ATTACHMENT A

Minnkota Power Cooperative
A Touchstone Energy® Cooperative

Minnkota Power Cooperative, Inc.
Milton R. Young Station Units 1 and 2

Mercury Testing Results for the MATS Residual Risk and Technology Review

Rev. 2 *
May 22, 2024
Project No.: A14559.013

S&L Nuclear QA Program Applicable:
☐ Yes
☒ No

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* Revision 2 corrects the report date exclusively, which was a typographical error in Revision 1.

1. INTRODUCTION

1.1. PURPOSE

Sargent & Lundy (S&L) was retained by Minnkota Power Cooperative, Inc. (Minnkota) tosupport the evaluation of mercury (Hg) emissions reductions in response to the pre-published 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 Hg emissions reductions on the Milton R. Young (MRY) Station Units 1 and 2. As part of this evaluation, S&L assisted Minnkota in the coordination ofa Hg control test campaign to determine if it is feasible to achieve incremental Hg emission reduction on a lignite-fired unit without a fabric filter that is sufficient to meet a 1.2 lb/TBtu Hg emission rate on a continuous basis.

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. Both boilers fire North Dakota lignite coal supplied from BNI Coal, Ltd.'s Center Mine located in close proximity to the plant. The MRY Unit 1 single wall cyclone boiler (Caroline type, radiant natural circulation) was placed into service in 1970 and has a typical output capacity rating of 257 MWg (gross). The MRY 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 units utilize selective non-catalytic reduction (SNCR) and separated overfire air (SOFA) systems for NOx control,fuel additive (or halide) injection system and non-halogenated (or non-brominated) 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.

1.2.1. Current Hg Control System Specifications

The existing Hg control system is designed to control Hg emissions below 4.0 lb/TBtu using a combination of M-Prove halide injection and non-halogenated PAC. The M-Prove is directly applied on the coal belt prior to reaching coal silos, whereas the non-halogenated PAC is injected into the duct downstream of the air pre heater (APH). Additional information on the design of the existing fuel additive and PAC injection systems for MRY Units 1 and 2 are summarized below:

- MRY Common Non-brominated PAC Storage Silo:
  - PAC Utilized: Cabot DARCO® Hg-H non-halogenated PAC
  - Single storage silo with three (3) outlet cones or discharge connections. Each cone is connected to a feeder train (A, B, and C).
  - Feeder Train A is dedicated to MRY Unit 1
  - Feeder Trains B and C are dedicated to MRY Unit 2
  - Storage Volume: 4,200 cu.ft. (Nominal)
  - Capacity: 105,000 lbs. (based on PAC density of 25 lbs/cu.ft.)

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    - Storage duration: Approximately 18 days based on silo capacity of 105,000 lbs. and total combined PAC consumption rate of 244 lb/hr (MRY Unit 1 at 86 lb/hr and MRY Unit 2 at 158 lb/hr)

- MRY Unit 1 (257 MWg)
    - Fuel Additive: ARQ (formerly ADA) M -Prove
        - Average M-Prove application rate: 6.0 ppm
        - Maximum M-Prove dosage pump rate: 18.0 ppm
    - Non-brominated PAC Injection:
        - Maximum Train A PAC injection at 100% feeder rate: 1.43 lb/min (approximately 86 lb/hr or 1.06 lb/MMacf)
        - Transport piping limited to 192 lb/hr (2.37 lb/MMacf) to avoid pluggage issues
        - PAC injected into flue gas using eight (8) lances located across the APH outlet duct.
        - The lance depths vary from 18" – 54" to provide even distribution of PAC into the flue gas stream

- MRY Unit 2 (470 MWg)
    - Fuel Additive: ARQ (formerly ADA) M -Prove
        - Average M-Prove application rate: 8.0 ppm
        - Maximum M-Prove dosage pump rate: 18.0 ppm
    - Non-brominated PAC Injection:
        - Maximum Train B and C PAC injection at 100% feeder rate: 2.64 lb/min (approximately 158 lb/hr or 1.12 lb/MMacf)
        - PAC injected into flue gas using eight (8) lances located across each of the North and South APH outlet ducts for a total of sixteen (16) lances.
        - The lance depths vary from 15" – 78" to provide even distribution of PAC into the flue gas stream

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2. TEST CAMPAIGN SUMMARY

The MRY Units 1 and 2 test campaign was completed in phases to control testing variables and to accommodate vendor availability, and scheduled outages. Testing included:

- November 23, 2023 to November 24, 2023: Maximizing MRY Unit 1 capabilities of the existing M-Prove fuel additive system and non-halogenated PAC injection (at 100% feeder rate) to evaluate if the current system can meet 1.2 lb/TBtu.

- December 19, 2023 to December 20, 2023: Maximizing MRY Unit 2 capabilities of the existing M-Prove fuel additive system and non-halogenated PAC injection (at 100% feeder rate) to evaluate if the current system can meet 1.2 lb/TBtu.

- March 19, 2024 to March 23, 2024: Utilizing a rental bulk bag unloading (BBU) system provided by Motus Group tied into the existing MRY Unit 1 PAC conveying lines and injection lances to inject brominated PAC (or BPAC), ARQ's FastPAC Platinum®, at varied injection rates ranging from 100 lb/hr (or 1.23 lb/MMacf) to a maximum of 185 lb/hr (2.28 lb/MMacf) to stay below the transport piping pluggage limit. The majority of this testing also included maximizing MRY Unit 1 capabilities of the existing M-Prove fuel additive system; however, test runs on March 22 and March 23 included BPAC injection with no fuel additive usage. Individual coal samples were taken and analyzed by a 3rd party lab for determination of inlet Hg coal content.

- March 28, 2024 to April 1, 2024: Individual coal samples were taken and analyzed by a 3rd party lab for determination of inlet Hg coal content.

This testing was not able to be completed during the proposed rule's short comment period of only 60 days. Due to timing of boiler cleaning outages, time required to develop a test protocol and schedule, and coordination with multiple vendors, rental equipment availability, various site activities, and unplanned unit upsets/outages, a much longer duration was needed.

2.1. INCREMENTAL HG REMOVAL TEST RESULTS

The Hg emissions achievable based on maximizing current design capabilities using non-brominated PAC and M-Prove without any modifications is summarized below for both MRY Units 1 and 2.

Table 2-1 — MRY Units 1 and 2 Existing System Capabilities

Parameter	Units	MRY Unit 1 18 ppm M-Prove and 100% Non-brominated PAC	MRY Unit 2 18 ppm M-Prove and 100% Non-brominated PAC
Unit Load during testing	MWg	242	469
PAC Injection Rate	lb/MMacf	1.06	1.12
Avg. Sorbent Trap Hg Emissions	lb/TBtu	2.17	1.61

Based on maximizing injection capabilities of the existing systems (without any modifications), the test results show that MRY Unit 1 and MRY Unit 2 cannot achieve the proposed MATS limit of 1.2 lb/TBtu.

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2.2. BROMINATED PAC PERFORMANCE

The proposed rule assumes a 90% Hg removal efficiency is feasible from all lignite units, even those equipped with an ESP.

- In the Beyond-the-Floor memo (Docket ID No. EPA-HQ-OAR-2009-0234), it states that "[g]reater than 90 percent control can be achieved at lignite-fired units at a 2.0 lb/MMacf injection rate for units with installed fabric filter and using treated (*i.e.*, brominated) activated carbon or at an injection rate of 3.0 lb/MMacf for units using treated activated carbon with installed ESPs."

- According to the proposed MATS rule, EPA reiterates that "[i]n the beyond-the-floor analysis in the final MATS rule, we noted that the results from various demonstration projects suggest that greater than 90 percent Hg control can be achieved at lignite-fired units using brominated activated carbon sorbent at an injection rate of 2.0 lb/MMacf for units with installed FFs for PM control and at an injection rate of 3.0 lb/MMacf for units with installed ESPs for PM control."

The Final Rule relies on the same assumption. In EPA's 2024 Technology Mem orandum, EPA finds, "In the beyond-the-floor analysis in the final MATS rule, we noted that the results from various demonstration projects suggest that greater than 90 percent Hg control can be achieved at lignite fired units using brominated activated carbon sorbent at an injection rate of 2.0 lb/MMacf for units with installed Fabric Filters for PM control and at an injection rate of 3.0 lb/MMacf for units with installed ESPs for PM control. . . all units (in 2022) would have needed to control their Hg emissions to less than 95 percent to meet an emission standard of 1.2 lb/TBtu. Based on this, we expect that the units could meet the proposed, more stringent, emission standard of 1.2 lb/TBtu by utilizing brominated activated carbon at the injection rates suggested in the beyond-the-floor memorandum from the final MATS rule."

During the MRY Unit 1 March testing, MRY secured a temporary rental injection skid. The materials of construction of the existing PAC silo (common to MRY Units 1 and 2) is not currently compatible to store halogenated PAC. The silo would require an internal coating to prevent corrosion (but could otherwise be reused). The temporary rental injection skid avoided corrosion to the existing silo, but also allowed for decoupling MRY Unit 1 from the common PAC storage silo to prevent interfering with MRY Unit 2 Hg control operation.

To achieve a dosage rate of 3.0 lb/ MMacf, an injection rate of 245 lb/hr would be required which would exceed the existing MRY Unit 1 Train A PAC injection/transport system limit of 192 lb/hr (2.37 lb/MMacf). The maximum BPAC injection rate tested was limited to 185 lb/hr (2.28 lb/MMacf) to avoid line pluggage.

The Hg emissions reductions achievable based on maximizing the use of BPAC (without any fuel additives) supplied via a temporary rental injection system tied into the existing transport piping/lances is summarized below for MRY Unit 1. A higher PAC injection rate was not possible due to maximum capability of the existing transport piping while preventing pluggage.

Table 2-2 — MRY Unit 1 Existing System Capabilities using Brominated PAC

Parameter	Units	MRY Unit 1 185 lb/hr BPAC
Unit Load during testing	MWg	257.1
PAC Injection Rate	lb/MMacf	2.28
Avg. Sorbent Trap Hg Emissions	lb/TBtu	2.57

At the current injection capabilities of the existing system (i.e. requiring minimal modifications/retrofit of the existing equipment), BPAC cannot be applied to reduce Hg emissions to 1.2 lb/TBtu.

2.3. MRY MERCURY REMOVAL EFFICIENCY

2.3.1. Lignite Coal Mercury Content

To calculate an overall mercury removal efficiency needed to control to 1.2 lb/TBtu, the coal Hg inlet must be defined.

- EPA reported the "Hg Inlet" level based on the ma ximum Hg content of the range of feedstock coals that the EPA assumes is available to each of the plants in the Integrated Planning Model (IPM).
  - With respect to MRY, EPA reported "Hg inlet":
    - MRY Units 1 and 2: 7.81 lb/TBtu

- According to the proposed rule, EPA estimated the 2021 Hg inlet concentration from actual 2021 fuel usage and 2021 Hg emissions reported to the EPA. However, based on the 2024 Technical Memo, EPA updated the information based on 2022 information.
  - With respect to MRY, EPA "Estimated Hg inlet" content documented in 2023 and 2024 Technical Memo is summarized in the table below:

Table 2-3 — EPA Estimated North Dakota Lignite Coal Hg Inlet

Parameter	Units	2023 Technical Memo (Estimated 2021 Hg Inlet)	2024 Technical Memo (Estimated 2022 Hg Inlet)
MRY Unit 1	lb/TBtu	7.78	9.70
MRY Unit 2	lb/TBtu	7.79	9.70

- However, recent test information and other resources for the North Dakota lignite fired at MRY has indicated that significantly higher inlet Hg is experienced at MRY:
  - Within the BNI Coal, Ltd.'s Center Mine, the Kinneman Creek (KC) and Hagel (HA) beds are targeted for the coal supply for MRY. Based on the 2021 BNI coal data (constructed from Carlson reports), the avg. coal Hg content is approximately 16 lb/TBtu for KC and 15 lb/TBtu for HA.
  - The variability of the projected lignite coal quality received from the Center Mine from 2025 through 2036 is shown in the following table.

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Table 2-4 — Forecasted 2025 – 2036 Center Mine Ultimate Coal Analyses (As-Received)

Fuel Parameter	Units	Average	Minimum	Maximum
Mercury Content	ppm	0.091	0.053	0.184
Higher Heating Value (HHV)	Btu/lb	6,625	6,489	6,739
Estimated Hg Emission	lb/TBtu	8.41	4.79	17.42

- 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. This variability was demonstrated by the range of coal analyses from MRY Unit 1 recent short-term testing in 2024 (average = 10.1 lb/TBtu, with individual results ranging from 4.9 – 18.6 lb/TBtu over the course of five (5) days of testing).Individual coal samples and how they varied across coal feeders, per day are shown in following table.

Table 2-5 — MRY Unit 1 Coal Sampling Analysis

Date	Sample	Coal Hg Inlet (lb/TBtu)				
		Feeder #1	Feeder #3	Feeder #4	Feeder #5	Feeder #7
19-Mar-24	#1@ 0730 hrs	14.5	13.0	-	-	-
	#2@ 1600 hrs	-	-	11.1	8.2	8.0
20-Mar-24	#3@ 0100 hrs	12.5	10.5	-	-	-
20-Mar-24	#1@ 0730 hrs	6.2	7.9	-	-	-
	#2@ 1600 hrs	-	-	7.2	10.1	18.5
21-Mar-24	#3@ 0100 hrs	10.9	8.1	-	-	-
21-Mar-24	#1@ 0730 hrs	14.1	7.9	-	-	-
	#2@ 1600 hrs	-	-	18.6	4.9	7.1
22-Mar-24	#3@ 0100 hrs	7.2	7.1	-	-	-
22-Mar-24	#1@ 0700 hrs	10.4	13.4	-	-	-
	#2@ 1600 hrs	-	-	6.9	11.0	11.4
23-Mar-24	#3@ 0100 hrs	9.2	7.8	-	-	-
28-Mar-24	#1@ 1030 hrs	10.2	8.3	-	-	-
	#2@ 1500 hrs	-	-	14.9	11.9	9.5
1-Apr-24	#1@ 0930 hrs	16.3	8.0	-	-	-
	#2@ 1300 hrs	-	-	6.0	12.1	12.3
	#3@ 1500 hrs	10.2	6.9	-	-	-

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2.3.2. Required Mercury Removal Based on Lignite Coal Mercury Content

Based on the recent Hg fuel analyses, Hg control higher than 90% would actually be required based on the range of inlet coal Hg content expected to control to 1.2 lb/TBtu (i.e. keeping the outlet value calculated by the EPA constant). Note that control to this value does not off er any operating margin for potential exceedances that may occur due to response delays associated with coal variability. The following table identifies the required Hg control needed based on several different coal Hg content references. Based on these estimations, any Hg control approach would need to be able to accommodate a wide range of inlet Hg in order to optimize operating costs long-term.

Table 2-6 — Hypothetical Hg Emissions and Control Performance Based on Coal Analyses

Fuel Hg Content Reference	Coal Hg Inlet (lb/TBtu)	Est. Hg Control at 4.0 lb/TBtu (%)	Est. Hg Control at 1.2 lb/TBtu (%)
EPA Technical Memo			
2023 Table 11 Docket ID. No: EPA-HQ-OAR-2018-0794[1]	7.81	48.8	84.6
2024 Table 10 Docket ID. No: EPA-HQ-OAR-2018-0794[2]	9.70	58.6	87.6
2024 MRY Unit 1 Test Campaign			
Average	10.1	60.4	88.1
Maximum	18.6	78.5	93.5
Minimum	4.9	18.4	75.5
Center Mine Forecast			
Average	8.41	52.4	85.7
Maximum	17.42	77.0	93.1
Minimum	4.79	16.5	75.0

2.3.3. Projected Mercury Removal Based 3.0 lb/MMacf BPAC

Based on the maximum BPAC rate that MRY Unit 1 was able to test due to current system limitations (185 lb/hr or 2.28 lb/MMacf), the figure below plots the estimated percent removal at the higher injection rate of 3.0 lb/MMacf BPAC using all measurements from the MRY Unit 1 March testing (with and without fuel additive usage). The plotted values demonstrate a trend line in which BPAC cannot even achieve 80% Hg removal efficiency.

[1] Benish S. et al. (January 2023). *2023 Technology Review for the Coal- and Oil-Fired EGU Source Category*. Environmental Protection Agency.
[2] Benish S. et al. (January 2024). *2024 Update to the 2023 Proposed Technology Review for the Coal- and Oil-Fired EGU Source Category*. Environmental Protection Agency.

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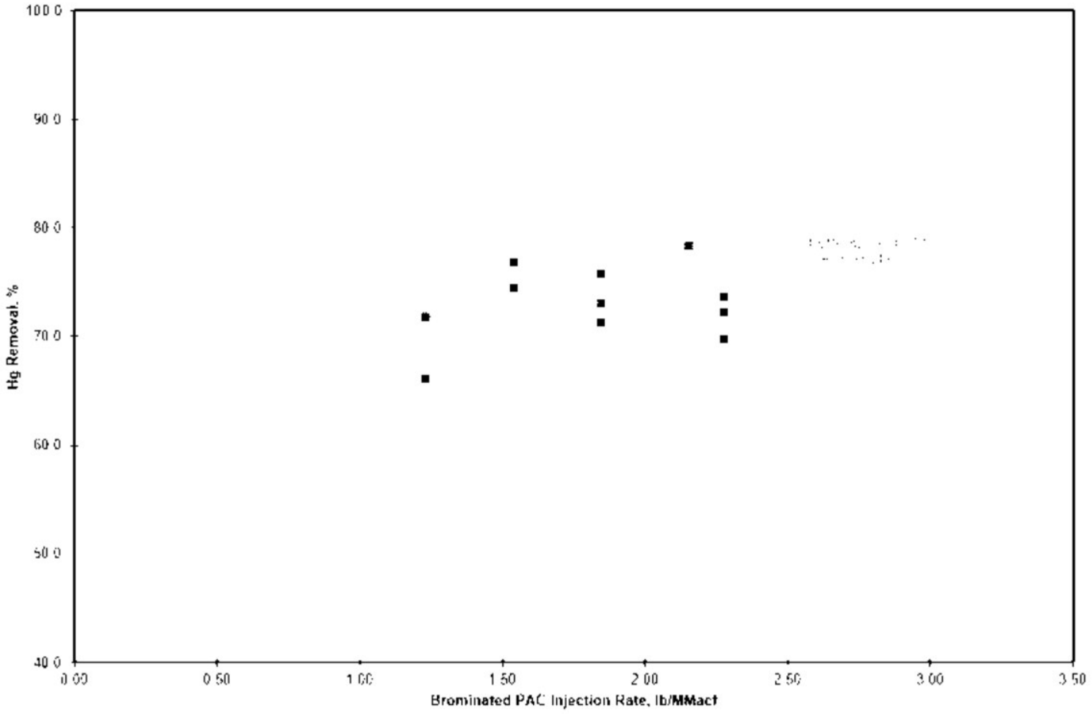
Figure 2-1 — MRY Unit 1 Existing System Mercury Removal Performance Capabilities using Brominated PAC



This result is contrary to EPA's assumption that BPAC at a rate of 3.0 lb/MMacf can be used to result in a 90% removal efficiency. The plotted curve shown in the figure shows a leveling off such that increasing the amount of sorbent results in diminishing improvement in Hg control. The projected curve based on the test campaign results shows this leveling off taking place somewhere less than 80% capture.

Although the plotted values do not support a conclusion that the new Hg 1.2 lb/TBtu limit can be met, f urther investigation into other Hg control options in combination with upgrading/optimizing existing Hg control equipment would be required to determine the lowest mercury emission rate in lb/TBtu that can be achieved on a long-term basis, considering the range of fuel Hg variability and other technological challenges inherent in capturing Hg resulting from lignite that have been documented to occur. Some proposed options for additional Hg control include:

- Increased fuel additive rate
- Improved reliability of fuel additive concentration in relation to real-time coal firing rates
- Implementation of inlet Hg monitor for improved feedback control of Hg control systems
- Improved lance design to achieve ideal distribution of PAC at all typical unit operating conditions
- Application of WFGD re-emission control additive

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Further analysis, engineering, testing and equipment modifications would be necessary to determine if these options would improve Hg control. However, it is clear that adding morebrominated PAC, as was assumed in the Final Rule, is not adequate, given the properties of lignite, compliance margin necessary, andimitation of mine mouth facilities in regards to fuel staging (i.e. must use coal received from mine; unableto fire only certain coals that have a more ideal or predictable range of Hg content during a 30-day rolling average).

It should be noted that the achievable Hg emission rate should not be construed to represent an enforceable regulatory or proposed permit limit. Corresponding permit limits must consider normal operating fluctuations and coal variability and take into account a minimum additional 20% margin for these fluctuations. Since a combination of new and/or upgraded control systems would be expected to be required, obtaining a guarantee from a single vendor to ensure that the unit achieves compliance below the permit limit will be challenging.

3. EPA COST VALIDITY

3.1.1. Current Hg Compliance Cost Effectiveness (4.0 lb/TBtu)

With respect to MRY, EPA estimated the cost effectiveness for current 2021 Hg emissions is shown below in an excerpt from Table 12 in 2023 Technology Review for the Coal - and Oil-Fired EGU Source Category (Docket ID. No: EPA-HQ-OAR-2018-0794).

TABLE 12. ESTIMATED COST-EFFECTIVENESS FOR CONTROL OF MERCURY IN 2021 AT LIGNITE-FIRED EGUS

Plant Name	PM Control	Est Hg Inlet (lb/TBtu)	Est Hg In (lb)	2021 Hg (lb/TBtu)	Est Hg Out (lb)	Avg Sorbent injection (lb/MMacf)	Avg Sorbent (lb/hr)	Sorbent Cost ($/lb) **	Est 2021 Sorbent Used (lb)	Est 2021 Sorbent Cost ($)	Est 2021 Additive Cost ($) *	2021 C/E ($/lb)
Spiritwood Station 1	FF	5.03	21.3	1.9	7.9	4.0	13.2	$0.83	111,662	$92,680	$92,680	$13,776
Leland Olds 1	ESPC	7.79	91.8	2.5	29.6	3.9	45.0	**$0.97**	299,689	$290,699	$290,699	$9,343
Leland Olds 2	ESPC	7.79	142.2	3.0	55.1	2.5	55.0	**$0.97**	294,762	$285,919	$285,919	$6,563
Milton R Young 2	ESPC	7.79	130.1	3.2	53.5	1.6	43.0	$0.83	177,431	$147,267	$147,267	$3,844
Milton R Young 1	ESPC	7.78	255.5	3.2	106.2	1.3	19.0	$0.83	273,988	$227,410	$227,410	$3,046
Major Oak Power 1	FF	14.62	193.6	1.2	16.4	1.9		**$0.83**	161,759	$134,260	$134,260	$1,515
Major Oak Power 2	FF	14.65	207.0	1.3	18.5	1.9	-	**$0.83**	172,603	$143,261	$143,261	$1,519
Red Hills Generating Facility 1	FF	12.40	192.7	1.3	20.7	2.6	36.0	**$0.76**	259,600	$197,296	$197,296	$2,293
Red Hills Generating Facility 2	FF	12.40	209.4	1.4	22.9	2.4	36.0	**$0.76**	262,834	$199,754	$199,754	$2,141
Oak Grove 1	FF	14.60	980.0	2.0	134.9	0.1	8.0	$1.15	65,331	$75,131	$75,131	$178
Martin Lake 1	ESPC	8.22	392.7	2.3	111.0	1.0	39.0	$0.97	313,150	$303,755	$303,755	$2,156
Oak Grove 2	FF	14.88	887.2	2.6	154.2	0.3	17.0	$1.15	126,484	$145,456	$145,456	$397
San Miguel 1	ESPC	14.62	346.6	2.8	66.7	2.7	59.5	$0.97	418,050	$405,509	$405,509	$2,897
Martin Lake 2	ESPC	8.13	331.1	3.0	121.7	3.0	112.0	$0.97	809,959	$785,660	$785,660	$7,504
Martin Lake 3	ESPC	7.85	372.8	3.0	144.1	3.4	126.0	$0.97	1,046,260	$1,014,872	$1,014,872	$8,877

* Additive costs are unknown. For this analysis, the EPA assumed the additive costs are the same, annually, as the sorbent costs
** Bolded costs are those that were provided to the EPA in the 2022 CAA section 114 information survey

Response: Flaws in EPA's cost analysis for current compliance:

- Est. Hg In (lb) & Hg Out (lb)
  - Table 12 would appear to have flipped MRY Unit 1 and Unit 2 in the table, utilizing the higher MRY Unit 2 operating conditions (heat input, hg loading, etc.) for the smaller sized Unit 1 and vice versa.

- PAC Injection Rate:
  - Table 12 Avg. Sorbent (lb/hr) – EPA noted MRY Unit 1: 19.0 lb/hr and MRY Unit 2: 43.0 lb/hr to achieve controlled Hg rate of 3.2 lb/TBtu.
  - Minnkota PAC sorbent injection rates to achieve controlled Hg rate of 3.85 lb/TBtu for MRY Unit 1 is expected to be 86 lb/hr and for MRY Unit 2 is 158 lb/hr.

- Cost of PAC:
  - Table 12 non-brominated PAC sorbent cost – EPA assumed a cost of $0.83/lb.
  - In the 2024 Technical Memo, EPA adjusted this cost down to $0.80/lb.
  - Based on MRY operational costs for 2023, non -brominated PAC sorbent cost is $0.86/lb.
  - Based on MRY operational costs for 2023, actual non -brominated PAC costs for achieving current compliance with 4.0 lb/TBtu indicated MRY Unit 1: $119,813 and MRY Unit 2: $329,328

- Cost of Fuel Additive:
  - Table 12 Est. 2021 Additive Cost – EPA noted that "Additive costs are unknown. For this analysis, the EPA assumed the additive costs are the same, annually, as the sorbent costs." And lists costs as MRY Unit 1: $227,410 and MRY Unit 2: $147,267
  - Based on MRY operational costs for 2023, actual fuel additive costs for achieving current compliance with 4.0 lb/TBtu indicated MRY Unit 1 $715,157 and MRY Unit 2:$1,574,793.
  - Based on the actual 2023 fuel additive usage r ates and costs, EPA's underestimate results in $487,747 and $1,347,383 that should have been included in the cost analysis for MRY Units 1 and 2, respectively.

3.1.2. Future Hg Compliance Cost Effectiveness (1.2 lb/TBtu)

EPA calculated unit-level cost-effectiveness to meet the proposed, more stringent, emissions standard using brominated activated carbon at an injection rate of 5.0 lb/MMacf for units with an ESP for PM control or at an injection rate of 2.5 lb/MMacf for units with fabric filter for PM control.

With respect to MRY, the EPA estimated the cost effectiveness (assuming 2021 operational characteristics) is shown below in an excerpt from Table 13 in 2023 Technology Review for the Coal- and Oil-Fired EGU Source Category (Docket ID. No: EPA-HQ-OAR-2018-0794):

TABLE 13. ESTIMATED COST-EFFECTIVENESS TO MEET A REVISED MERCURY OF 1.2 LB/TBTU AT LIGNITE-FIRED EGUS (ASSUMING 2021 OPERATIONAL CHARACTERISICS)

Plant Name	PM Control	Est Hg Inlet (lb/TBtu)	Est Hg In (lb)	Hg Out (lb)	Br-ACI rates (lb/MMacf)	Est Br-AC Sorbent Used (lb)	Br-AC cost ($)	C/E ($/lb) assuming no chemical additives	C/E ($/lb) assuming previous chemical additives
Spiritwood Station 2	FF	5.03	21.3	5.09	3.0	83,123	$95,592	$5,884	$11,589
Leland Olds 1	ESPC	7.79	91.8	14.15	5.0	385,175	$442,952	$5,702	$9,444
Leland Olds 2	ESPC	7.79	142.2	21.90	5.0	595,945	$685,337	$5,695	$8,071
Milton R Young 2	ESPC	7.79	130.1	20.05	5.0	545,753	$627,616	$5,702	$7,040
Milton R Young 1	ESPC	7.78	255.5	39.42	5.0	1,072,786	$1,233,703	$5,209	$6,761
Major Oak Power 1	FF	14.62	193.6	15.89	3.0	259,507	$298,433	$1,679	$2,434
Major Oak Power 2	FF	14.65	207.0	16.96	3.0	276,903	$318,439	$1,675	$2,429
Red Hills Generating Facility [illegible]	FF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Red Hills Generating Facility 2	FF	12.40	209.4	20.26	3.0	330,893	$380,526	$2,0[illegible]	$3,067
Oak Grove 1	FF	14.60	980.0	80.56	3.0	1,315,485	$1,512,808	$1,682	$1,765
Martin Lake 1	ESPC	8.22	392.7	57.35	5.0	1,560,741	$1,794,852	$5,352	$6,257
Oak Grove 2	FF	14.88	887.2	71.55	3.0	1,168,333	$1,343,583	$1,647	$1,826
San Miguel 1	ESPC	14.62	346.6	28.45	5.0	774,167	$890,292	$2,798	$4,073
Martin Lake 2	ESPC	8.13	331.1	48.90	5.0	1,330,919	$1,530,557	$5,423	$8,207
Martin Lake 3	ESPC	7.85	372.8	56.99	5.0	1,550,850	$1,783,478	$5,647	$8,861

EPA's incremental cost-effectiveness per the 2024 Update to the 2023 Proposed Technology Review for the Coal- and Oil-Fired EGU Source Category (Docket ID. No: EPA-HQ-OAR-2018-0794) is based on a model 800 MW Gulf Coast lignite-fired EGU with a heat rate of 11,000 Btu/kWh operating at an 80% capacity factor and a Hg concentration of 25.0 lb/TBtu, resulting in an incremental cost-effectiveness of $28,176 per pound of Hg controlled. It assumes that the unit currently meets a Hg emission standard of 4.0 lb/TBtu using an injection rate of 2.5 lb/MMacf of non-brominated activated carbon at a sorbent cost of $0.80/lb and that the

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unit can meet a Hg emission standard of 1.2 lb/TBtu using an injection rate of 5.0 lb/MMacf of brominated activated carbon at a sorbent cost of $1.15/lb.

- Note that the example does not include fuel additives or any equipment upgrade costs.
- EPA made following changes to the calculations between 2023 and 2024 Technical Memo's:
    - EPA updated the Gulf Coast Hg concentration from 14.9 lb/TBtu (2023) to 25.0 lb/TBtu (2024). This resulted in the baseline annual uncontrolled Hg emissions to change from 919 lb Hg to 1,542 lb Hg.
    - EPA corrected the formula for conversion of sorbent injection rate from lb/MMacf to lb/hr by adjusting the conversion factor from (520 R / 785 R) to (785 R / 520 R). The conversion factor was applied incorrectly in 2023 Technical Memo.
    - EPA added an additional factor to update the formula for conversion of sorbent injection rate from lb/MMacf to lb/hr which was not previously accounted for in 2023 Technical Memo.
- For comparison with the values calculated by the EPA in Table 13, it should be noted that the 2024 calculated cost effectiveness of the 800 MW example used by the EPA to meet 1.2 lb/TBtu, without fuel additives, is $5,083 per pound of Hg controlled.

Response: Flaws in EPA's cost analysis for future compliance with 1.2 lb/TBtu:

- Est. Hg In (lb) & Hg Out (lb)
    - See previous responses on Table 12 for flipped MRY Unit 1 and MRY Unit 2 unit information/sizing and cost of fuel additive.

- BPAC Injection Rate:
    - EPA's cost analysis assumes lignite units with an ESP can achieve 1.2 lb/TBtu, which has not been demonstrated. The injection level has a direct bearing on the operational costs because it dictates the amount of BPAC necessary to reduce Hg emissions. Therefore, cost calculations are hypothetical because no project data demonstrates what the injection level would be, if 1.2 lb/TBtu is feasibl e.
    - Although the overall feasibility of complying with the proposed Hg limit is undetermined, the testing confirms that based on maximizing injection capabilities of the existing systems, MRY's current equipment configuration cannot achieve 1.2 lb/TBtu

- Cost of BPAC:
    - Table 13 brominated PAC sorbent cost – EPA assumed of $1.15/lb.
    - MRY Unit 1 test campaign brominated PAC cost = $1.25/lb.

- Missing capital costs:
    - Irrespective of feasibility, EPA calculated cost-effectiveness shown in Table 13 does not include capital costs for modifying, upgrading and/or adding new equipment that would be necessary for the MRY Station due to limitations of existing equipment.
    - Modification to the existing PAC injection system, would include, but not be limited to, the following:
        - The materials of construction of the existing PAC silo (common to MRY Units 1 and 2) is not currently compatible to store halogenated PAC. The silo would require an internal coating to prevent corrosion in order to store brominated PAC.

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    - New feeding equipment, transport piping and injection lances would be required to accommodate a higher injection rate.
    - As the existing PAC storage silo is shared by MRY Units 1 and 2, the higher injection rate required for achieving 3.0 lb/MMacf for both units would reduce the total storage duration to less than seven (7) days of storage. Due to the weather experienced at the site and the remote location, seven (7) days of storage is recommended for each unit. Improved equipment redundancy would also likely be required to accommodate the range of coal Hg expected to be experienced in the future. Therefore, it is likely that the existing equipment would be dedicated to MRY Unit 1, and a separate silo would be required for MRY Unit 2 to ensure adequate supply, turndown flexibility, and reliability is achieved to maintain compliance with a defined Hg emission limit.
  - As such, a new MRY Unit 2 system would be required to achieve higher injection rates of PAC. An analogous project to install Hg control equipment at a 500 MW coal-fired unit in 2021 costs roughly $5.0 million dollars, based on S&L internal mercury control database, actual project costs from recent relevant projects, and adjusted for MRY specific design

Overall, the cost-effectiveness calculated is still a substantial under-estimation for the incremental Hg control on MRY Units 1 and 2.

- To provide an example, hypothetical MRY Unit 2 costs are summarized in the following table to underscore the magnitude of dollars that EPA failed to include in its calculations and that must be expended by Minnkota.
- Note the table below does not include or account for any costs associated with MRY Unit 1 system upgrades.

Table 3-1 — Example MRY Unit 2 Cost Underestimations Summary

Parameter	EPA Example Hypothetical 800 MW	EPA Assumed MRY U2 Costs 447 MW	Est. Actual MRY U2 Costs 447 MW
Current Hg Compliance (4.0 lb/TBtu) Cost [1]	$2.6 M	$0.3 M	$1.9 M
Current Hg Removed	1,295 lb	77 lb	149 lb
Current C/E ($ per lb Hg Removed)	2,004	3,845	12,754
Hg Control System Annualized Capital Cost	Not included	Not included	$472k [2]
BPAC Cost @ 5 lb/MMacf	$7.5 M	$0.6 M	$1.3 M [3]
M-Prove Cost	Not included	$0.2 M	$1.6 M [4]
Future Hg Compliance (@ 5 lb/MMacf) Cost	$7.5 M	$0.8 M	$3.4 M
Future Hg Removed (EPA Assumed @ 1.2 lb/TBtu)	1,447 lb [5]	110 lb	216 lb
Future C/E ($ per lb Hg Removed)	5,083	7,040	15,678
Incremental C/E ($ per lb Hg Removed)	28,176	14,360	22,217

Note 1 – EPA example only based on sorbent. EPA assumed current compliance cost includes sorbent and chemical fuel additive. Est. actual cost based on 2023 MRY Unit 2 usage rate & pricing for both sorbent and chemical additive.
Note 2 – Cost of $5.0 million dollars from S&L project database was annualized using a capital recovery factor calculated based on annual interest rate of 7% (pre-tax marginal rate of return on private investment, EPA Cost Manual Section 5) and 20 year evaluation period (EPA Cost Manual Section 6)
Note 3 – Cost based on EPA assumed rate but using 2023 MRY BPAC pricing.
Note 4 – Cost based on 2023 MRY Unit 2 usage rate & pricing instead of assuming same as sorbent costs.
Note 5 – Based on calculated value for EPA example inlet Hg of 1,542 lbs (current Hg coal content) – 95 lbs (future emitted amount). However, the EPA example identifies 1,468 lb for the incremental cost effectiveness calculation.

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