ATTACHMENT B

Minnkota Power
COOPERATIVE
A Touchstone Energy Cooperative

Minnkota Power Cooperative, Inc.
Milton R. Young Station Unit 2

Particulate & Mercury Control Technology Evaluation & Risk Assessment for Proposed MATS Rule

Final

June 23, 2023

Project No.: A14559.010

S&L Nuclear QA Program Applicable:

Yes

No

55 East Monroe Street
Chicago, IL 60603-5780 USA
312-269-2000
www.sargentlundy.com

Sargent & Lundy

1. INTRODUCTION

1.1. PURPOSE

Sargent & Lundy (S&L) was retained by Minnkota Power Cooperative, Inc. (Minnkota) to evaluate potential filterable particulate matter (PM) and mercury (Hg) emissions reductions in response to the proposed rule to amend the National Emission Standards for Hazardous Air Pollutants (NESHAP) for Coal-and Oil-Fired Electric Utility Steam Generating Units (EGUs), commonly known as Mercury and Air Toxics Standards (MATS) published on April 24, 2023 that would require additional filterable PM and Hg emissions reductions on the Milton R. Young (MRY) Station Unit 2. These proposed revisions are the result of EPA's review of the residual risk and technology review (RTR) from May 22, 2020. Based on the proposed rule, EPA is planning to revise the filterable PM standards from 0.030 lb/MMBtu to 0.010 lb/MMBtu and is soliciting comments to consider even more stringent standard of 0.006 lb/MMBtu or lower. For lignite-fired units, EPA is also proposing to revise and tighten mercury emission standard from 4.0 lb/TBtu to 1.2 lb/TBtu to make it same as other units firing bituminous and subbituminous coal.

S&L reviewed the existing MRY Unit 2 PM and Hg control technologies to determine potential optimizations that could achieve incremental emission reductions as well as consider new PM and Hg control technologies S&L prepared an evaluation of available control technologies including technical feasibility and effectiveness, and costs based on the current emissions from the unit S&L's evaluation was completed based on past experience on similar projects, as well as input from established original equipment manufacturers (OEMs) regarding predicted performance for the lignite application at MRY Unit 2.

1.2. FACILITY BACKGROUND

The MRY station is located approximately seven (7) miles southeast of Center, North Dakota or forty (40) miles northwest of Bismarck, North Dakota on ND Highway 25 at 3401 24th Street SW, Center, North Dakota 58530. MRY station provides energy to the Midcontinent Independent System Operator (MISO) system. MRY station consists of two (2) units. Both MRY units are lignite-fired Babcock and Wilcox (B&W) cyclone boilers. The Unit 1 single wall cyclone boiler was placed into service in 1970 and has a typical output capacity rating of 257 MWg (gross). The Unit 2 opposed wall cyclone boiler (Carolina type, radiant pump assisted natural circulation) was placed into service in 1977 and has a typical output capacity rating of 470 MWg (gross). Both boilers fire North Dakota lignite coal supplied from BNI Coal, Ltd.'s Center Mine located in close proximity to the plant. Both units utilize selective non-catalytic reduction (SNCR) and separated overfire air (SOFA) systems for NOx control, fuel additive (halide injection) system and non-halogenated powdered activated carbon (PAC) for Hg control, dry electrostatic precipitators (ESP) for PM emissions control, and wet flue gas desulfurization (WFGD) systems for sulfur dioxide (SO_2) control.

1.3. DIFFERENCES IN MRY UNIT 1 AND 2 DESIGN & OPERATION

MRY Unit 1 and 2 have the same air pollution control equipment in series; however, the design of the equipment differ in ways other than unit MWg size. Of particular note, the Unit 2 ESP design attributes are superior to Unit 1, with use of a wider plate spacing (12 vs. 9 inches), and a higher specific collection area (375 ft^2/1000 actual cubic feet per minute (acfm) vs. 288 ft^2/1000 acfm). However, the Unit 2 ESP design consists of the first 2 fields' specific corona power = 160 W/1000 acfm and the last 2 fields = 240 W/1000 acfm which is consistent with historic ESP designs where transformer-rectifier (T/R) sets were typically selected to provide lower current density at the inlet sections, where the dust concentration will tend to suppress the corona current, and to provide higher current density at the outlet sections, where there is a greater percentage of fine particles. In comparison, the Unit 1 ESP design does not follow this approach, with all fields' specific corona power = 493 W/1000 acfm and is currently achieving significantly lower PM emissions than Unit 2. The single Unit 1 WFGD vessel has four (4) slurry recycle pumps (SRPs). Each of the two (2) WFGD vessels on Unit 2 have five (5) SRPs.

Furthermore, manual cleaning of the boiler on Unit 1 is also able to include air preheater (APH) cleaning, whereas the large hoppers below the Unit 2 APH prevent APH washes from being completed during short-term boiler cleaning outages. The Unit 1 offline cleaning occurs on average every 110-115 days and requires the unit to be offline typically for three (3) days. The Unit 2 offline cleaning (only including APH tube rodding) occurs on average every 85-90 days and requires the unit to be offline typically for four (4) days.

1.4. CURRENT BASELINE EMISSIONS

Minnkota provided the past five (5) years of emissions to establish baseline emissions used for this evaluation. The baseline emissions were developed using data submitted by Minnkota to the EPA between January 01, 2018 through December 31, 2022 as part of emissions reporting requirements. For PM emissions, a 30-boiler operating day rolling average was selected as the baseline PM emission calculation methodology to be in-line with the permit reporting requirements. For Hg emissions, the maximum 30-boiler operating day experienced during the evaluation period was selected as the baseline Hg emission.

Table 1-1 — Baseline Unit 2 PM & Hg Emissions

Parameter	Units	Unit 2
PM Emissions	lb/MMBtu	0.015
Hg Emissions	lb/TBtu	3.90

2. PARTICULATE TECHNOLOGY EVALUATION

As part of this evaluation, PM control technologies were evaluated based on achieving post-upgrade emissions limits in accordance with the proposed emissions included in the April 24, 2023, MATS proposed rule, 0.010 lb/MMBtu and potentially 0.006 lb/MMBtu. The description and assessment of each control option are discussed in the sections below.

2.1. OPTIONS TO REACH 0.010 LB/MMBTU

2.1.1. Increased Boiler Cleaning Outages

When manual cleaning of the boiler occurs, the following unit operation indicates reduced economizer outlet temperatures and subsequently APH outlet temperatures. The fly ash resistivity is reduced at lower temperatures making it easier to capture in the ESP. The decrease in temperature would also slightly reduce the volumetric flow through the ESP, which may also allow for improved flow and velocity through the ESP, subsequently improving the ESP overall performance Although scheduling short term outages to complete cleaning of the boileron a regular basis (regardless of nearterm long-term outages) has shown the ability to maintain emissions below the baseline emissions, a PM emission of 0.010 lb/MMBtu likely cannot be achieved and therefore this option was not considered further.

2.1.2. Flow & Distribution Devices

Uniform gas and dust distribution to each ESP casing will allow for uniform treatment/conditions of each casing to facilitate optimal performance of each. Concentrated flow and/or dust to a casing will require that casing to work harder than the others, ultimately contributing to and/or causing other operating inefficiencies within the ESP to reduce its PM removal capabilities. Replacement of existing inlet and outlet flow & dust distribution devices to achieve the latest standards of the Institute of Clean Air Companies (ICAC) Publication No. E-7 will improve the ESP overall performance. Implementation of other flow correction devices to minimize sneakage between cells and/or around collecting fields as well as to minimize particle re-entrainment from hoppers and collecting surfaces when rapped can also be implemented, as required, to meet best industry practices, if not already implemented as part of ESP designs.

A detailed assessment including computational flow dynamic (CFD) analysis and physical flow model studies would be performed to determine the design and placement of all flow and dust distribution devicesNew designs of perforated plates (with rappers) would be implemented to allow for the easy removal of fly ash into the first field hopper to minimize the potential fly ash accumulation in the inlet plenum. Although PM emissions reductions are expected to be achieved with this option, a PM emission of 0.010 lb/MMBtu likely cannot be achieved and therefore this option was not considered further.

2.1.3. Increased Power Supply

In an ESP, the collection efficiency is proportional to the amount of corona power supplied to the unit, assuming the corona power is applied effectively (maintains a good sparking rate). The resulting corona current charges the PM in the flue gas which are then attracted to the grounded, oppositely charged collecting plates. For a given flow rate, the collection efficiency will increase as the corona power is increased. To achieve a high collection efficiency, corona power is usually between 100 and 500 W/1000 acfm, but newer ESP installations have been designed for as much as 800-900 W/1000 acfm.

Increasing the power delivered into the ESP casing for this option would be done by replacing the T/R sets with higher rated power supplies, e.g. switch mode power supplies (SMPS), also referred as high frequency T/R sets, or 3-phase power supplies. Replacement of the T/R sets will require new cables, as the existing cables for 2-phase will need to be upgraded to accommodate 3phase; cables are assumed to be able to be pulled while the unit continues to operate. Further assessment would be required to determine all electrical infrastructure modifications required, including the ability to reuse the existing MCC and T/R set controls. Although PM emissions reductions are expected to be achieved with this option, a PM emission limit of 0.010 lb/MMBtu with adequate operating margin likely cannot be achieved and therefore this option was not considered further.

2.1.4. Additional ESP Field

As ESP performance does depend on the number of fields in the direction of flue gas flow, the addition of another field will increase the amount of power that can be supplied to the ESP and provide incremental removal of the filterable PM. As approximately 80% of the ash is expected to be collected in the first field, with decreasing degrees of particulate removal in the following fields, the last field in the ESP casing is expected to have the least amount of fly ash removed. This option can be implemented by either increasing the sectionalization of the last field (adding a T/R set) or potentially by utilizing the ESP outlet nozzle to retrofit another independently operated ESP field.

Sectionalization in the direction of gas flow is not feasible without a rebuild of the fields to be sectionalized as the current high voltage frames span the entire length of the field. Therefore, this option is only feasible if a new field is added at either the inlet or outlet of the existing ESP casing (assuming space available). However, the retrofit implications of this option would be considered to be a large capital retrofit project in lieu of an equipment optimization. This option is not anticipated to provide significant enough cost savings compared to the other large capital retrofit options that will be evaluated later in this evaluation. Therefore, this option is not considered further.

2.1.5. Additional ESP Casing

Installation of additional ESP casings in parallel to the existing Unit 2 ESP casings would increase the specific collecting area (SCA) and improve the velocity and treatment time of the existing ESP casings. The smaller wing ESP casings would be installed adjacent to the existing ESP casings, one added to north of Casing A and one added to the south of Casing B. The new wing casings will utilize a separate support structure and new power supplies to be independent, stand-alone structures. It is anticipated that modifications to the inlet and outlet ductwork would be required to evenly balance the flow to the new casings. The hoppers of the new ESP casings would be tied into the existing fly ash handling system. Although PM emissions reductions are expected to be achieved with this option, a PM emission limit of 0.010 lb/MMBtu with adequate operating margin likely cannot be achieved and therefore this option was not considered further.

2.1.6. ESP Rebuild

Rebuilding the existing Unit 2 ESP would involve replacement of all internals, while only reusing the outer shell/walls, hoppers, support structures, and ash conveying system. To accomplish the rebuild of the ESP casings, the roof, T/R sets, high voltage bus ducts, top end frames, intermediate roof beams, the top section of the inlet and outlet nozzles and all internal components of the existing ESPs will be removed, and replaced with new equipment. The flow distribution and correction devices in the inlet and outlet plenums would be replaced to optimize the flue gas and fly ash distribution to the casings. The hot and cold roofs would also be replaced as well to accommodate construction activities.

Before moving forward with rebuild, a structural integrity and thickness study should be completed on the entire structure to ensure that the steel has not thinned as a result of normal long-term option. The design of the support structure (casing, structural members, and determination of ESP loads to steel), support steel and foundation will need to be reviewed to verify if acceptable for reuse or if modifications are required for the weight change in the ESP casings as a result of the rebuild, which may result in additional reinforcement required. The existing ash handling systems would be reused without requiring any modifications for the incremental increase in the amount of ash collected. It would be assumed that the complete rebuild of the ESP casings and optimization of the flow distribution/collection devices in the inlet and outlet nozzles should be capable of achieving no net increase in the current pressure drop across the ESP and therefore would not require modifications or replacement of the existing ID fans.

The level of rebuild and repair to the existing ESP casings will require a longer construction outage, most likely requiring a twelve (12) week outage, if not longer. Limited access to the Unit 2 casings will also limit the construction sequence, and may cause delays, further extending the outage. Winter weather conditions experienced at the site could also prolong the construction process. Additional construction personnel would likely be required to complete work in multiple areas in an effort to reduce the outage duration.

With this option, the PM emissions are estimated to potentially achieve an emission rate of 0.008 lb/MMBtu. However, vendors would likely have to complete a more detailed qualitative study in order to provide a guarantee and would require baseline testing to qualify ESP inlet and outlet emissions.

2.2. OPTIONS TO REACH 0.006 LB/MMBTU

To achieve PM emissions that would allow for compliance with the more stringent proposed standard, a baghouse would be required. It should be noted that a baghouse will likely not provide sufficient operating margin to achieve the proposed 0.006 lb/MMBtu emission rate. It will likely be challenging to obtain a guarantee below 0.006 lb/MMBtu from baghouse OEMs. However, a baghouse is not considered to be economically feasible[1] and is therefore not evaluated further. The baghouse installation options that could be considered, described below, and the expected timeline for implementation of this control option, described in Table 2-2, are included for reference only.

- Conversion of ESP to Baghouse:
  - The existing ESP casings would be reused and ESP internals and all roof mounted equipment would be removed. A vertical partition wall, running in the direction of gas flow from the hopper bend line to the tube sheet, would be constructed in the center of each ESP casing.
- Polishing Baghouse (Downstream of ESP):
  - The existing ESP would continue to operate. Due to the reduced inlet ash loading, a polishing

[1] A high-level estimation of the cost effectiveness of a baghouse retrofit on MRY Unit 2 is approximately $162k/ton, based on the annualized capital and O&M costs ($/yr) divided by the annual reduction in annual emissions (ton/yr).

baghouse can be designed using a 6.0air-to-cloth (AC) ratio, which allows for a reduced footprint compared to a 4.0 AC ratio sized to handle the entire unit fly ash loading
  - There is not adequate space available adjacent to the existing ESP casings for placement of a baghouse. Therefore, long tiein ductwork will be required to route flue gas to an o pen area where the baghouse can be constructed. As such, thereduced size of the polishing baghouse is not anticipated to provide significant enough cost savings when compared to a baghouse that utilizes a 4.0 AC ratio.
- Baghouse (Primary PM Collection):
  - The existing ESP would be abandoned in place (could be demolished at a later date). As mentioned previously, long tie-in ductwork will be required to route flue gas to an open area where the baghouse can be constructed while the unit continues to operate in order to minimize the tie-in outage duration.

A baghouse is expected to have a pressure drop of 8 in. w.c., but could be higher depending onthe location of the baghouse in relation to thetie-in to the existing flue gas path. The current axial fans are already operated very close to their stall curve, and do not have any pressure drop operating margin. Therefore, either replacement of the existing ID fans or installation of new booster fanswould be required to accommodate the additional pressure drop through the baghouse.

2.3. PARTICULATE EMISSIONS SUMMARY

Table 2-1 below provides a summary of the postupgrade achievable emission rate for the feasible PM control option evaluated to achieve a proposed PM emission limit of 0.010 lb/MMBtu The estimated emission rates included in the following tables are considered to be representative of an average emission rate that could be achieved under normal operating conditions. The emission rates provided **should not be** construed to represent an enforceable regulatory or proposed permit limit. Corresponding regulatory and/or permit limits must be evaluated on a control systemspecific basis taking into consideration normal operating variability (i.e., a minimum additional20% margin would likely be needed to account for operating margin).

Table 2-1 — Unit 2 PM Emissions Summary

Parameter	Control Efficiency Note 1	Projected Emissions Note 2 (lb/MMBtu)	Expected Emissions (ton/year)
Baseline (Dry ESP)	**--**	**0.015**	**254**
ESP Rebuild	46.7%	0.008	135

Note 1 – Control efficiency is based on incremental improvement achieved with the option in addition to baseline dry ESP operation (e.g. not to be misconstrued as a total percent removal from uncontrolled PM emissions).
Note 2 – No compliance margin is included in these estimates. The emissions rate projections should not be used as an achievable limit for these upgrades.

2.4. TIMELINE FOR INSTALLATION

A high-level implementation schedule that outlines the time needed for the project steps necessary for the implementation of the feasible control options are summarized below. It should be noted that although a baghouse is not considered to be economically feasible, the control option is included in the summary below for reference on the expected timeline required for implementation of this control option.Other projectrelated activities, such as the time needed to obtain internal project approval, financing or permitting, if required, are not included. It should be noted that these time frames are separate from the regulatory time frames foEPA to take final action on the Proposed MATS RTR

Lead times of equipment that would be used in these types of retrofits have been observed to be double or triple the lead times typically provided by suppliers before the COVID pandemic, with longer durations observed for electrical and instrumentation and control equipment. With continued supply-chain issues, it is anticipated that longer and longer lead times may be required that are difficult to quantify at this time. Therefore, timelines represented are estimated based on past project durations and not reflective of post-pandemic market delays nor the limited number of experienced OEMs capable of providing the equipment

Table 2-2 — PM Control Implementation Schedule

PM Control Option	Design/ Specification/ Procurement (months)	Detail Design/ Fabrication (months)	Construction/ Commissioning/ Startup (months)	Minimum Total (months)
ESP Rebuild	8	16	12	36
Baghouse	10	20	18	48

3. MERCURY TECHNOLOGY EVALUATION

3.1. MERCURY EMISSIONS BACKGROUND

3.1.1. Mercury Speciation

Mercury (Hg) is contained in varying concentrations in different coal supplies. During combustion, Hg is released in the form of elemental Hg in the high temperature combustion zone of a boiler. As the combustion gases cool, a portion of the elemental Hg transforms or oxidizes to ionic Hg. However, the amount of elemental Hg that oxidizes is dependent on the cooling rate of the gas and the presence of halogens in the flue gas Ultimately, there are three possible forms of Hg:

- Elemental (Hg^0):
  - The conversion of elemental Hg to the other forms depends upon several factors including cooling rate of the gas, presence of halogens or sulfur trioxide (SO_3) in the flue gas, amount and composition of fly ash, presence of unburned carbon, and the installed APC equipment.
  - Hg^0 is insoluble in water and therefore removal requires injected sorbents or must be converted to another form to be captured, depending on the installed APC equipment.
- Ionic or Oxidized (Hg^{++} or Hg^{2+}):
  - In contrast to elemental Hg, ionic Hg is highly water soluble, allowing for collection in water streams that may be utilized in certain APC equipment and subsequently leave the process with the solid by-product or as a constituent in the purge water.
- Particulate-bound:
  - Particulate-bound Hg typically is bound to fly ash or unburned carbon. Particulate-bound Hg is efficiently removed from the flue gas by the particulate control device, making it desirable to convert as much Hg as possible to particulate-bound Hg.
  - High SO_3 levels have been shown to inhibit the binding of ionic Hg to fly ash or Hg sorbents. The addition of halogens increase the conversion of elemental and ionic Hg to particulate-bound Hg.

The proportion of the various Hg forms is referred to as Hg speciation. As such, Hg speciation testing has indicated that the distribution of Hg species varies with coal type The effectiveness of post-combustion Hg control technologies is highly influenced by the Hg speciation in the flue gas, with gaseous oxidized (or ionic) Hg compounds (i.e. $HgCl_2$) being easier to capture by downstream APC equipment.

3.1.2. Lignite Coal Variability

Industry experience has shown that lignite coal deposits vary significantly in quality, including fuel combustion performance, mineral content, and Hg content, resulting in a coal that can change on a day-to-day basis depending on the coal seam being mined at the time. For example, during the 2005 Energy & Environmental Research Center (EERC) sixty (60) day testing on MRY Unit 2[2], the coal samples analyzed ranged from 6.22

[2] Refer to the EERC "Large-Scale Mercury Control Technology Testing for Lignite-Fired Utilities - Oxidation Systems for Wet FGD" report (Cooperative Agreement No. DE-FC26-03NT41991) dated March 2007 for further details on the testing completed from March 15, 2005 to May 15, 2005 on MRY Unit 2.

lb/TBtu to 10.9 lb/TBtu (Hg content varied from 0.05 to 0.25 ppm, and averaged 0.112 ± 0.014 ppm on a dry coal basis). As such, units firing lignite coal with lower heating values have to accommodate frequently changing coal quality and require a wide range of flexibility to account for instances of firing high-Hg seams of coal to consistently achieve adequate operating margin below the required Hg emission limit.[3]

The variability of the projected lignite coal quality received from the Center Mine from 2025 through 2036 is shown in Table 3-1.

Table 3-1 — Center Mine Ultimate Coal Analyses (As -Received)

Fuel Parameter	Units	Average	Minimum	Maximum
Carbon	wt.%	40.53	39.73	41.24
Hydrogen (fuel-based)	wt.%	2.78	2.71	2.82
Nitrogen	wt.%	0.30	0.26	0.34
Sulfur	wt.%	0.86	0.68	1.07
Oxygen (by difference)	wt.%	9.97	9.47	10.83
Moisture	wt.%	38.83	38.53	39.25
Ash	wt.%	6.73	6.00	7.87
Higher Heating Value (HHV)	Btu/lb	6,625	6,489	6,739
Mercury Content	ppm	0.091	0.053	0.184
Estimated Hg Emission	lb/TBtu	8.41	4.79	17.42

3.1.3. Hg Removal with ESPs

For ACI on ESP applications, 80% of Hg capture occurs in the flue gas, and 20% occurs on the dust within the ESP (as the dust on the collecting plates are consistently removed as part of the process). Therefore, for ESP applications, achieving ideal mixing and residence time to allow for elemental Hg to oxidize to ionic Hg and for Hg to be adsorbed on the carbon particles (of the PAC or unburned carbon content in the fly ash) is critical. It should be noted that this ratio is the exact opposite for baghouse applications, i.e. 20% capture in-duct and 80% capture on the dust of the filter cake accumulated in the baghouse. For this reason, fabric filters can result in extremely high Hg capture and can improve the capture with any Hg sorbent.

3.1.4. Existing System Limitations

Documented evidence of a lignite unit achieving 1.2 lb/TBtu or below has not been found/reviewed at the time of this report. Minnkota personnel recently completed short-term parametric testing in May 2023 to determine the Hg emissions that could be achieved by maximizing the existing fuel additive and PAC injection. Even when maximizing the fuel additive rate in addition to maximizing the non-halogenated ACI addition, an emission rate of 1.2 lb/TBtu was not able to be achieved. Due to the variability of the coal, a longer period of testing would be required to gauge the Hg emissions that could be achieved just using the capacity within the existing equipment.

[3] Based on Response of Minnkota Power Cooperative Clean Air Act Section 114 Request, dated July 29, 2022.

3.2. INCREMENTAL HG CONTROL ON A LIGNITE UNIT

As mentioned previously, S&L is not aware of anydocumented evidence of a lignite unit achieving 1.2 lb/TBtu or below. As such, the following sections describe issues that need to be resolved/tested to establish if it is feasible to achieve a 1.2 lb/TBtu Hg emission rate with sufficient operating margin on a lignite unit and if so, develop an overall Hg compliance approach that likely would consist of a suite of control approaches It should be noted that any achievable Hg emission should not be construed to represent an enforceable regulatory or proposed permit limit. Corresponding regulatory and/or permit limits must be evaluated on a control system-specific basis taking into consideation normal operating and coal variability (i.e., a minimum additional 20% margin or higher would likely be needed to account for coal fluctuations and operating margin).

3.2.1. Increased Oxidation of Elemental Hg

Recent 2011 Hg speciation data measured at the Unit 2 stack, with no control technologies, indicated the Hg emissions consisted of approximately 98.3% elemental Hg, 0.8% oxidized Hg, and 0.9% particulate Hg. Recent operating data from a retired Hg process monitor indicates that the Unit 2 Hg emissions, with the currently installed Hg control technologies, consisted of approximately 86% elemental Hg, and 14% oxidized Hg. Because the current Hg emissions are made up mostly of elemental Hg, the unit emissions would benefit from an increased amount of halogen in an attempt to oxidize the elemental Hg in the flue gas. The additional halogen (chlorine, iodine, and bromine) can be added to the PAC, to the coal, or both.

The current fuel additive injection could be increased and/or replaced with a different halogen-based additive. In addition, the current non-halogenated PAC would be replaced with a more expensive halogenated PAC. The increased amount of halogen present is expected to increase the amount of elemental Hg that is oxidized to be more easily captured on the surface area of the PAC and in downstream APC.[4]

3.2.2. Increased PAC

It is anticipated that additional halogenated PAC (i.e. more than the current capabilities of the existing equipment) will need to be injected for the increased amount of oxidized Hg to be efficiently captured. However, preliminary feedback received from PAC suppliers have indicated that demonstration testing would be required to determine a PAC dosage rate and the emissions rate that can be achieved when considering the Hg content variability of the lignite Therefore, additional modifications that may be required cannot be concluded at this time; however, it is likely that the existing lances and transport piping would need to be replaced to accommodate a higher injection rate. As the existing PAC storage silo is shared by Units 1 and 2, it is likely that a separate silo would be required for Unit 2 to ensure adequate supply, turndown flexibility and reliability is achieved to maintain compliance with a defined Hg emission limit.

The degree of increased PAC injection rates can have an impact on the ESP performance as the increased amount of carbon particles that have low resistivity will decrease the overall resistivity of the fly ash (can cause particles to rapidly lose their charge on arrival at the collecting plate and become re-entrained). If/when

[4] It should be noted that the existing PAC silo is not currently compatible to store halogenated PAC due to the material of construction of the fluidizing air nozzles and may also require an internal coating of the silo to prevent corrosion. Additional assessment will be required to determine modifications required to reuse the existing silo, and may be subject to the brominated PAC utilized.

additional testing is completed to determine the supplier recommended brominated PAC injection rate, PM emissions should also be closely monitored to confirm no longer term impacts are caused by the increased ACI rate. In order to mitigate potential increases or deviations for the current PM emissions, it would be reasonable to anticipate some ESP upgrades (operational changes and/or equipment optimizations) to be required to ensure the ESP maintains its current performance.

3.2.3.Increased Contact

Increasing the degree of flue gas and PAC mixing can optimize the sorbent utilization to ensure adequate mixing of the oxidized Hg and PAC is achieved, which potentially could result in the use of less PAC to achieve the same Hg emission rate. Similarly, additional testing and evaluation would be required to determine the beneficial incremental Hg removal improvement that could be achieved. Additional mixing could be implemented by either adding static mixers into the flue gas path and/or using a more advanced injection lance design to increase sorbent dispersion relative to a straight lance design to optimize sorbent usage.

Increased contact time could also be achieved by relocating the injection lances upstream of the APH.[5] Hg reduction effectiveness with PAC has been shown to be temperature limited, as the absorption capacity of the carbon is reduced at temperatures above approximately 350°F. Although flue gas temperatures downstream of the APH are more ideal for capture, temperatures upstream of the APH are within an ideal zone for mercuric halogens to be formed, taking advantage of the additional halogen introduced with the PAC. Furthermore, for applications with SO_3 concentrations above 5 ppm in the flue gas (as is on the MRY units), carbon active sites may be preferentially occupied by SO_3. Although adsorption rates slow down above 350°F, injection upstream of the APH is sometimes considered to lower the impact of SO_3 competition. Furthermore, tubular APH designs will not offer as much mixing compared to Ljungstrom type APHs; therefore, relocating the injection lances upstream of the APH will likely only achieve added residence time for adsorption to occur in lieu of additional mixing. Therefore, the high temperature environment and resulting residence time for injection at the APH inlet would need to be evaluated further.

3.2.4.WFGD Re-Emission Control

Oxidized Hg is highly water soluble and exists in vapor phase at back-end equipment flue gas temperatures. WFGDs readily capture approximately 90% of oxidized Hg because it is highly soluble, but will not remove elemental Hg. However, re-emission of Hg is possible in some circumstances when Hg precipitates out in scrubber solids (mercuric sulfide or equivalent) and the scrubber slurry converts some of the oxidized Hg back into elemental form. Re-emission of elemental Hg can be mitigated through the use of a sulfide-donating liquid reagent additive that enhances the Hg capture within the WFGD by decreasing soluble Hg in the WFGD slurry. Testing would be required to determine the amount of re-emission currently occurring based on recent operating conditions.

3.3. MERCURY EMISSIONS SUMMARY

Presently, there is not any publicly available information to determine if improvements to any of the above categories (individually or in combination) can achieve a Hg emission of 1.2 lb/TBtu or below on a lignite unit.

[5] It should be noted that this approach is patented by Alstom, and use of this approach would need to consider intellectual property implications.

Therefore, additional testing would be required to establish if it is feasible to achieve a 1.2 lb/TBtu Hg emission rate with sufficient operating margin on a lignite unit and if so, develop an overall Hg compliance approach that likely would consist of a suite of control approaches to achieve this rate on MRY Unit 2.

In summary, additional testing would include, but not be limited to, the following:

- Hg speciation data upstream of the ESP, upstream of the WFGD and at the stack (with no controls, current operation and maximum capacity of existing Hg control equipment, and test conditions for other listed items)
- Performance with increased concentrations of current fuel additive system, including additional injection locations, as well as potentially testing other halogen -based fuel additives than what is currently used.
- Performance with halogenated PAC, considering capabilities of existing Hg control equipment and increased injection rates (while also consid ering other test conditions for other listed items). Note that due to the limitations of the existing equipment, a separate test skid will be required to facilitate this testing campaign.
- If WFGD re-emission is determined to be occurring based on Hg speciation upstream and downstream of the WFGD, the performance of a re-emission additive can also be tested.

As mentioned previously, PAC suppliers have indicated that testing would be required in order to obtain any guaranteed performance. Therefore, recommended consumption and/or injection rates to determine the modifications and/or new systems required are not available at this time to develop the subsequent cost of the suite of Hg controls needed to achieve adequate operating margin below a 1.2 lb/TBtu Hg emission limit on MRY Unit 2.

4. SUMMARY

The existing MRY Unit 2 PM and Hg control technologies were found to not be capable of achieving the proposed emissions included in the April 24, 2023, MATS rule: filterable PM emissions limit of 0.010 lb/MMBtu and potentially 0.006 lb/MMBtu and Hg emissions limit of 1.2 lb/TBtu.

The evaluation of available PM control technologies found that an ESP rebuild would be required to achieve the proposed PM emission limit of 0.010 lb/MMBtu considering the need for adequate operating margin However, testing to determine the baseline ESP inlet flow profile, ESP inlet and outlet emissions, and amount of PM removal occurring across the WFGD will likely be required in order for a vendor to complete a detailed qualitative study required to provide a PM emission guarantee. A baghouse will likely not provide sufficient operating margin for compliance with the more stringent 0.006 lb/MMBtu proposed emission limit; furthermore, this alternative was not considered to be economically feasible, and OEMs may not offer a PM emission guarantee with sufficient operating margin. A significant outage will be required to complete an ESP rebuild on MRY Unit 2, likely requiring the unit to be offline 12 weeks or longer as part the retrofit. Due to current post-pandemic market delays and the limited number of experienced OEMs capable of completing an ESP rebuild, it is highly likely that the implementation of this large-scale capital project will take longer than the estimated 36-month implementation schedule.

At the time of this evaluation, no evidence or examples demonstrating that an operating lignite unit could achieve the proposed Hg emission limit of 1.2 lb/TBtu were found. As the Hg content of the lignite coal fired at MRY Unit 2 can range from as low as 4.8 lb/TBtu to as high as 17.4 lb/TBtu, a wide range of flexibility in Hg control to account for instances of firing high Hg seams of coal to consistently achieve adequate operating margin below the proposed Hg emission limit will be required. Additional testing will also be required to navigate the challenges of Hg speciation, flue gas temperature, flow profile/mixing, residence time, and coal variability for application on a lignite fired unit to establish if it is feasible to achieve a 1.2 lb/TBtu Hg emission rate with sufficient operating margin. Furthermore, PAC suppliers have indicated that testing would be required in order to obtain any guaranteed performance. Once testing is completed, recommended consumption/injection rates, required flexibility of the suite of Hg control approaches and the subsequent costs of the modifications and/or new systems required to achieve adequate operating margin below a 1.2 lb/TBtu Hg emission limit on MRY Unit 2 can be developed