is considered available if it can be obtained through commercial channels. An available technology is applicable if it can be reasonably installed and operated on the source type under consideration.

### **STEP 3 – Rank Remaining Control Technologies by Control Effectiveness**

The third step in the top-down BACT analysis is to rank all remaining control technologies with respect to control effectiveness. The control technologies are ranked in order of control effectiveness (i.e., by emission limit or removal efficiency, as applicable) and are pollutant-specific. The emission limit or removal efficiency used in the ranking process is the level that the technology has demonstrated it can consistently achieve under reasonably foreseeable worst-case conditions with an adequate margin of safety. It is not a limit or removal efficiency that can sometimes be achieved.

### **STEP 4 – Evaluate Most Effective Controls and Document Results**

In this step, an analysis is performed on each remaining control technology in order to determine whether the energy, economic or environmental impacts from a given technology outweigh their



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benefits. Information including control efficiency, anticipated emission rate, expected emissions reduction, and economic, environmental and energy impacts are to be considered.

If the top-ranked technology is chosen and there are no significant or unusual environmental impacts associated with that technology that have the potential to affect its selection, the BACT analysis is complete and no further information regarding economic, environmental, and energy impacts is required. However, if the top-ranked option is not chosen, an assessment of economic, environmental, and energy impacts (taking into consideration source-specific circumstances that distinguish it from other sources where the technology is in use or has been required) is performed on the next most cost-effective technology until the technology under consideration is not eliminated.

In performing economic analyses, U.S. EPA's Air Pollution Control Cost Manual published in January 2002 (EPA/452/B-02-001) provides capital and annual operating cost factors for use in determining the economic impact of each control technology. For all analyses contained in the sections that follow, actual cost estimates and quotes from various equipment vendors were used.

### **STEP 5 – Select BACT**

The fifth, and final, step is selection of the BACT emission limit corresponding to the most stringent and technically feasible technology that was not eliminated based upon adverse economic, environmental, and energy impacts.

Finally, pursuant to 40 CFR 52.21(b)(12), the chosen BACT emission limit must not be less stringent than any applicable federal NSPS, NESHAP, or state-specific emission standard. The BACT emission limits chosen for this project are at least as stringent as applicable federal or state standards.



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### 2.0 CFB BOILER BACT EVALUATION

In response to comments received on the draft permit during the open public comment period held in December 2008 and as a result of the U.S. EPA's proposed rule to repeal the PM<sub>10</sub> surrogate policy, HBPW has prepared a control technology review for direct emissions of PM<sub>2.5</sub>. The relevant emission sources are the CFB boiler, cooling tower, and material handling. The sections that follow provide a BACT analysis of PM<sub>2.5</sub> emissions each source and follow the five step top-down procedure identified above. Pollutant-specific determinations are summarized at the end of each section.

#### 2.1 PARTICULATE MATTER (PM<sub>2.5</sub>)

Particulate matter emissions, including PM<sub>2.5</sub>, occur from a variety of processes including, the combustion of coal, handling of coal or other materials, and the operation of cooling towers. Particulate matter may be emitted as a solid, or as a condensable material. Solid particulate is measured using U. S. EPA's Method 5 sampling procedure and is commonly referred to as filterable or "front half" emissions. The condensable particulate emissions are measured using U. S. EPA's Method 202 procedure, and are commonly referred to as "back half" emissions. PM<sub>2.5</sub> is defined as particulate matter, both front-half and back-half, with an aerodynamic diameter of less than 2.5 micrometers (µm).

PM<sub>2.5</sub> emissions may consists of both filterable ("front-half") particulate and condensable ("back-half") particulate. Emissions from a combustion source such as the CFB boiler include condensable particulate matter that consists of sulfuric acid compounds, condensable organic material and possibly some nitrogen compounds, all of which exist in vapor form at the high temperatures of the boiler flue gas stream and will condense, or nucleate, into aerosol particles when cooled. Because of the differences in properties between the types of PM<sub>2.5</sub> particulate matter, and the differences in operating principle for each control technology, each technology will control filterable and condensable particulate to different efficiencies. Furthermore, some technologies, such as sorbent injection (SI), specifically remove only the inorganic (i.e. sulfuric acid) component of condensable particulate material.



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Method 202 is used to measure the condensable fraction of PM from a coal-fired utility boiler and uses impingers to capture and cool condensable particulate from the emissions stream. This method can be problematic in that secondary particulate can form in the measurement process resulting in an overstatement of the regulated particulate matter, known as artifact formation. Examples include oxidation of SO<sub>2</sub> to SO<sub>3</sub> in the impinger, ammonia slip reactions with sulfur constituents in the impinger to produce ammonium bisulfate (NH<sub>3</sub> → NH<sub>4</sub>HSO<sub>4</sub>), and absorption of soluble NO<sub>x</sub> components<sup>1</sup>. To address these problems, U. S. EPA has established a workgroup and is performing studies to address the inherent problem of artifact formation with Method 202 (i.e., the measurement of sulfates in the impinger solution as a result of chemical reactions). In the meantime, permits are being written to provide for adjustments to Method 202 to allow more accurate measurement of condensable particulate matter.

A BACT analysis is a process that determines the best available control technology for a pollutant source based on an evaluation of the measured performance of similar technology when applied to similar sources. In other words, BACT is a technology based emission limit. Because U. S. EPA has not formally promulgated a test method for PM<sub>2.5</sub> it is difficult to complete a valid BACT analysis for PM<sub>2.5</sub> emissions for the CFB boiler project that conforms to established process. Until such time as U. S. EPA promulgates an official method, and a body of test data is developed using this method, it will not be possible to complete a PM<sub>2.5</sub> analysis that is truly applicable to the standards for such an analysis. However, in the interest of evaluation of this project, certain assumptions are made regarding the pollutant emissions and effectiveness of various technologies for control of these emissions. Generally the highest control efficiency and highest incoming pollutant loading is assumed for the various technologies, resulting in the lowest cost per ton of pollutant removed. Under more realistic assumptions, the cost per ton would be higher so that if a technology is not found to be economically feasible under these assumptions, then it can not be feasible under more realistic assumptions.

### 2.1.1 Possible Control Technologies – STEP 1

PM<sub>2.5</sub> emissions from combustion sources such as the CFB boiler consist of both filterable and condensable particulate. There are control technologies that are specific to filterable particulate,

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<sup>1</sup> *Particulate Emissions – Combustion Source Emissions Dependent of Test Method*, Andracsek and Gaige, Burns & McDonnell.



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other technologies that are specific to condensable particulate and some that are effective at removing both fractions. These three groups of control technologies are listed separately below. Proven and accepted technologies such as wet electrostatic precipitators (WESP) and sorbent injection (SI), are included, as well as range of emerging technologies that have been identified as having some potential to provide enhanced control of fine particulate such as  $PM_{2.5}$ .

### **Filterable Particulate**

The following is a list of technologies specifically designed for control of filterable  $PM_{2.5}$  emissions from the CFB boiler.

- 1) Fabric Filter
- 2) Dry Electrostatic Precipitator
- 3) Wet Particle Scrubber
- 4) Mechanical Collectors (cyclone, multiclone, elutriator)
- 5) Fabric Filter with Enhanced Bags
- 6) Advanced Hybrid™ Filter Technology
- 7) Indigo Bi-Polar Agglomerator
- 8) ElectroCore® Electrostatic Centrifuge
- 9) Max-9™ Electrostatic Fabric Filter

### ***Fabric Filter (Baghouse)***

A fabric filter system consists of a structure containing fabric bags arranged in numerous rows whereby the filterable particulate matter is captured on the surface of the bags as the flue gas passes through the filter bags. Particles are “removed”, or filtered, from the exhaust gas by various mechanisms, including inertial impaction and impingement, as the gas passes through the fabric bags. The accumulated particles (“dust cake”) are periodically removed from the bags using either mechanical or pneumatic means.

Fabric filters achieve high removal efficiencies by designing the system with an air-to-cloth ratio that ensures that the exhaust gas velocity through the bags is low enough to allow the dust to accumulate on the surface of the filter bags and not penetrate through the filter medium. This build up of dust on the surface effectively increases the removal efficiency of the bags. Typical



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collection efficiencies for a fabric filter system are on the order of 99.5 percent for particles down to 2.5 microns in size.

Fabric filters are typically installed in three basic designs referring to how the filter cake is removed from the filter media: pulse jet, mechanical shaker, and reverse gas. With pulse jet fabric filters, as a filter cake forms on the outside of the bags, a pulse of air is blown vertically down the inside of the bags to dislodge the filter cake, which falls into a hopper for collection. In mechanical shaker fabric filters, the bags are mechanically shaken to remove the accumulated filter cake. In reverse gas units, flue gas from the clean side of the fabric filter is forced through the bags in the opposite direction of normal flow to remove the particulate cake.

### ***Dry Electrostatic Precipitators (DESP)***

Dry electrostatic precipitators remove particles from a gas stream through the use of electrical currents and forces. Dust laden flue gas flows through channels formed by vertical collection plates mounted in the precipitator box. Discharge electrodes with a high electrical potential are located at the center of the channels between the collection plates to provide a negative charge to the dust particles as the flue gas flows between the plates. The collection plates are grounded and attract the negatively charged dust particles. The dust collected on the collecting plates is periodically removed by rapping or vibrating the plates, promoting the dust to fall into collection hoppers at the bottom of the precipitator.

### ***Mechanical Collectors***

Mechanical collectors are often referred to as “pre-cleaners” since these function most often to remove large particles upstream of the primary particulate control device. The most common type of mechanical collector is a cyclone and operates on the principle of centrifugal separation to remove particles from the gas stream. The incoming gas stream enters the conical-shaped cyclone and the centrifugal force of the accelerated gas stream forces the particles to the cyclone wall. The gas stream enters the top of the cyclone and is forced downward through the cyclone in a spiral path. Once the gas stream reaches the bottom of the cyclone, it is then forced upwards in the center of the cyclone and discharged. The particulate that has migrated to the wall of the cyclone falls out of the bottom of the cyclone chamber due to gravity.



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### ***Wet Particle Scrubbers***

Wet particle scrubbers remove particulate through impaction of the particulate in the flue gas stream with water droplets generated in the wet particle scrubber. The water droplets are separated from the flue gas and the particulate is removed from the system as slurry. Water droplets are produced through a variety of mechanisms such as atomized water sprays, or shear, as the flue gas is accelerated through a venturi. Particulate removal efficiency is a function of the degree of impaction of the particulate with the water droplets, which is essentially promoted by turbulent mixing of the flue gas. High flue gas pressure losses are generally required to promote the turbulent mixing needed to achieve high PM removal efficiencies; thus requiring more fan energy.

Historically, wet particle scrubbers for utility boiler applications have used wet venturi scrubbers, where the turbulent mixing of the PM laden flue gas, generation of water droplets, and impaction of the droplets and PM occur as the flue gas is accelerated through the throat of the venturi. These systems were generally applied to pulverized coal boilers in conjunction with wet flue gas desulfurization systems to achieve economies through integrated scrubber modules and shared systems, such as sludge disposal. There are no instances where a wet particle scrubber has been applied to a CFB utility boiler.

### ***Fabric Filter with Enhanced Bags***

Fabric filters for control of filterable particulate material on coal fired power plants generally use felted PPS (polyphenylene sulfide) or P84 (polyimide) bags. These bags have been found to provide high efficiency for collecting filterable particulate along with resistance to the environments of these applications, allowing for bag life-spans in the range of three to five years. Recently, enhanced types of filter media have emerged that appear to be capable of operating in the chemical and thermal environment of a power plant and have been shown in laboratory testing to achieve higher collection efficiencies. These enhanced media types either have a micro-porous membrane coating, generally consisting of expanded polytetrafluoroethylene, or have a surface layer of finer denier (smaller diameter) fibers than “conventional” bags.



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### ***Advanced Hybrid™ Filter Technology***

The Advanced Hybrid™ Filter Technology integrates dry electrostatic precipitation with fabric filtration. Exhaust gas is directed first to the DESP zone, which removes a majority of the larger particulate. The exhaust gas exits the DESP zone through perforations in the DESP plates and passes into a fabric filter section where it travels through filter bags. Pulse jets clean the filter bags in similar fashion to a pulse jet fabric filter and the collected dust falls into hoppers located at the base of the filters. This dislodged dust falls through the DESP zone of the device, minimizing re-entrainment of dust. This technology has been patented by the University of North Dakota's Energy and Environmental Research Center (EERC).

### ***Indigo Bi-Polar Agglomerator***

The Indigo Bi-Polar Agglomerator is a process developed by Indigo Technologies that uses alternating electrical charges to enhance particulate control in a downstream electrostatic precipitator. The flue gas is first split into two streams. Particles in one stream are positively charged while particles in the second stream are negatively charged. Once the two flue gas streams exit the separate charging mechanisms, they combine in a mixing chamber and the positive and negatively charged particles are attracted to each other and agglomerate to larger particles, which are more efficiently captured in a conventional DESP located downstream.

### ***ElectroCore® Electrostatic Centrifuge***

The ElectroCore® Electrostatic Centrifuge has been developed by EPRI and LSR Technologies, and it is mainly used to augment underperforming electrostatic precipitators. The ElectroCore® Electrostatic Centrifuge typically consists of an array of cylindrical core separators, each with a tangential inlet, a tangential outlet, and two axial outlets. The core separators employ electrostatic and centrifugal forces to concentrate and separate particulate matter from an exhaust stream. The incoming particles are precharged in a precharger and enter the core separators along their outer wall. A large-diameter electrode, placed along the separator's central axis, is given an electric charge of the same polarity as the particles to create an electric field that induces a radial outward electrical force on the charged particles. The combined electrical and centrifugal forces cause the particles to remain in the near-wall region where they are extracted with the bleed flow from the tangential outlet slot. The clean flow is extracted axially from the ends of the separators. The bleed



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flow, which is about 10 percent of the clean flow, is directed either back to the inlet of the upstream ESP or to a separate collector.

### ***Max-9™ Electrostatic Fabric Filter***

The Max-9™ Electrostatic Fabric Filter is a particulate removal device offered by BHA/GE Energy. It is an electrostatic fabric filter that operates as a hybrid of a pulse-jet fabric filter and high efficiency electrostatic precipitator. In this technology, filter bags with charged metal inserts are used instead of collecting plates. The particles repel each other on the filter bags, making the dust-cake extremely porous, which reportedly improves the performance and reduces filter pressure drop.

### **Condensable Particulate**

The following is a list of technologies specifically designed for control of condensable PM<sub>2.5</sub> emissions from the CFB boiler.

- 1) Limestone Injection (LI)
- 2) Dry Flue Gas Desulfurization (DFGD)
- 3) Sorbent Injection (SI)
- 4) Integrated Flue Gas Treatment (CHX™-IFGT)
- 5) Electro-Catalytic Oxidation ECO™ Process

The following sections provide a brief description of the above control technology options for condensable PM<sub>2.5</sub> for the CFB boiler.

### ***Limestone Injection (LI)***

In limestone injection (LI), crushed limestone (primarily calcium carbonate) is injected into the CFB boiler. The crushed limestone forms a portion of the recirculating fluidized bed inside the boiler. The limestone reacts with sulfur compounds from the boiler fuel to form solid phase calcium sulfur compounds that exit the boiler with bed ash or as filterable particulate entrained in the flue gas. LI is primarily effective at controlling PM<sub>2.5</sub> emissions by removing sulfur trioxide (SO<sub>3</sub>), which will condense in the flue gas stream to produce sulfuric acid mist (H<sub>2</sub>SO<sub>4</sub>) and will be



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measured as back-half (condensable)  $PM_{2.5}$ . It provides no significant removal of other (non-sulfuric acid) condensable  $PM_{2.5}$  or filterable  $PM_{2.5}$ .

### ***Dry Flue Gas Desulfurization (DFGD)***

Dry flue gas desulfurization systems (DFGD) are primarily intended for control of  $SO_2$  emissions, but are effective at removing acid gases, such as  $SO_3$  and HCl, as a co-benefit. There are two major sub-types of DFGD systems; spray dryer absorbers and circulating fluidized bed scrubbers. These systems both operate on the same basic principle; injection of sorbent with a controlled quantity of moisture to absorb the target pollutants. Spray dryers finely atomize a slurry of sorbent and water into the flue gas stream, whereas fluidized bed systems inject dry powdered sorbent along with water into a reactor designed to support a fluidized bed. These systems differ from SI systems in that they include more elaborate and effective means for contacting the sorbent reagent with the flue gas, thus insuring higher levels of removal. They are always deployed upstream of a particulate control device, generally a fabric filter, to collect the injected reagent and reaction products. DFGD is primarily effective at controlling  $PM_{2.5}$  emissions by removing sulfur trioxide ( $SO_3$ ), which will condense in the flue stream to produce sulfuric acid mist ( $H_2SO_4$ ) and will be measured as back-half (condensable)  $PM_{2.5}$ . It provides no significant removal of other (non-sulfuric acid) condensable  $PM_{2.5}$  or filterable  $PM_{2.5}$ . The ability of DFGD to capture acid gases from the flue gas is directly related to the concentration of the pollutant and it will be less effective when installed downstream of another acid gas control technology such as CFB boiler limestone injection.

### ***Sorbent Injection***

Sorbent injection (SI) systems function by injection of dry sorbent, either hydrated lime, trona, or sodium carbonate, into the flue gas via injection nozzles installed within the ductwork downstream of the air heater and upstream of a filterable particulate control device. The sorbent reacts with gas phase acid compounds (primarily  $SO_3$ , HCl, HF, and  $SO_2$ ) contained within the flue gas to form solid phase products that can be effectively captured by the downstream particulate control device. SI is primarily effective at controlling condensable  $PM_{2.5}$  emissions by removing sulfur trioxide ( $SO_3$ ), which will condense in the flue stream as sulfuric acid mist to produce back-half (condensable)  $PM_{2.5}$ . SI provides no significant removal of other (non sulfuric



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acid) condensable  $PM_{2.5}$  or filterable  $PM_{2.5}$ . The ability to capture acid gases from the flue gas is directly related to the concentration of the pollutant. Thus, when used downstream of another control technology, such as limestone injection, the effectiveness of SI is reduced due to the lower concentration of these pollutants in the gas phase. These various sorbents (hydrated lime, trona, and sodium carbonate) use similar equipment and are generally equivalent with respect to performance and cost effectiveness.

### ***Integrated Flue Gas Treatment (CHX<sup>TM</sup>-IFGT)***

The CHX<sup>TM</sup>-IFGT system is a joint technology that was developed by Condensing Heat Exchanger Corporation and Babcock & Wilcox Company. In the CHX<sup>TM</sup>-IFGT process, flue gas is first cooled by cross-flow polytetrafluoroethylene covered heat exchanger tubes, then a reagent spray system saturates the flue gas and removes pollutants prior to a final additional cooling stage using more cross flow Teflon covered tubes. The flue gas cooling causes condensable particulates to condense and collect on the exchanger surfaces. The heat recovered from the flue gas in the cooling process is integrated into the thermal cycle of the generating unit.

### ***Electro-Catalytic Oxidation (ECO<sup>TM</sup>) Process***

The ECO<sup>TM</sup> process is a multi-pollutant control technology under development by Powerspan Corporation that simultaneously controls various pollutants, along with  $PM_{2.5}$ . The ECO process takes place in three stages:

- 1) Combustion flue gas, after passing through a particulate removal system such as an electrostatic precipitator, is sent to the ECO reactor. In the ECO (dielectric barrier discharge) reactor, pollutants are oxidized by non-thermal plasma / high energy electrons. The oxidation of NO, SO<sub>2</sub>, and Hg by collision with high energy electrons, produces soluble compounds and aerosol mists that are more easily removed by downstream equipment.
- 2) The second stage consists of the collection of the converted and non-converted pollutants, such as sulfur dioxide, nitrogen dioxide and oxidized mercury. Flue gas enters the ECO system absorber, where a recirculating ammonia solution absorbs various pollutants.
- 3) In the third stage of the ECO process, flue gas is further processed in a vertical wet electrostatic precipitator that is integral with, and located in the upper part of the absorber.



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The aerosols, including sulfuric acid mist, are removed by this wet ESP. The mists are collected in vertical plates, and the liquid is returned to the bottom of the absorber.

### **Total PM<sub>2.5</sub>**

Control of combined condensable and filterable particulate (total PM<sub>2.5</sub>) material can be accomplished either by a technology that is capable of controlling both fractions, or by combining a technology for filterable particulate removal with a technology for condensable particulate removal. The following is a list of technologies capable of some level of control of both filterable and condensable PM<sub>2.5</sub> emissions from the CFB boiler.

- 1) Combined Filterable and Condensable Technologies (i.e. combinations of the technologies discussed above)
- 2) Wet Electrostatic Precipitator (WESP)
- 3) Laminar Flow ESP
- 4) Membrane Wet ESP
- 5) Cloud Chamber Scrubber (CCS™)

### ***Combined Filterable and Condensable Technology***

Control of combined particulate emissions can be accomplished by installing a technology specific to filterable particulate followed by a second technology specific to condensable particulate. The technologies for control of the specific PM<sub>2.5</sub> fractions are previously discussed. The combination can include more than one technology for condensable and/or filterable particulate, as well as technologies that have some effectiveness for both types of particulate.

### ***Wet Electrostatic Precipitator***

Wet electrostatic precipitators are capable of capturing both filterable and condensable particulate material, but have primarily been used for control of condensable particulate emissions from industrial and utility sources where the exhaust gas contains high concentrations of condensable organic and inorganic compounds. WESP installations have historically been used on coal-fired generating sources that utilize high-sulfur fuels and have higher concentrations of inorganic condensable PM in the form of sulfuric acid emissions. WESP technology works on the same principles as a dry electrostatic precipitator (DESP) where the particulate is charged by the ions



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created by discharge electrodes subjected to a high-voltage potential. The charged particulate migrates to grounded collecting plates where it is collected. Water is sprayed onto the collecting plates and washes the collected particulate from the surfaces. Since the particulate is removed by wash water, a means of utilizing the wastewater or additional wastewater treatment provisions are typically required for a plant equipped with a WESP.

WESPs require that the incoming exhaust gas stream be saturated with moisture in order to promote condensation and electrical charging of the particulate and to allow washing of the collecting surfaces. Most commonly, WESPs are used in conjunction with, and downstream of, a wet FGD system, which effectively provides this saturation. In situations where the exhaust gas stream is not saturated, saturation must be induced through the use of water sprays directly upstream of the WESP. In the case of the CFB boiler, the exhaust gas will be dry and quenching with water sprays will be required. In addition, because the flue gas exiting the WESP is saturated with water, condensation of water will occur in the downstream ductwork and chimney. As a result, when a WESP is installed, the chimney flue and connecting ductwork must be made of material (e.g., fiberglass reinforced plastic or alloy metals) that can resist corrosion and damage from the continually wet environment and be designed to collect and remove the condensed water.

### ***Laminar Flow ESP***

The laminar flow wet electrostatic precipitator, developed by the Ohio Coal Research Center at Ohio University, is a laboratory-scale prototype collector for fine particulate. The laminar flow ESP is a wet ESP with the collecting electrodes made of membranes, such as a woven silica fiber, that are spaced close to planar discharge electrodes to promote laminar flow. A separate dry ESP section upstream of the wet collecting electrodes charges the particulates entering the wet ESP to promote collection on the oppositely charged collecting electrode.

### ***Membrane Wet ESP***

Developed over the last six years by Southern Environmental, the membrane wet electrostatic precipitator is a variation of WESP that uses fabric (polypropylene) membranes in place of traditional steel collecting electrodes. The membranes are made from porous materials that



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transport liquid (primarily water) by capillary action. Capillary flow promotes well-distributed water flow both vertically and horizontally which is important for particle collection, removal and transport. This contributes to keeping the collecting electrodes continuously clean. Flushing water at relatively low flow rate is typically delivered to the membrane by “dripping”, rather than being sprayed, over the collecting surface. Capillary action of the membrane material, along with an assist from gravity, delivers the water throughout the membrane eliminating splashing or spraying.

### *Cloud Chamber Scrubber (CCS<sup>TM</sup>)*

The Cloud Chamber Scrubber (CCS) is a multi-pollutant control system supplied by Tri-Mer Corporation. CCS treats PM<sub>2.5</sub>, and condensable particulate, as well as PM<sub>10</sub>, and more coarse particles simultaneously with soluble acid and caustic gases. The CCS consists of a quench system that cools the flue gas to avoid damaging plastic components in the control device followed by two cloud generation vessels oriented in series. Each vessel injects a cloud of positively charged water droplets to control particulate emissions. The droplets entrain both neutral and charged particulate, and are then collected by gravity at the bottom of the cloud chamber.

### **2.1.2 Eliminate Technically Infeasible Options – STEP 2**

As stated in the step 1 discussion above, PM<sub>2.5</sub> emissions from the CFB boiler consist of both filterable and condensable particulate. The feasibility of the control technologies that are specific to filterable particulate, condensable particulate, and total particulate are discussed below.

#### **Filterable Particulate**

Of the nine technologies specific to filterable particulate listed in STEP 1 of this analysis, four are considered technically feasible options for controlling filterable PM<sub>2.5</sub> emissions from the CFB boiler. The four technically feasible options are listed below.

- 1) Fabric Filter
- 2) Dry Electrostatic Precipitator
- 3) Wet Particle Scrubber
- 4) Mechanical Collectors (cyclone, multiclone, elutriator)



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The remaining five technologies, listed below, are not considered technically feasible for of reasons provided in the following paragraphs. Note that although some of these technologies may be more effective than others in controlling PM<sub>2.5</sub> based on operating theory, none have been sufficiently characterized for the control of PM<sub>2.5</sub> from utility-scale CFB boilers.

- 1) Fabric Filter with Enhanced Bags
- 2) Advanced Hybrid™ Filter Technology
- 3) Indigo Bi-Polar Agglomerator
- 4) ElectroCore® Electrostatic Centrifuge
- 5) Max-9™ Electrostatic Fabric Filter

### ***Fabric Filter with Enhanced Bags***

Operational test data regarding the improvement in filterable PM<sub>2.5</sub> emission associated with enhanced bags in a coal fired power plant application is currently not available. Because test data is not available, enhanced bags can not be considered a proven technology for PM<sub>2.5</sub> emission control for the CFB boiler.

Although operational test data on coal-fired boiler applications is lacking, there is laboratory test data for PM<sub>2.5</sub> removal available from the U.S. EPA Environmental Technology Verification Program (ETV). In this program, the U.S. EPA has conducted controlled laboratory testing of filtration media and the results of these tests are available to the public on the U.S. EPA website (<http://www.epa.gov/etv/vt-apc.html#bfp>). This data appears to show that the enhanced media types may be capable of improved levels of filterable PM<sub>2.5</sub> removal as compared to conventional bags. However, the PM<sub>2.5</sub> removal efficiencies measured in this testing, 99.9968 percent for the worst performing non-membrane (conventional) media, are not consistent with PM<sub>10</sub> removal efficiencies (99.8 percent to 99.9 percent) demonstrated in real-world fabric filter installations on coal fired boilers. It would be expected that the removal efficiency for PM<sub>10</sub> would be higher than for PM<sub>2.5</sub> as larger particles are generally easier to capture than smaller particles. The difference between the very high efficiency levels for PM<sub>2.5</sub> measured in the ETV testing and the more moderate levels typical for PM<sub>10</sub> removal in full size fabric filters may be explained by two possible factors: system leakage in the full size systems, or lack of realism in the ETV protocol.



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System leakage is the combination of all paths by which incoming gas can pass through the fabric filter system without passing through the filter media. This can include flaws (holes) in the filter media, gaps at the interface between the filter bags and the tube sheet, gaps in the tube sheets (such as gas leaks through weld cracks), leakage through bypass dampers, and other sources. The system leakage is dependent on a wide variety of factors, such as quality control during construction, consistency in installing the bags, precision of the bag manufacture, age of the system, and other factors. Given that a large fabric filter on a coal fired power plant can contain 20,000 to 40,000 individual filter bags, the challenges associated with reducing emissions via leakage paths is considerable.

The ETV tests are conducted under laboratory conditions using a 140 mm (5.51”) diameter filter sample patch. The testing is conducted using an aluminum oxide test dust with a measured mass mean aerodynamic diameter of 1.5  $\mu\text{m}$ . There are number of potential factors that could skew the ETV removal efficiency results as compared to real-world operation in a fabric filter, including:

- The size distribution of the inlet particulate is different in the ETV testing than the fly ash generated in a coal-fired application
- The geometry of the filter in the ETV testing is a flat circle with a diameter of 140 mm, supported only at the edges. Whereas in fabric filter system installations, the filters are approximately 5” diameter tubes supported by cages with 12 – 20 wires. The ETV testing does not realistically re-create the level of flexing of the fabric associated with cleaning in a full sized filter.
- The ETV testing is conducted at nearly ambient conditions (77°F); whereas fabric filters in CFB applications operate in the range of 250-350°F.
- The chemical makeup of the inlet filterable particulate is different with the ETV testing using an aluminum oxide test dust while CFB boilers systems are exposed to a particulate composed of a wide variety of metal oxides along with some unburned carbon and possible salt precipitates.

Because it is not possible to apply the ETV data to a full-scale installation and distinguish between the factors that predominately impact performance, it is not possible to use the ETV data to estimate the effect of the enhanced bags on  $\text{PM}_{2.5}$  removal in real-world applications.



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### ***Advanced Hybrid™ Filter Technology***

The Advanced Hybrid™ Filter Technology has, thus far, only been used as a demonstration project on a utility boiler. The demonstration occurred at the Big Stone power plant where 1,820,000 acfm of the flue gas was diverted to an Advanced Hybrid™ Filter housing for particulate removal. During full-scale testing at Big Stone, operational issues were encountered that forced the facility to retrofit a fabric filter and abandon this system. Another larger scale demonstration was scheduled to be installed at the SACCI Cement Plant in Cagnano, Italy to treat 250,000 acfm of kiln exhaust gas; however it is unclear if this facility has been built or if testing has occurred.

The Big Stone project is the only demonstration project that is documented to date and required significant federal funding to financially support the project. Because long term operation on coal-fired boilers has not been demonstrated, this technology is determined to be infeasible for the CFB project.

### ***Indigo Bi-Polar Agglomerator***

There have been over 12 installations of the Indigo Agglomerator throughout the world including TVA's 500 MW Widows Creek Unit 8 (125 MW treated, installed March 2007), TVA's 350 MW Widows Creek Unit 4 (175 MW treated, installed December 2007), and Dynergy's 480 MW Havana Unit 6 (2 x 240 MW treated, installed April 2006). All of the existing installations have been installed in conjunction with a DESP, generally to improve the performance of existing underperforming DESP units. There are no full scale installations in conjunction with fabric filtration, which is the selected technology for filterable particulate and, therefore, the Indigo Bi-Polar Agglomerator is not applicable to the CFB boiler project and considered infeasible.

### ***ElectroCore® Electrostatic Centrifuge***

There are a number of ElectroCore® systems installed in the United States and other countries. Most of the systems are small scale and industrial, and not relevant to the utility industry. One test system was installed at Alabama Power Company, E.C. Gaston Unit No.4, and located downstream of an electrostatic precipitator. The testing involved removing a 6,000 acfm slipstream, and sending it to an ElectroCore® system. Testing took place over a period from November 2001 to February 2002. An earlier ElectroCore® system was installed at the Plant Miller utility boiler of



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Alabama Power Company and tested in May and June 1997. LSR and EPRI are no longer marketing this system so the technology is not considered to be technically feasible because it is no longer commercially available.

### ***Max-9™ Electrostatic Fabric Filter***

The Max-9™ technology has been implemented at full scale at two sites; one at a paper mill in the Midwest and another at a pulverized coal utility boiler in the Northeast. The paper mill site was shut down after approximately 1½ years for reasons not associated with the Max-9 system and the utility boiler application has only accumulated a handful of operating hours to date. Because insufficient run time has been accumulated on full-scale installations, it is not possible to assess the long term reliability and performance to any reasonable degree. Therefore, the Max-9™ technology is considered to currently be in the early stages of larger scale demonstration, but is not a fully deployed commercial technology. Therefore, the Max-9™ technology is not feasible for the CFB boiler project.

### **Condensable Particulate**

Of the five technologies specific to condensable particulate listed in STEP 1 of this analysis, three are considered technically feasible options for controlling condensable PM<sub>2.5</sub> emissions from the CFB boiler. The three technically feasible options are listed below.

- 1) Limestone Injection (LI)
- 2) Dry Flue Gas Desulfurization (DFGD)
- 3) Sorbent Injection (SI)

The remaining two technologies, listed below, are not considered technically feasible for reasons explained in the following paragraphs. Note that although some of these technologies may be more effective than others in controlling PM<sub>2.5</sub> based on operating theory, none have been sufficiently characterized for the control of PM<sub>2.5</sub> from utility scale CFB boilers.

- 1) Integrated Flue Gas Treatment (CHX™-IFGT)
- 2) Electro-Catalytic Oxidation ECO™ Process



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### ***Condensing Heat Exchanger – Integrated Flue Gas Treatment (CHX<sup>TM</sup>-IFGT)***

CHX was contacted by phone and they indicated that they ended their relationship with Babcock & Wilcox (responsible for the flue gas treatment part) a number of years ago. This technology is no longer actively marketed and, therefore, is determined to be infeasible for the CFB project due to lack of commercial availability.

### ***Electro-Catalytic Oxidation ECO<sup>TM</sup> Process***

In 2005, the ECO technology was demonstrated during a 180-day pilot testing run (50 MW ECO system) at the FirstEnergy R.E. Burger Plant in Shadyside, Ohio. The ECO system treated an 110,000 acfm flue gas slipstream from either of the 156 MW Unit 4, and Unit 5, steam generators. The ECO technology is still in the pilot plant stage of development. Because there is only limited testing of this process and no commercial installations have been deployed, the ECO process is determined to be infeasible for the CFB project.

### **Total PM<sub>2.5</sub>**

Of the five technologies specific to total particulate listed in STEP 1 of this analysis, two are considered technically feasible options for controlling total PM<sub>2.5</sub> emissions from the CFB boiler. The two technically feasible options are listed below.

- 1) Combined filterable and condensable technology
- 2) Wet Electrostatic Precipitator (WESP)

The remaining three technologies, listed below, are not considered technically feasible for the reasons explained in the following paragraphs. Note that although some of these technologies may be more effective than others in controlling PM<sub>2.5</sub> based on operating theory, none have been sufficiently characterized for the control of PM<sub>2.5</sub> from utility scale CFB boilers.

- 1) Laminar Flow ESP
- 2) Membrane Wet ESP
- 3) Cloud Chamber Scrubber (CCS<sup>TM</sup>)



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***Laminar Flow ESP***

The laminar wet electrostatic precipitator is a laboratory-scale prototype with no full scale operating history. Therefore, it is not considered to be technically feasible because it is not proven on full scale sources similar to the Unit 10 CFB boiler.

***Membrane Wet ESP (Southern Environmental)***

Several pilot test have been completed using the membrane technology and the first commercial size unit has been deployed collecting fine particulate and sulfuric acid mist from two boilers firing No. 6 fuel oil with 4 percent sulfur. There are no installations on coal fired utility boilers of the scale of the Unit 10 boiler, and no applicable PM<sub>2.5</sub> emissions performance data have been developed. Therefore, this technology is considered technically infeasible.

***Cloud Chamber Scrubber (CCS<sup>TM</sup>)***

The Cloud Chamber Scrubber (CCS) has not been demonstrated on coal-fired boiler applications, therefore it is considered technically infeasible because of the lack of both performance data and demonstrated reliability.

**2.1.3 Ranking of Technically Feasible Options – STEP 3**

Tables 2-1 through 2-3 provide a ranking of feasible control technologies, as identified in STEP 2, for filterable PM<sub>2.5</sub>, condensable PM<sub>2.5</sub>, and total PM<sub>2.5</sub> respectively.

**Table 2-1. Ranking of Filterable PM<sub>2.5</sub> Control Technologies<sup>1</sup>**

<b>Control Technology</b>	<b>Control Efficiency (percent)</b>
Fabric Filter	90 – 99.5
Dry ESP	90 – 99
Wet Particle Scrubber	80 – 95
Mechanical Collector	20 – 50

<sup>1</sup> The control efficiencies represent a range of efficiencies for general applications of a technology on a coal-fueled boiler. The actual control efficiency attained for a specific application will depend on several factors including the quantity and properties of the flue gas to be treated and the concentration and characteristics of the pollutant to be controlled.



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**Table 2-2. Ranking of Condensable PM<sub>2.5</sub> Control Technologies<sup>1</sup>**

<b>Control Technology</b>	<b>Control Efficiency (percent)</b>
LI + SDA + WESP	90 – 99.9
LI + SI + WESP	90 – 99.8
LI + WESP	90 – 99.7
LI + SDA	90 – 98
LI + SI	90 – 96
LI	90 – 93

<sup>1</sup> The control efficiencies represent a range of efficiencies for general applications of a technology on a coal-fueled boiler. The actual control efficiency attained for a specific application will depend on several factors including the quantity and properties of the flue gas to be treated and the concentration and characteristics of the pollutant to be controlled.

**Table 2-3. Ranking of Combined PM<sub>2.5</sub> Control Technologies<sup>1</sup>**

<b>Control Technology</b>	<b>Control Efficiency (percent)</b>
FF + LI + SDA + WESP	90 – 99.9
FF + LI + SI + WESP	90 – 99.8
FF + LI + WESP	90 – 99.5
FF + LI + SDA	90 – 99
FF + LI + SI	90 – 98.5
FF + LI	90 – 98

<sup>1</sup> The control efficiencies represent a range of efficiencies for general applications of a technology on a coal-fueled boiler. The actual control efficiency attained for a specific application will depend on several factors including the quantity and properties of the flue gas to be treated and the concentration and characteristics of the pollutant to be controlled.

**2.1.4 Evaluate Most Effective Controls and Document Results – STEP 4**

The technologies identified in STEP 3 are evaluated in this step and the results for each technology are described below. A detailed economic analysis documenting the incremental and total costs associated with the installation of each technology is provided in Tables I-2 through I-7, included at the end of this document.



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When considering multi-pollutant control devices, such as the installation of sorbent injection for mercury control and limestone injection for SO<sub>2</sub> control, and the resulting increase in particulate loading to the particulate control device, use of fabric filters has become a preferred option for most new boiler installation projects. This is because fabric filters are much less sensitive to changes in particulate loading and particulate characteristics than DESPs. In addition, fabric filters remove the particle bound trace metals known to exist in fly ash, including mercury and lead, better than DESPs. Therefore, use of a fabric filter is considered to provide better control of PM<sub>2.5</sub> than a DESP, wet particle scrubber, and mechanical collector for this project. Because it is the top-ranked control technology, a fabric filter is proposed as BACT for removal of filterable PM<sub>2.5</sub> for the CFB unit. Several combinations of technologies that include fabric filter will be considered for total PM<sub>2.5</sub> control.

Control technology options for total PM<sub>2.5</sub> can consist of either a technology that is capable of control of both filterable and condensable PM<sub>2.5</sub> or a combination of filterable and condensable control technologies. The only feasible technology capable of control of both filterable and condensable particulate is the WESP.

It has already been determined that limestone injection (LI) will be implemented on the CFB boiler for control of SO<sub>2</sub> and acid gases. However, LI can be used in conjunction with other feasible technologies for PM<sub>2.5</sub> removal as discussed in the previous section. As the economic analysis detailed below shows, construction and installation costs for a WESP, sorbent injection (SI), and dry flue gas desulfurization (i.e., SDA) systems are significant. A detailed economic analysis documenting the incremental and total costs associated with the installation of these systems for condensable PM<sub>2.5</sub> control is provided in Tables I-2 through I-7 found at the end of this document.

### ***Wet Electrostatic Precipitator (WESP)***

The paragraphs below address the economic, energy, and environmental impacts associated with the installation and operation of a wet electrostatic precipitator for the purposes of further controlling emissions of PM<sub>2.5</sub>.



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### *Energy*

Addition of a WESP will increase parasitic energy consumption of the CFB boiler by approximately 400 kW. This value includes the electricity required to power the transformer-rectifiers, to move the flue gas through the precipitator and associated ductwork, to power the associated pumps and equipment for quenching and cleaning water distribution and treatment, and to power the required instrumentation and controls.

### *Economic*

The total capital and operating cost for the WESP is summarized in Table I-7. This table shows the capital and operating costs cost for a WESP of the size necessary for the proposed Unit 10 CFB boiler. These costs are then use to derive a total annual cost for the WESP which is used with the estimated quantity of PM<sub>2.5</sub> pollutant removed to calculate the cost per ton of pollutant removed.

The quantity of pollutant removed is based on application of the WESP in combination with the BACT control technology for filterable material (FF) and SO<sub>2</sub> (LI) particulate material. The removal efficiency of total PM<sub>2.5</sub> assumed for the WESP is on the high end of the capability of WESP systems, 96 percent removal of filterable and condensable particulate. The emission limit from the CFB boiler for these pollutants with the baseline control technology (limestone injection and fabric filter) is already very low. With the assumed 96 percent WESP control efficiency, the emission levels will be below 0.001 lb/MMBtu, a level where reliable measurement becomes doubtful. This factor, combined with lack of experience (among equipment suppliers) at controlling these pollutants at such low levels, makes it unlikely that a commercial guarantee could be obtained for this level. The installation of a WESP in addition to the fabric filter and limestone injection to increase the removal efficiency of condensable and filterable PM<sub>2.5</sub> results in incremental cost increase of \$36,232 per ton removed. Table I-2 provides a summary of the average and incremental costs in support of this BACT analysis.

### *Environmental*

The addition of a WESP will require saturation of the flue gas stream as discussed in STEP 2. This saturation process will both consume water as a resource and will create a waste water stream from



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the WESP. This waste water stream will potentially be contaminated with pollutants removed from the flue gas stream and may require additional treatment to achieve acceptable discharge levels.

### *Sorbent Injection*

The paragraphs below address the economic, energy, and environmental impacts associated with the installation and operation of a sorbent injection (SI) system for the purposes of further controlling emissions of PM<sub>2.5</sub>.

### *Energy*

A SI system will increase the parasitic power consumption of the CFB boiler installation by approximately 40 kW. This value includes the electricity required to transport and inject the sorbent reagent and the power required for instrumentation and controls.

### *Economic*

The total capital and operating cost for the SI system is summarized in Table I-5. This table shows the capital and operating costs cost for a SI system of the size necessary for the proposed Unit 10 CFB boiler. These costs are used to estimate the total annual cost for the SI system which, along with the estimated quantity of PM<sub>2.5</sub> pollutant removed, used to calculate the cost per ton of pollutant removed. The quantity of pollutant removed is based on use of SI in combination with LI, as LI is selected as the BACT technology for SO<sub>2</sub>. The assumed efficiency of condensable PM<sub>2.5</sub> removal is on the high end of the capability of SI systems, 80 percent removal of H<sub>2</sub>SO<sub>4</sub> for this application. The emission limit from the CFB boiler for this pollutant with the baseline control technology (LI) is very low, under 2 ppmv. With the assumed 80 percent control efficiency, the emission levels will be below 0.04 ppmv, a level where reliable measurement becomes doubtful. This factor, combined with lack of experience (among equipment suppliers) at controlling this pollutant at such low levels, makes it unlikely that a commercial guarantee could be obtained for this particular application. The installation of SI in addition to the fabric filter and limestone injection to increase the removal of condensable PM<sub>2.5</sub> results in incremental cost in excess of \$15,800 per ton of PM<sub>2.5</sub> removed. Table I-2 provides a summary of the incremental costs in support of this analysis.



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### *Environmental*

The addition of SI will require the use of powdered sorbent as a reagent to effect removal of  $PM_{2.5}$  from the flue gas stream as discussed in STEP 2. This will increase the quantity of waste material collected from the fabric filter by approximately 300 tons per year. There will also be additional environmental impacts associated with truck traffic on-site when receiving sorbent reagent as well as transportation and disposal of the additional waste material.

### *Dry Flue Gas Desulfurization*

The paragraphs below address the economic, energy, and environmental impacts associated with the installation and operation of a dry flue gas desulfurization (DFGD) system for the purposes of further controlling emissions of  $PM_{2.5}$ .

### *Energy*

A DFGD system will increase the parasitic energy consumption of the CFB boiler by approximately 350 kW. This value includes the electricity required to power the atomizers, to move the flue gas through the absorber and associated ductwork, to power the associated pumps and equipment for water distribution and treatment, and to power the required instrumentation and controls.

### *Economic*

The total capital and operating cost for the DFGD is summarized in Table I-6. This table shows the capital and operating costs for a DFGD of the size necessary for the proposed Unit 10 CFB boiler. These costs are used to estimate the total annual cost for the DFGD, which was then used with the estimated quantity of  $PM_{2.5}$  pollutant removed to calculate the cost per ton of pollutant removed. The quantity of pollutant removed is based use of DFGD in combination with LI, as LI is selected as the selected technology for  $SO_2$ , acid gasses and condensable  $PM_{2.5}$ . The efficiency of condensable  $PM_{2.5}$  removal is on the high end of the capability of DFGD systems, 90 percent removal of  $H_2SO_4$ . The emission limit from the CFB boiler for this pollutant with the baseline control technology (limestone injection and fabric filter) is very low, under 2 ppmv. With the assumed 90 percent control efficiency, the emission levels will be below 0.02 ppmv, a level where reliable measurement becomes doubtful. This factor, combined with lack of experience (among



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equipment suppliers) at controlling this pollutant at such low levels, makes it unlikely that a commercial performance guarantee could be obtained. The installation of a DFGD in addition to the fabric filter and LI to increase the removal efficiency of PM<sub>2.5</sub> results in incremental cost of \$126,965 per ton of PM<sub>2.5</sub> removed. Table I-2 provides a summary of the average and incremental costs in support of this BACT analysis.

*Environmental*

The addition of a DFGD will require the use of pebble lime as a reagent to effect removal of PM<sub>2.5</sub> from the flue gas stream as discussed in STEP 2. This will increase the quantity of waste material collected from the fabric filter by approximately 1,400 tons per year. There will also be additional environmental impacts associated with truck traffic on-site receiving the pebble lime reagent as well as transportation and disposal of the additional waste material.

**2.1.5 Proposed BACT Emission Limit – STEP 5**

The proposed BACT limit based upon this top-down analysis is a filterable particulate (PM<sub>2.5</sub>) limit of 0.012 lb/MMBtu heat input based on a 2-hour average. The proposed BACT limit will be achieved by utilizing a new fabric filter from the combustion of the proposed fuels. The proposed BACT limit for total PM<sub>2.5</sub> (filterable and condensable) is 0.025 lb/MMBtu based upon a 2-hour average. Condensable particulate will be controlled through systems and processes installed to minimize the formation of SO<sub>3</sub> and sulfuric acid mist and includes limestone injection directly into the CFB boiler. Table I-4 provides a summary of recently issued and proposed BACT limits for PM<sub>2.5</sub> for comparison purposes.

**Table 2-4. Summary of PM<sub>2.5</sub> Limits for New and Proposed CFB Boilers**

Facility Name	State	Size (MW)	Year Issued Status	Limit (lb/MMbtu)	Averaging Period	Control Technology
New Steel International, Inc., Haverhill	OH	5	2008	0.358		Fabric Filter
Sappi Fine Paper PLC <sup>1</sup>	MN	30	2009	0.031		Fabric Filter
Virginia City Hybrid Energy Center	VA	600	2008	0.012	3-hour	Fabric Filter

<sup>1</sup> Current permit does not contain a specific PM<sub>2.5</sub> limit.



## APPENDIX I

### 3.0 COOLING TOWERS

The selection of power plant cooling systems (heat rejection systems) is a fundamental aspect of the initial conceptual design of the project. Unless constrained by the availability of water, the optimum selection from a thermal cycle efficiency perspective is a wet cooling tower. Analysis of cooling systems over the past decades has shown the wet cooling tower to be the optimum selection if makeup water is available. The James DeYoung Generating Station site has sufficient permitted water resources; therefore, a wet mechanical draft counter flow cooling tower was selected early in the project design. Other cooling technologies have been employed in semi-arid locations or in regions with limited water availability.

#### 3.1 PARTICULATE MATTER (PM<sub>2.5</sub>)

A small portion of the circulation in the water flow is released in the form of water droplets referred to as “drift”. As the water droplets evaporate into the air, the mineral compounds are left behind in the form of particulate emissions. As presented below, drift emissions from the wet cooling tower are relatively minor in comparison to the impacts the other cooling systems have on cycle efficiency (electrical output). Also, the emissions of PM<sub>2.5</sub> are very small as compared to PM and PM<sub>10</sub> emissions.

##### 3.1.1 Possible Control Technologies – STEP 1

The heat rejection system options range from wet cooling towers to dry air cooled condensers (ACC), hybrid systems combining wet cooling towers and ACCs, and the “Heller” system. The range of options considered operate within the standard parameters of turbine backpressure (5 in HgA maximum), circulating water temperature rise (20°F maximum) and approach to dry or wet bulb temperature, as appropriate. Also, the dry systems presented may in fact require a separate heat rejection system for balance of plant equipment cooling as the temperatures reached with dry systems often exceed equipment limits.

##### *Circulating Water with a Wet Cooling Tower*

The steam exiting the low pressure (LP) turbines enters the condenser where it passes over the outside of metal tubes; circulating water flows through the inside of the tubes to cool and



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condense the steam. The heated circulating water flows to a wet mechanical draft (WMD) cooling tower where it is sprayed over a fill material. Air also flows through the WMD cooling tower, evaporating a portion of the circulating water, and thereby cooling the remaining circulating water. The cooled circulating water collects in a basin below the WMD cooling tower and is pumped back to the condenser.

In addition to the loss of circulating water by evaporation, some of the circulating water is also lost due to drift, small water droplets entrained in the airflow. These water droplets contain the minerals in the circulating water; as the water droplets evaporate in the ambient air, the minerals are left behind to form particulate emissions. WMD cooling towers are often constructed with high efficiency drift eliminators, which operate as a control mechanism to minimize the amount of water droplets that exit with the air stream. In a very generic sense, a drift eliminator is a solid surface that causes the exiting water droplets to lose velocity and drain back into the cooling tower collection basin. Since the emissions of moisture and water droplets are minimized, so are the particulate emissions.

There are variations to the wet cooling tower such as a wet cooling tower with heating coils, sometimes termed a wet-dry tower or plume abated tower. This type of cooling tower is employed to reheat the plume and reduce the evaporation losses. However, the drift is a function of circulating water flow rate. Since the circulating water flow rate through a wet-dry cooling tower is the same as for a wet cooling tower, the wet-dry cooling tower does not present an advantage in drift reduction. In addition, the capital cost of a wet-dry cooling tower is substantially greater (50 percent or more) than for a wet cooling tower.

One possible method for reducing cooling tower  $PM_{2.5}$  emissions is to reduce the TDS within the circulating water of the cooling tower. For a closed heat rejection system, the TDS in the circulating water is primarily determined by the quality of the make-up water along with the cycles of concentration for the cooling tower. The cycles of concentration are determined by the flow rate of make-up water and blow-down water. The TDS level and emissions could be reduced by either improving the make-up water quality or by reducing the cycles of concentration (altering make-up and blow-down flow rates).



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### *Air Cooled Condensers (ACC)*

The steam exiting the LP turbines flows through large ducting to distribution headers along the top of the ACC. Finned heat transfer tubes slope down from the steam headers; typically two rows of heat transfer tubes are utilized in an “A” frame configuration. Ambient air flows over the outside of the finned heat transfer tubes, cooling and condensing the steam inside. A condensate drain header runs along the bottom of each row of finned heat transfer tubes.

Since water is not used as the cooling media, there are no drift or particulate emissions associated with an ACC.

### *Circulating Water/ACC Hybrid*

Both the circulating water/WMD cooling tower system and the ACC are used in this technology. The sizing and operation of each system depends on water availability, waste water discharge, particulate emissions, and plume issues with the circulating water system.

At colder ambient temperatures, the ACC can be utilized for up to 100 percent of the heat rejection system load, or up to 100 percent of the ACC size, to reduce these issues. At warmer ambient temperatures the circulating water system can be utilized for up to 100 percent of the heat rejection system load, or up to 100 percent of the circulating water system size, to maintain the proper LP turbine exhaust pressure (vacuum) and plant performance.

It was assumed that a circulating water/ACC hybrid system for the proposed CFB unit would be sized and operated with a 50/50 split of the heat load between the two systems on a yearly basis for the development of cost and particulate emission estimates.

### *Heller Cycle*

Cooled circulating water (condensate) is sprayed into the steam exiting the LP turbines in a jet condenser causing the steam to condense and the condensate temperature to rise. A portion of the condensate is pumped forward into the steam cycle by condensate pumps. The remaining condensate is pumped through finned tubes while air flows over the finned tubes to cool the condensate for re-use in the cycle.



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Since the water in the finned tubes does not come in contact with the air, there are no drift and particulate emissions associated with a Heller system.

### 3.1.2 Eliminate Technically Infeasible Options – STEP 2

All of the above heat rejection systems are available and applicable to the HBPW site with the exception of reduction of the cooling tower TDS. The heat rejection system for Unit 10 will be integrated with the once-through heat rejection systems for Units 4 and 5 in order to meet lake water discharge temperature and heat load limitations of the overall plant site. Thus, the Unit 10 cooling tower will not operate as a closed system, but more in an open mode where the inflow and outflow of circulating water from the Units 4 and 5 system will be significant. The resulting TDS in the circulating water will be dependent on the amount of Units 4 and 5 circulating water that is cooled by the Unit 10 tower and the quality of the water from the lake. In addition, with the integrated arrangement of the cooling systems and the overall need to satisfy the thermal discharge limits of the plant, control of heat rejection system to target a circulating water TDS it is not feasible; therefore, consideration of a controlled reduction of circulating water TDS as a means of reducing PM<sub>2.5</sub> emissions from the Unit 10 cooling tower is also not feasible.

### 3.1.3 Ranking of Technically Feasible Options – STEP 3

The ACC and Heller systems represent the top control technology since there is no drift (i.e., no particulate emissions).

The particulate emissions from the hybrid system are estimated to be approximately half of those from the circulating water/WMD cooling tower system, or 0.00035 tpy.

For the circulating water/WMD system, particulate control is achieved through the use of drift eliminators with a drift rate of 0.0005 percent (gallon drift per gallon flow). This equates to a PM<sub>2.5</sub> emission rate of 0.00016 lb/hr for a total of 0.00070 tpy.

### 3.1.4 Evaluate Most Effective Control and Document Results – STEP 4

Each technology is evaluated to determine any beneficial or adverse energy, environmental, and economic impacts.



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### *Energy*

The circulating water outlet temperature from a WMD cooling tower is a function of the ambient wet bulb temperature. Using typical cooling tower and circulating water system design parameters and wet bulb temperature for the site results in a condenser backpressure of approximately 1.53 inHgA, which is below the maximum acceptable condenser backpressure of 5.0 inHgA. At cooler ambient conditions (wet bulb temperature) the circulating water/WMD cooling tower system will result in lower condenser backpressures and improved plant performance. At even colder ambient conditions, the speed of the cooling tower fans is reduced, cooling tower fans are turned off, circulating water flow to cooling tower cells is bypassed and/or the circulating water system flow rate is reduced by approximately 40 percent, which reduces auxiliary power usage and further improves plant performance.

ACCs are typically designed with a minimum temperature difference between the steam turbine exhaust and ambient dry bulb temperature of 40°F. Heller systems are designed for a similar temperature difference. With these systems a condenser backpressure of approximately 2.0 inHgA will be achieved which is below the maximum acceptable condenser backpressure of 5.0 inHgA. At cooler ambient dry bulb temperatures, both systems will result in lower condenser backpressures and greater plant performance. At even colder ambient conditions, fans are operated at reduced speeds and/or turned off, thereby reducing auxiliary power usage and further improving plant performance.

Because of the higher turbine backpressure, the heat rates (based on the annual mean temperature of the site) are higher for the ACC, hybrid and Heller systems than for the WMD/cooling tower. These higher heat rates mean less electrical output from the CFB unit (for the same fuel input). The difference in electrical output is summarized in Table 3-1.



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**Table 3-1. Annual Electrical Output Reduction Associated with Alternative Cooling Systems**

	<b>Electrical Output (Change)</b>
Circulating Water (Cooling Tower)	Base
Air Cooled Condenser (ACC)	Base + 2.5%
Circulating Water/ACC Hybrid	Base + 0.6%
Heller	Base + 2.5%

*Environmental*

The WMD cooling system requires water and produces water effluent through the blow-down process that is necessary to control dissolved solids concentration in the system. The hybrid system uses approximately half as much water as a full WMD system. The ACC, and Heller systems use no cooling water and therefore will not draw water resources that would be required for the base WMD cooling system. In other respects, the cooling systems will have similar environmental performance.

The incremental cost associated with the ACC, hybrid and Heller systems are shown in Table 3-2 below. This incremental cost includes the annualized increased capital cost of the alternative cooling technologies as well as the value of the saleable power that is lost because of the reduction in plant output caused by the use of these technologies.

**Table 3-2. Annual Cost for Heat Rejection Systems**

<b>Heat Rejection System</b>	<b>Annualized Cost Difference from Cooling Tower (\$)</b>	<b>PM<sub>2.5</sub> Emissions Difference from Cooling Tower (tpy)</b>	<b>Incremental Cost (\$/ton)</b>
Air Cooled Condenser (ACC)	2,451,000	0.005	\$0.49 billion
Circulating Water/ACC Hybrid	1,378,000	0.0025	\$0.55 billion
Heller	2,700,000	0.005	\$0.54 billion



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As shown, the cost associated with reducing PM<sub>2.5</sub> emissions through the use of an alternative heat rejection system is not economically feasible for the CFB project.

**3.1.5 Proposed BACT Emission Limit – STEP 5**

HBPW is proposing a drift rate of 0.0005 percent. This represents BACT for the proposed cooling tower.

As shown, the cost associated with reducing PM<sub>2.5</sub> emissions through the use of an alternative heat rejection system is not economically feasible for the CFB project.

A recent PM<sub>2.5</sub> BACT for another facility considered, and rejected, drift eliminators achieving 0.0002, 0.0003, or 0.0004% drift rate. Drift rates lower than 0.0005% are not consistently achieved in practice. Recent contacts on behalf of HBPW to two vendors revealed that no guarantees beyond the 0.0005% drift rate are offered.

A review of the EPA RACT/BACT/LAER Clearinghouse (RLBC) finds recent determinations for cooling towers as summarized in Table I-7.

As shown in Table 3-3, all of the projects since April 2006 have drift rates 0.0005% or greater.

**Table 3-3. Summary of PM<sub>2.5</sub> BACT Limits for New Cooling Towers**

Facility Name	Date Permit Issued	Circulating Water Flow (gpm)	BACT LIMIT	
			Value	Unit
WOLF HOLLOW POWER PLANT NO. 2	3/3/2010		0.0005	%
PANDA SHERMAN POWER STATION	2/3/2010		0.0005	%
LINDALE RENEWABLE ENERGY	1/8/2010		0.0005	%
MGM MIRAGE	11/30/2009	10,890	0.091	lb/hr
ST. CHARLES REFINERY	11/17/2009		NO LIMITS	
ST. CHARLES REFINERY	11/17/2009		NO LIMITS	
ST. CHARLES REFINERY	11/17/2009		0.01	lb/hr
SAPPI CLOQUET LLC	10/28/2009		0.02	%
TUSCALOOSA	9/28/2009		0.4	tpy



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Facility Name	Date Permit Issued	Circulating Water Flow	BACT LIMIT	
		(gpm)	Value	Unit
HARRAH'S OPERATING COMPANY, INC.	8/20/2009	7,200	0.215	lb/hr
HARRAH'S OPERATING COMPANY, INC.	8/20/2009	6,900	0.425	lb/hr
HARRAH'S OPERATING COMPANY, INC.	8/20/2009	20,400	0.744	lb/hr
CHOCOLATE BAYOU FACILITY	6/30/2009	165,000	0.002	%
LAKE CHARLES GASIFICATION FACILITY	6/22/2009	436,000	0.0005	%
V & M STAR	4/10/2009	30,000	0.75	lb/hr
V & M STAR	4/10/2009	30,000	N/A	
V & M STAR	4/10/2009	50,000	N/A	
V & M STAR	4/10/2009	50,000	1.25	lb/hr
PLAQUEMINE PVC PLANT	2/27/2009	38,750	0.08	lb/MM GAL
PLAQUEMINE PVC PLANT	2/27/2009	106,000	0.06	lb/MM GAL
PLAQUEMINE PVC PLANT	2/27/2009	43,000	0.057	lb/MM GAL
SUN COMPANY, INC., TOLEDO REFINERY	2/23/2009	2,000	0.12	lb/hr
SUN COMPANY, INC., TOLEDO REFINERY	2/23/2009	2,000	0.084	lb/hr
SUN COMPANY, INC., TOLEDO REFINERY	2/23/2009	2,000	N/A	
PRYOR PLANT CHEMICAL	2/23/2009	24,500	1.18	lb/hr
PRYOR PLANT CHEMICAL	2/23/2009	40,000	1.92	lb/hr
FORMOSA PLASTICS - BATON ROUGE PLANT	2/18/2009	154,000	0.0006	lb/1000 GAL
POWER COUNTY ADVANCED ENERGY CENTER	2/10/2009	985	0.001	%
POWER COUNTY ADVANCED ENERGY CENTER	2/10/2009	985	0.001	%
POWER COUNTY ADVANCED ENERGY CENTER	2/10/2009	121,000	0.0005	%
POWER COUNTY ADVANCED ENERGY CENTER	2/10/2009	121,000	0.0005	%
CHOUTEAU POWER PLANT	1/23/2009		0.4	lb/hr/CELL
LION OIL COMPANY	1/20/2009	19,977	3000	MG/L TDS CONC
OHIO RIVER CLEAN FUELS, LLC	11/20/2008	240	0.0005	%
OHIO RIVER CLEAN FUELS, LLC	11/20/2008	240	0.0005	%
CPV ST CHARLES	11/12/2008		0.0005	%
CPV ST CHARLES	11/12/2008		0.0005	%



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Facility Name	Date Permit Issued	Circulating Water Flow	BACT LIMIT	
		(gpm)	Value	Unit
CPV ST CHARLES	11/12/2008		0.0005	%
TATE & LYLE INDGREDIENTS AMERICAS, INC.	9/19/2008	30,000	0.0005	%
TATE & LYLE INDGREDIENTS AMERICAS, INC.	9/19/2008	30,000	0.0005	%
TATE & LYLE INDGREDIENTS AMERICAS, INC.	9/19/2008	30,000	0.0005	%
CANE ISLAND POWER PARK	9/8/2008		0.0005	%
FPL WEST COUNTY ENERGY CENTER UNIT 3	7/30/2008		0.0005	%
PLAQUEMINE COGENERATION FACILITY	7/23/2008		0.01	%
SHINTECH PLAQUEMINE PLANT 2	7/10/2008	38,750	0.08	lb/MMGAL
SHINTECH PLAQUEMINE PLANT 2	7/10/2008	106,000	0.06	lb/MMGAL
ACTIVATED CARBON FACILITY	5/28/2008	10,750	0.41	lb/hr
TUSCALOOSA REFINERY	5/20/2008		NO LIMITS	
TUSCALOOSA REFINERY	5/20/2008		NO LIMITS	
NEW STEEL INTERNATIONAL, INC., HAVERHILL	5/6/2008	24,000	3.42	lb/hr
NEW STEEL INTERNATIONAL, INC., HAVERHILL	5/6/2008	24,000	3.42	lb/hr
ENID NITROGEN PLANT	5/1/2008		NO LIMITS	
ARSENAL HILL POWER PLANT	3/20/2008	140,000	1.4	lb/hr
NELLIS AIR FORCE BASE	2/26/2008	1,200	0.005	%
LITTLE GYPSY GENERATING PLANT	11/30/2007	5,000	0.001	%
DRY FORK STATION	10/15/2007	N/A	0.005	%
CRYSTAL RIVER POWER PLANT	10/12/2007	342,306	0.0005	%
AVENTINE RENEWABLE ENERGY - AURORA WEST LLC	9/27/2007	N/A	0.005	%
SPIRITWOOD STATION	9/14/2007	80,000	0.0005	%
MINNESOTA STEEL INDUSTRIES, LLC	9/7/2007	N/A	0.005	%
MINNESOTA STEEL INDUSTRIES, LLC	9/7/2007	N/A	0.005	%
MINNESOTA STEEL INDUSTRIES, LLC	9/7/2007	N/A	0.005	%
HOMELAND ENERGY SOLUTIONS, LLC, PN 06-672	8/8/2007	50,000	0.0005	%
HOMELAND ENERGY SOLUTIONS, LLC, PN 06-672	8/8/2007	50,000	0.0005	%
HOMELAND ENERGY SOLUTIONS,	8/8/2007	50,000	0.0005	%



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Facility Name	Date Permit Issued	Circulating Water Flow	BACT LIMIT	
		(gpm)	Value	Unit
LLC, PN 06-672				
ADM CORN PROCESSING - CEDAR RAPIDS	6/29/2007	150,000	0.0005	%
ADM CORN PROCESSING - CEDAR RAPIDS	6/29/2007	150,000	0.0005	%
ADM CORN PROCESSING - CEDAR RAPIDS	6/29/2007	150,000	0.0005	%
SOUTHWEST IOWA RENEWABLE ENERGY	4/19/2007	50,000	3.12	lb/hr
SOUTHWEST IOWA RENEWABLE ENERGY	4/19/2007	50,000	NO LIMITS	
GARYVILLE REFINERY	12/27/2006	up to 96250	0.005	%
GARYVILLE REFINERY	12/27/2006	up to 96250	0.005	%
ANCLOTE POWER PLANT	12/22/2006	660,000	0.0005	%
HILLSBOROUGH COUNTY RESOURCE RECOVERY FACILITY	11/3/2006	N/A	0.001	%
ASA BLOOMINGBURG, LLC	8/10/2006	55,000	0.005	%
ASA BLOOMINGBURG, LLC	8/10/2006	55,000	0.005	%
WESTERN GREENBRIER CO-GENERATION, LLC	4/26/2006	55,000	0.0005	%
GOLDEN GRAIN ENERGY	4/19/2006		1.33	lb/hr
NRG COAL HANDLING PLANT	4/13/2006		5.78	lb/hr
CRYSTAL RIVER POWER PLANT	4/4/2006	180,000	0.0015	%



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### 4.0 MATERIAL HANDLING

A new material handling system will be installed to facilitate the delivery and on-site transport of fuel, limestone, and other raw materials necessary to operate the CFB boiler and associated ancillary equipment, including the air quality control system. The CFB material handling systems associated with the proposed CFB boiler will generate fugitive and non-fugitive PM<sub>2.5</sub> emissions.

Fugitive emissions are emissions that are not emitted through a stack, chimney, vent, or other functionally equivalent opening. By the same reasoning, non-fugitive emissions are those that are captured and vented through a defined vent or stack.

Fugitive and non-fugitive PM<sub>2.5</sub> emissions from material handling sources essentially consist entirely of filterable (“front-half”) particulate with no appreciable condensable (“back-half”) particulate. Because of this, control technology for the material handling sources will focus on filterable control technologies only.

### 4.1 NON-FUGITIVE EMISSIONS

Storage silos and enclosed material handling sources, which represent non-fugitive emissions, associated with CFB boiler include:

- Transfer / Crusher House
- CFB Fuel Silos
- Sorbent (PAC) Silo

Since the time of the original application, HBPW has determined that venting of the new ash silo and new limestone silo associated with the construction and installation of Unit 10 will be directed to the fabric filter servicing Unit 10. Therefore, there is no longer an emission unit associated with these two sources. The small particulate emissions and additional air flow can be easily accommodated by the Unit 10 fabric filter without the need for resizing or new design engineering.



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### 4.1.1 Possible Control Technologies – STEP 1

PM<sub>2.5</sub> emissions are created when granular solid materials are transported, handled, processed or dropped. These activities cause fine particles in the material to become airborne as well as potentially creating additional fine particles by abrasion or fracturing of the solid granules. Some of the particles that become airborne have an aerodynamic diameter under 2.5 micrometers that would be considered PM<sub>2.5</sub>.

Control options for non-fugitive material handling emissions are those that either lower the PM<sub>2.5</sub> generation rate or capture the airborne dust prior to release. Those that lower the generation rate include the application of dust palliatives (water or surfactants) to bind the fines to the large material or to suppress emissions through direct contact between the spray droplets and the airborne dust.

Fabric filters are the highest efficiency add-on control device for capturing the airborne dust prior to release. Cyclones may be used where low efficiencies (40-70 percent) are required or very large particles are involved, such as certain wood working operations. Wet scrubbers may also be used with 80 to 95 percent efficiency. These are usually used for materials that are highly water soluble, such as salt.

Another technology identified for control of PM<sub>2.5</sub> emissions from the non-fugitive material handling sources is a fabric filter with disposable back-up filters. The disposable back-up filter consists of a bank of disposable filter modules mounted into a housing located downstream of a fabric filter. There are currently no operating systems of this type used for material handling emissions at coal fired power plants, but the technology is common in industries that deal with toxic particulate, such as lead dust, so there is valid experience for the suppliers to reference. In addition, this technology is planned for use on material handling sources at the Prairie State Energy Campus currently under construction in southern Illinois, a coal fired utility boiler.

The disposable back-up filter technology achieves lower PM<sub>2.5</sub> emissions because the back-up filter can effectively collect particulate material that penetrates the fabric filter. This technology is useable in the material handling system because the emission temperature is near ambient, unlike the CFB boiler exhaust which is in the 250-350°F range, which is too hot for disposable



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elements. The back-up filters will plug if operated in moisture condensing environments so heating of the air by 10°F prior to introducing it to the fabric filter is required to eliminate condensation.

### 4.1.2 Eliminate Technically Infeasible Options – STEP 2

Material conditioning is not a technically feasible option, because the added dust palliatives would adversely impact the material or the material handling system. For example, adding water or surfactant solution to the CFB fuel during wintertime temperatures at outdoor locations is not feasible due to freezing. Adding water or surfactant solution to the powdered activated carbon in the sorbent silo is not feasible because it would cause the particles to stick together, preventing the material from being transported and injected.

Fabric filters are technically feasible to control PM<sub>2.5</sub> emissions whenever the process can be enclosed or the dust can be captured in an air ventilation system and passed through a vent. Wet scrubbers and cyclones are also technically feasible options in these situations.

The fabric filter with disposable back-up filter has not been demonstrated on material handling sources at coal-fired power plants and is considered infeasible because of lack of demonstrated performance and reliability.

### 4.1.3 Ranking of Technically Feasible Options – STEP 3

Table 4-1 presents the ranking of technically feasible control options. Fabric filters are extremely effective at reducing emissions when the process is totally enclosed. Fabric filters can achieve control efficiencies of 99 percent and higher. The application of water to the coal can effectively bind the fines to the surface of the coal and sorbent. However, water is not a 4-season option in Michigan for outdoor material handling activities and is not compatible with the sorbent.



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**Table 4-1. Ranking of PM<sub>2.5</sub> Control Technologies**

<b>Control Technology</b>	<b>Controlled Efficiency (percent)<sup>1</sup></b>
Fabric Filter	98 – 99+
Wet Scrubber	80 – 95
Cyclone	40 – 70

<sup>1</sup>The controlled emission level represents indicative values for material handling applications on a coal-fueled boiler. The actual controlled emissions attained for a specific application will depend on several factors including the quantity and properties of the gas to be treated, and the concentration and characteristics of the pollutant to be controlled.

**4.1.4 Evaluate Most Effective Controls and Document Results – STEP 4**

The top ranked control technology, fabric filter, is selected for the non-fugitive material handling emission sources. Because there are no unusual environmental impacts associated with this technology, it is considered BACT for these sources.

**4.1.5 Proposed BACT Emission Limit/Practices – STEP 5**

The proposed PM<sub>2.5</sub> BACT limits and work practice standards for all enclosed material handling sources are presented in Table 4-2 along with the dust control method used to achieve the limit, when applicable. Additionally, HBPW proposes a limit of 0.004 gr/dscf for the transfer/crusher house baghouse, coal storage silos baghouse and sorbent (PAC) silo.

**Table 4-2. Selected BACT for PM/PM<sub>10</sub> Emissions from Material Handling Operations**

<b>Emission Unit</b>	<b>BACT</b>
Transfer/Crusher House	Fabric Filter (0.004 gr/dscf)
Unit 10 Fuel Storage Silos	Fabric Filter (0.004 gr/dscf)
Unit 10 PAC Silo	Fabric Filter (0.004 gr/dscf)

**4.2 FUGITIVE EMISSIONS**

Fugitive emissions of particulate as a result of coal handling and processing are expected from 3 sources; barge unloading and receiving, the active coal storage pile, and the conveyor system. On average, HPBW will receive a shipment every 5 days. A typical shipment will consist of 13,000 tons, with an annual delivery of approximately 503,262 tons.



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The coal will be unloaded using a moveable boom, to minimize the fugitive emissions. Once the coal is received, it will be shaped and compacted, with a bulldozer, into an outdoor raw coal storage pile. The bulldozer will also push the coal into the underground hopper, which feeds the conveyor system.

Fugitive emissions can be generated from these coal handling activities:

- Dropping of the coal from the barge offloading conveyors belt.
- Wind erosion.
- Dozer activity on the coal piles.
- Feeding the outdoor reclaim hoppers.

Fugitive emissions can also result from:

- Transfers from ash storage silos to trucks for transport.
- Traffic on paved on-site roads, for employees, deliveries and ash transport to off site locations.

### 4.2.1 Possible Control Technologies – STEP 1

Lower emitting processes and practices are those that reduce the generation rate of PM<sub>2.5</sub> emissions. These include conditioning of the material before transport, limiting vehicle speeds, minimizing drop heights, sweeping and/or washing paved roads and using dozers to compact long-term storage piles.

Add on controls to prevent the release of fugitive dust include the use of wet suppression consisting of water or surfactant sprays, surface sealants, partial enclosures and road cleaning. Wet suppression using water and surfactant sprays control the creation of the fugitive dust by binding the fine particles to the surface of the material, or by suppressing emissions through direct contact between the spray droplets and the airborne dust. Surface sealants create a protective layer on the surface of the material and bind the PM<sub>2.5</sub>. Partial enclosures control fugitive dust by partially isolating the material from the wind. Examples include engineered



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chutes with rubber dust curtains on the end of outdoor conveyor drop points to minimize wind exposure. Total enclosure of active portions of the coal piles are being proposed by some new facilities.

### 4.2.2 Eliminate Technically Infeasible Options – STEP 2

The technologies identified in Step 1 were evaluated for technical feasibility and are summarized below.

Material conditioning is a technically feasible option for controlling PM<sub>2.5</sub> emissions during material handling operations, but only to the extent that the use of the conditioning agent (e.g., addition of water) does not adversely impact the material or the material handling process.

Compaction is a technically feasible method of controlling fugitive dust emissions, but only when applied to the large piles of compactable material (e.g., coal in the long-term reserve storage pile) that are not frequently disturbed.

Minimizing drop heights of the material is a technically feasible control technology. The use of chutes at the discharge end of conveyors at transfer points and luffing of the conveyor are technically feasible ways to minimize drop heights. Using ground level reclaim hoppers where the coal is pushed by a dozer into the receiving hoppers is another technically feasible method of minimizing the generation of PM/PM<sub>10</sub>/PM<sub>2.5</sub>.

Limiting the vehicle speeds on unpaved roads is a technically feasible way to minimize the generation of fugitive dust.

The paving of unpaved roads is a technically feasible way to minimize the generation of fugitive dust.

Water and surfactant sprays are technically feasible for all applications to coal except during freezing conditions. The use of surface sealants is technically feasible when applied to the long-term reserve storage coal pile, where material is not frequently disturbed.



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The use of a coal barn for the active portion of the coal pile is not technically feasible for this site because of severe space constraints. Installing a coal barn for the active storage pile would require a re-design of the fuel handling activity, including more transfer points, and more space to separate the active from the receiving pile and the inactive pile. In addition to the space constraints on the site, a re-design would not likely reduce potential emissions, as additional handling steps would likely more than offset a portion of the 0.06 tpy of PM<sub>2.5</sub> that could be reduced by enclosing the active pile.

### 4.2.3 Ranking of Technically Feasible Options – STEP 3

The technically feasible methods for the control of PM<sub>2.5</sub> emissions from the proposed material handling operations are employed individually and in combination with other technologies to provide the optimum level of control effectiveness.

Water sprays and surface sealants, when employed in combination, are extremely effective at reducing PM<sub>2.5</sub> emissions from long-term storage piles. Generally, control efficiencies in excess of 95 percent can be achieved through the combined use of these technologies. For active outdoor coal piles the only technically feasible option is water sprays during non-winter months and application of a dust suppressant prior to placement on the pile in winter months.

Sweeping and/or water washing of the paved roads, along with limiting the vehicle speed can be over 90 percent effective in reducing potential dust emissions, but 80 percent control has been conservatively assumed in this analysis.

### 4.2.4 Evaluate Most Effective Controls and Document Results – STEP 4

A review of the RBLC database and other sources indicate that each of the PM/PM<sub>10</sub>/PM<sub>2.5</sub> control technologies identified for use at the proposed new plant has been proven to be effective and established as BACT for PM<sub>2.5</sub> emissions control in comparable applications at other facilities.



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The following design and operation practices will all result in minimizing the generation of fugitive PM<sub>2.5</sub> emissions:

- Use of a single underground reclaim hopper which will be covered with coal or not in use 23 hours per day.
- The movement of the coal into the plant within a three-sided enclosure.
- The transfer of coal into fabric filter controlled silos that are inside the power plant.

Based upon this and a review of all site specific considerations for the proposed PM<sub>2.5</sub> emission control technologies, the energy and environmental impacts associated with the use of the identified PM<sub>2.5</sub> emission control technologies would not preclude their selection as BACT.

**4.2.5 Proposed BACT Emission Limit/Standards – STEP 5**

The selected BACT limits and work practice standards for each material handling source at the proposed CFB is shown in Table 4-3.

**Table 4-3. Selected BACT for PM<sub>2.5</sub> Emissions from Material Handling Operations**

<b>Emission Unit</b>	<b>BACT</b>
Coal Drop from Barge	Water or dust suppressants, minimized drop height
Bulldozer Activity on the Coal Pile	Water or dust suppressants
Drop Emissions at Underground Hopper	Partial enclosure, minimum drop height, opening generally covered with coal
Active Pile Area	Compaction, water sprays for entire pile, and sealer on inactive areas
Compacted Pile Area	Compaction, water sprays for entire pile, and sealer on inactive areas
Paved Roads	Will be swept or watered to reduce silt and speed restriction.
Truck loading of Ash	Flyash will be conditioned with water to 10-25% moisture content as it leaves the storage silos. Chutes will be used to minimize exposure of material to wind.

Table I-1  
 BACT Hierarchy  
 865 MMBtu/hr CFB Boiler

Pollutant	Technology	Range of Control (%)	Control Level for BACT Analysis	Emissions Limit (lb/MMBtu)
Filterable PM <sub>2.5</sub>	Fabric Filter	90 - 99.5	98.8	0.012
	Dry Electrostatic Precipitator	90 - 99	95.1	0.05
	Wet Particle Scrubber	80 - 95	90.3	0.1
	Mechanical Collector	20 - 50	39.6	0.62
Condensable PM <sub>2.5</sub>	LI + SDA + WESP	90 - 99.9	99.82	0.000304
	LI + SI + WESP	40.0 - 68.0	99.82	0.0003
	LI + WESP	99.0 - 99.9	99.7	0.0005
	LI + SDA	90 - 98	95.5	0.008
	LI + SI	90 - 96	95.1	0.008
	LI	90 - 93	92.2	0.013
Total PM <sub>2.5</sub> (filterable + condensable)	FF + LI + SDA + WESP	90 - 99.9	99.93	0.0008
	FF + LI + SI + WESP	90 - 99.8	99.93	0.0008
	FF + LI + WESP	90 - 99.5	99.92	0.001
	FF + LI + SDA	90 - 99	98.4	0.0196
	FF + LI + SI	90 - 98.5	98.3	0.020
	FF + LI	90 - 98	97.9	0.025



Table I-2  
 Summary of Top-Down BACT Impact Analysis Results

Technology Assessment				Economic Impacts			Environmental Impacts		Energy Impacts	
Pollutant	Control Alternative	Emissions		Emissions Reduction (tpy)	Total Annualized Cost (\$/yr)	Average Cost Effectiveness (\$/ton)	Incremental Cost Effectiveness (\$/ton)	Toxics Impact (Y/N)	Adverse Environmental (Y/N)	Incremental Increase over Baseline (kW-h/yr)
		(pph)	(tpy)							
<b>CFB Boiler</b>										
Filterable PM <sub>2.5</sub>	FF	10.38	45.5	3,845.5	\$ 2,238,400	\$ 582	\$ -	N	N	1,166,667
Condensable PM <sub>2.5</sub>	LI	11.25	49.3	583.5	\$ 1,816,000	\$ 3,112	\$ -	N	Y	
	LI + SI	7.08	31.0	601.7	\$ 2,105,600	\$ 3,500	\$ 15,891	N	Y	350,400
	LI + SDA	6.57	28.8	603.9	\$ 4,413,565	\$ 7,308	\$ 126,847	N	Y	3,111,406
	LI + WESP	0.45	2.0	630.7	\$ 5,110,500	\$ 8,102	\$ 69,676	N	Y	3,521,824
	LI + SI + WESP	0.28	1.2	631.5	\$ 5,400,100	\$ 8,551	\$ 110,533	N	Y	3,872,224
	LI + SDA + WESP	0.26	1.1	631.6	\$ 7,708,065	\$ 12,205	\$ 119,208	N	Y	6,633,230
Total PM <sub>2.5</sub> (filterable + condensable)	FF + LI	21.63	94.72	4,429.0	\$ 4,054,400	\$ 915	\$ -	N	Y	1,165,080
	FF + LI + SI	17.47	76.53	4,447.2	\$ 4,344,000	\$ 977	\$ 15,925	N	Y	1,515,480
	FF + LI + SDA	16.95	74.26	4,449.4	\$ 6,651,965	\$ 1,495	\$ 126,965	N	Y	4,274,880
	FF + LI + WESP	0.87	3.79	4,519.9	\$ 7,348,900	\$ 1,626	\$ 36,232	N	Y	4,686,600
	FF + LI + SI + WESP	0.70	3.07	4,520.6	\$ 7,638,500	\$ 1,690	\$ 44,843	N	Y	5,037,000
	FF + LI + SDA + WESP	0.68	2.98	4,520.7	\$ 9,946,465	\$ 2,200	\$ 46,219	N	Y	7,796,400
<b>COOLING TOWER</b>										
PM <sub>2.5</sub>	WMD Cooling Tower	0.001123	0.005					N	N	
	Hybrid	0.000562	0.002	0.002	1,378,000	\$ 560,162,602	\$ 560,162,602	N	N	40,996,800
	ACC	0	0	0.005	2,451,000	\$ 498,170,732	\$ 498,170,732	N	Y	17,082,000
	Heller	0	0	0.005	2,700,000	\$ 548,780,488	\$ 548,780,488	N	Y	17,082,000



Cost Item	Cost Description	Cost Factor	Cost 2007 \$
<b>DIRECT CAPITAL INVESTMENT (DCI)</b>			
	Buildings		\$ 99,000
	Site Preparation		\$ 49,000
	Installation Cost		\$ 2,470,000
	Purchased Equipment		\$ 4,940,000
	Taxes		\$ 25,000
	<b>TOTAL DCI</b>		<b>\$ 7,583,000</b>
<b>INDIRECT CAPITAL INVESTMENT (ICI)</b>			
	Engineering		\$ 1,137,000
	Construction & Field Expenses		\$ 1,896,000
	Contractor Fees	Included with Field Expense	\$ -
	Start-up	Included with Field Expense	\$ -
	Performance Test	Included with Field Expense	\$ -
	Contingencies		\$ 379,000
	<b>TOTAL ICI</b>		<b>\$ 3,412,000</b>
<b>TOTAL CAPITAL INVESTMENT (TCI)</b>	DCI + ICI		<b>\$ 10,995,000</b>
<b>DIRECT OPERATING COSTS (DOC)</b>			
	Labor		
	- Operator	1 equivalent operators @ \$115,000/year	\$ 115,000
	- Supervisory	20% of Operator Labor Cost	\$ 23,000
	- Maintenance	1 technician @ \$115,000/year	\$ 115,000
	Materials		
	- Maintenance Materials	3% of purchased equipment	\$ 148,200
	- Reagent (Lime)		\$ -
	- Limestone		\$ -
	- Water		\$ -
	Utilities		
	- Electricity	\$0.06 per kWh	\$ 70,000
	- Fuel		\$ -
	- Pressure Drop	8 " pressure drop	\$ 192,000
	- Waste Disposal		\$ 16,500
	<b>TOTAL DOC</b>		<b>\$ 679,700</b>
<b>INDIRECT OPERATING COSTS (IOC)</b>			
	Overhead	60% of Operator labor & Maintenance	\$ 152,000
	Property Taxes	1.28% of TCI	\$ 141,000
	Insurance	0.07% of TCI	\$ 7,700
	Administrative Charges	2% of TCI	\$ 220,000
	Capital Recovery	20 years; 7% interest = 0.0944 CRF	\$ 1,038,000
	<b>TOTAL IOC</b>		<b>\$ 1,558,700</b>
<b>RECOVERY CREDITS (RC)</b>			
	Materials		\$ -
	<b>TOTAL RC</b>		<b>\$ -</b>
<b>TOTAL ANNUALIZED COSTS (TAC)</b>	DOC + IOC - RC		<b>\$ 2,238,400</b>
<b>PM<sub>2.5</sub> EMISSIONS</b>			
	Uncontrolled (ton/yr)	Filterable PM <sub>2.5</sub>	3,892
	Controlled (ton/yr)	98.8% removal	45
	<b>TOTAL REDUCTION</b>		<b>3,847</b>
	Cost-Effectiveness	\$ per ton of PM <sub>2.5</sub> removed	<b>\$ 582</b>



Cost Item	Cost Description	Cost Factor	Cost 2007 \$
<b>DIRECT CAPITAL INVESTMENT (DCI)</b>			
	Buildings		\$ -
	Site Preparation		\$ -
	Installation Cost		\$ -
	Purchased Equipment	no equipment	\$ -
	Taxes		\$ -
	<b>TOTAL DCI</b>		<b>\$ -</b>
<b>INDIRECT CAPITAL INVESTMENT (ICI)</b>			
	Engineering		\$ -
	Construction & Field Expenses		\$ -
	Contractor Fees		\$ -
	Start-up		\$ -
	Performance Test		\$ -
	Contingencies		\$ -
	<b>TOTAL ICI</b>		<b>\$ -</b>
<b>TOTAL CAPITAL INVESTMENT (TCI)</b>	DCI + ICI		<b>\$ -</b>
<b>DIRECT OPERATING COSTS (DOC)</b>			
	Labor		
	- Operator		\$ -
	- Supervisory		\$ -
	- Maintenance		\$ -
	Materials		
	- Maintenance Materials		\$ -
	- Reagent (Lime)		\$ -
	- Limestone	\$40/ton	\$ 1,816,000
	- Water		\$ -
	Utilities		
	- Electricity		\$ -
	- Fuel		\$ -
	- Pressure Drop		\$ -
	- Waste Disposal		\$ -
	<b>TOTAL DOC</b>		<b>\$ 1,816,000</b>
<b>INDIRECT OPERATING COSTS (IOC)</b>			
	Overhead		\$ -
	Property Taxes		\$ -
	Insurance		\$ -
	Administrative Charges		\$ -
	Capital Recovery		\$ -
	<b>TOTAL IOC</b>		<b>\$ -</b>
<b>RECOVERY CREDITS (RC)</b>			
	Materials		\$ -
	<b>TOTAL RC</b>		<b>\$ -</b>
<b>TOTAL ANNUALIZED COSTS (TAC)</b>	DOC + IOC - RC		<b>\$ 1,816,000</b>
<b>PM<sub>2.5</sub> EMISSIONS</b>			
	Uncontrolled (ton/yr)	Condensable PM <sub>2.5</sub>	632.7
	Controlled (ton/yr)	92.2% removal of H <sub>2</sub> SO <sub>4</sub>	49.3
	<b>TOTAL REDUCTION</b>		<b>583.5</b>
	Cost-Effectiveness	\$ per ton of PM <sub>2.5</sub> removed	<b>\$ 3,112</b>



Table I-5  
 Control Technology Cost Basis for SI for Condensable PM<sub>2.5</sub> After FF + LI  
 One (1) 78 MW Circulating Fluidized Bed (CFB) Boiler

Cost Item	Cost Description	Cost Factor	Cost 2008 \$
<b>DIRECT CAPITAL INVESTMENT (DCI)</b>			
	Buildings		\$ -
	Site Preparation		\$ 85,000
	Installation Cost		\$ 240,000
	Purchased Equipment		\$ 550,000
	Taxes	6% on 50% of buildings and foundations	\$ 2,550
	<b>TOTAL DCI</b>		<b>\$ 877,550</b>
<b>INDIRECT CAPITAL INVESTMENT (ICI)</b>			
	Engineering	Included with Field Expenses	\$ -
	Construction & Field Expenses	25% of DCI	\$ 219,388
	Contractor Fees	Included with Field Expenses	\$ -
	Start-up	Included with Field Expenses	\$ -
	Performance Test	Included with Field Expenses	\$ -
	Contingencies		\$ -
	<b>TOTAL ICI</b>		<b>\$ 219,388</b>
<b>TOTAL CAPITAL INVESTMENT (TCI)</b>	DCI + ICI		<b>\$ 1,096,938</b>
<b>DIRECT OPERATING COSTS (DOC)</b>			
	Labor		
	- Operator	0.2 operator @ \$115,000/year	\$ 23,000
	- Supervisory	20% of operator labor cost	\$ 4,600
	- Maintenance	0.2 technician @ \$115,000/year	\$ 23,000
	Materials		
	- Maintenance Materials	3% of purchased equipment DCI	\$ 16,500
	- Reagent (Hydrated Lime)	\$120 per ton	\$ 27,000
	- Limestone	NA	\$ -
	- Water		\$ -
	Utilities		
	- Electricity	\$0.06 per kWh	\$ 22,000
	- Fuel		\$ -
	- Pressure Drop		\$ -
	- Waste Disposal	\$12 per ton	\$ 2,700
	<b>TOTAL DOC</b>		<b>\$ 118,800</b>
<b>INDIRECT OPERATING COSTS (IOC)</b>			
	Overhead	60% of Operator labor & Maintenance	\$ 30,000
	Property Taxes	1.28% of TCI	\$ 14,000
	Insurance	0.07% of TCI	\$ 800
	Administrative Charges	2% of TCI	\$ 22,000
	Capital Recovery	20 years; 7% interest = 0.0944 CRF	\$ 104,000
	<b>TOTAL IOC</b>		<b>\$ 170,800</b>
<b>RECOVERY CREDITS (RC)</b>			
	Materials		\$ -
	Energy		\$ -
	<b>TOTAL RC</b>		<b>\$ -</b>
<b>TOTAL ANNUALIZED COSTS (TAC)</b>	DOC + IOC - RC		<b>\$ 289,600</b>
<b>PM<sub>2.5</sub> EMISSIONS</b>			
	Uncontrolled (ton/yr)	Condensable PM <sub>2.5</sub>	49.3
	Controlled (ton/yr)	80% removal of H <sub>2</sub> SO <sub>4</sub>	31.0
	<b>TOTAL REDUCTION (ton/yr)</b>		<b>18.2</b>
	Cost-Effectivness	\$ per ton of condensable PM <sub>2.5</sub> removed	<b>\$ 15,891</b>



Cost Item	Cost Description	Cost Factor	Cost 2007 \$
<b>DIRECT CAPITAL INVESTMENT (DCI)</b>			
	Buildings		\$ 122,000
	Site Preparation		\$ 61,000
	Installation Cost		\$ 3,055,000
	Purchased Equipment		\$ 6,110,000
	Taxes		\$ 31,000
	<b>TOTAL DCI</b>		<b>\$ 9,379,000</b>
<b>INDIRECT CAPITAL INVESTMENT (ICI)</b>			
	Engineering		\$ 1,407,000
	Construction & Field Expenses		\$ 2,345,000
	Contractor Fees	Included with Field Expense	
	Start-up	Included with Field Expense	
	Performance Test	Included with Field Expense	
	Contingencies		\$ 469,000
	<b>TOTAL ICI</b>		<b>\$ 4,221,000</b>
<b>TOTAL CAPITAL INVESTMENT (TCI)</b>	DCI + ICI		<b>\$ 13,600,000</b>
<b>DIRECT OPERATING COSTS (DOC)</b>			
	Labor		
	- Operator	1 equivalent operators @ \$115,000/year	\$ 115,000
	- Supervisory	20% of Operator Labor Cost	\$ 23,000
	- Maintenance	1 technician @ \$115,000/year	\$ 115,000
	Materials		
	- Maintenance Materials	3.5% of DCI	\$ 328,265
	- Reagent (Hydrated Lime)	\$120 per ton	\$ 52,000
	- Limestone	NA	\$ -
	- Water	60 gpm @ \$0.50/1,000 usg	\$ 15,000
	Utilities		
	- Electricity	\$0.06 per kWh	\$ 78,000
	- Fuel		\$ -
	- Pressure Drop	4.5 " pressure drop	\$ 108,000
	- Waste Disposal	not estimated	
	<b>TOTAL DOC</b>		<b>\$ 834,265</b>
<b>INDIRECT OPERATING COSTS (IOC)</b>			
	Overhead	60% of Operator labor & Maintenance	\$ 152,000
	Property Taxes	1.28% of TCI	\$ 174,000
	Insurance	0.07% of TCI	\$ 9,500
	Administrative Charges	2% of TCI	\$ 272,000
	Capital Recovery	20 years; 7% interest = 0.0944 CRF	\$ 1,284,000
	<b>TOTAL IOC</b>		<b>\$ 1,891,500</b>
<b>RECOVERY CREDITS (RC)</b>			
	Materials		\$ -
	SO <sub>2</sub> Market Credits	320.5 tpy based on 67% removal @ \$400/ton	\$ (128,200)
	<b>TOTAL RC</b>		<b>\$ (128,200)</b>
<b>TOTAL ANNUALIZED COSTS (TAC)</b>	DOC + IOC - RC		<b>\$ 2,597,565</b>
<b>PM<sub>2.5</sub> EMISSIONS</b>			
	Uncontrolled (ton/yr)	condensable after limestone injection	49.3
	Controlled (ton/yr)	90% removal of H <sub>2</sub> SO <sub>4</sub>	28.8
	<b>TOTAL REDUCTION</b>		<b>20.5</b>
	Cost-Effectivness	\$ per ton of PM <sub>2.5</sub> removed	<b>\$ 126,847</b>



Cost Item	Cost Description	Cost Factor	Cost 2007 \$
<b>DIRECT CAPITAL INVESTMENT (DCI)</b>			
	Buildings		\$ 165,000
	Site Preparation		\$ 83,000
	Installation Cost		\$ 4,135,000
	Purchased Equipment		\$ 8,270,000
	Taxes		\$ 41,000
	<b>TOTAL DCI</b>		<b>\$ 12,694,000</b>
<b>INDIRECT CAPITAL INVESTMENT (ICI)</b>			
	Engineering		\$ 1,904,000
	Construction & Field Expenses		\$ 3,174,000
	Contractor Fees	Included with Field Expense	\$ -
	Start-up	Included with Field Expense	\$ -
	Performance Test	Included with Field Expense	\$ -
	Contingencies		\$ 635,000
	<b>TOTAL ICI</b>		<b>\$ 5,713,000</b>
<b>TOTAL CAPITAL INVESTMENT (TCI)</b>	DCI + ICI		<b>\$ 18,407,000</b>
<b>DIRECT OPERATING COSTS (DOC)</b>			
	Labor		
	- Operator	1 equivalent operators @ \$115,000/year	\$ 115,000
	- Supervisory	20% of Operator Labor Cost	\$ 23,000
	- Maintenance	1 technician @ \$115,000/year	\$ 115,000
	Materials		
	- Maintenance Materials	3% of purchased equipment	\$ 248,100
	- Reagent (Lime)		\$ -
	- Limestone		\$ -
	- Water	225 gpm @ \$0.50/1,000 usg	\$ 59,000
	Utilities		
	- Electricity	\$0.06 per kWh	\$ 139,000
	- Fuel		\$ -
	- Pressure Drop	3" pressure drop	\$ 72,000
	- Waste Disposal		\$ 16,500
	<b>TOTAL DOC</b>		<b>\$ 787,600</b>
<b>INDIRECT OPERATING COSTS (IOC)</b>			
	Overhead	60% of Operator labor & Maintenance	\$ 152,000
	Property Taxes	1.28% of TCI	\$ 236,000
	Insurance	0.07% of TCI	\$ 12,900
	Administrative Charges	2% of TCI	\$ 368,000
	Capital Recovery	20 years; 7% interest = 0.0944 CRF	\$ 1,738,000
	<b>TOTAL IOC</b>		<b>\$ 2,506,900</b>
<b>RECOVERY CREDITS (RC)</b>			
	Materials		\$ -
	<b>TOTAL RC</b>		<b>\$ -</b>
<b>TOTAL ANNUALIZED COSTS (TAC)</b>	DOC + IOC - RC		<b>\$ 3,294,500</b>
<b>PM<sub>2.5</sub> EMISSIONS</b>			
	Uncontrolled (ton/yr)	Total PM <sub>2.5</sub>	94.7
	Controlled (ton/yr)	96% removal of filterable and condensable	3.8
	<b>TOTAL REDUCTION</b>		<b>90.9</b>
	Cost-Effectivness	\$ per ton of PM <sub>2.5</sub> removed	<b>\$ 36,232</b>

