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# Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan

Prepared for
ArcelorMittal Minorca Mine Inc.

ArcelorMittal

December 2018

aq-ei2-11a

# Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emission Reduction Plan

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## Abbreviations and Acronyms

| Abbreviation / Acronym | Description |
|---|---|
| ACI | Activated Carbon Injection |
| AMERP | Alternative Mercury Emissions Reduction Plan |
| BACT | Best Available Control Technology |
| BAMRT | Best Available Mercury Reduction Technology |
| Barr | Barr Engineering Co. |
| BART | Best Available Retrofit Technology |
| $CaBr_2$ | Calcium Bromide |
| $CaCl_2$ | Calcium Chloride |
| CCM | EPA Air Pollution Control Cost Manual |
| CEMS | Continuous Emission Monitoring System |
| CMM | Continuous Mercury Monitor |
| DEDTC | Diethyl Dithiocarbamate |
| DNR | Minnesota Department of Natural Resources |
| EERC | Energy & Environmental Research Center |
| EGU | Electrical Generating Unit |
| EPA | U.S. Environmental Protection Agency |
| FAMS | Flue-gas Absorbent-trap Mercury Speciation |
| gpm | gallons per minute |
| $H_2O_2$ | Hydrogen Peroxide |
| HBr | Hydrogen Bromide |
| HCl | Hydrogen Chloride |
| HEDT | High Energy Dissociation Technology |
| HTC | Hibbing Taconite Company (Hibtac) |
| ICI | Industrial, Commercial, and Institutional |
| Keetac | U. S. Steel – Keetac |
| MACT | Maximum Achievable Control Technology |
| MATS | Mercury and Air Toxics Standards |
| ME2C | Midwest Energy Emissions Corporation |
| Minn. R. | Minnesota Rules |
| Minntac | U. S. Steel – Minntac |
| Minorca | ArcelorMittal Minorca Mine Inc. |
| MPCA | Minnesota Pollution Control Agency |
| NaBr | Sodium Bromide |
| NaCl | Sodium Chloride |
| $NaClO_2$ | Sodium Chlorite |
| NESHAP | National Emission Standards for Hazardous Air Pollutants |
| NSR | New Source Review |

| | |
|---|---|
| OHM | Ontario Hydro Method |
| PAC | Powdered Activated Carbon |
| PM | Particulate Matter |
| PSD | Prevention of Significant Deterioration |
| RATA | Relative Accuracy Test Audit |
| SAM | Sulfuric Acid Mist |
| $SO_2$ | Sulfur Dioxide |
| TMDL | Total Maximum Daily Load |
| TVOP | Title V Operating Permit |
| UTAC | United Taconite LLC |

# 1 Executive Summary

In accordance with Minn. R. 7007.0502, ArcelorMittal Minorca Mine Inc. (Minorca) evaluated potentially available mercury emissions reduction technologies to achieve a 72% reduction of mercury air emissions from the indurating furnace at its taconite processing plant (the Facility) located in Virginia, Minnesota. This report describes the background and methods used in the Best Available Mercury Reduction Technology (BAMRT) analysis, the alternative mercury emissions reduction evaluation, and the proposed alternative mercury emissions reduction plan (AMERP).

The taconite processing industry completed an evaluation of potentially available mercury emissions reduction technologies by adapting an approach similar to the U.S. Environmental Protection Agency (EPA)-approved Best Available Retrofit Technology (BART) analysis and top-down Best Available Control Technology (BACT) analysis. The BAMRT analysis sought to determine if mercury reductions required by Minn. R. 7007.0502, subp. 6, are technically achievable, using the adaptive management and acceptable environmental impacts criteria. The steps of this evaluation are outlined below. The details of each step, including the methods used to analyze acceptability of each step, are discussed further in Sections 4.1 through 4.8.

The BAMRT analysis evaluated the following potentially available mercury emissions reduction technologies:

- Mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal
- Mercury oxidation and capture by existing wet scrubbers
    - Halide injection
    - In-scrubber oxidation
    - High energy dissociation technology (HEDT)
- Activated carbon injection (ACI)
    - ACI at varying rates with existing wet scrubbers
    - ACI with baghouse
    - ACI with replacement high efficiency scrubber
- Fixed carbon beds
- GORE$^{TM}$ (previously known as Monolithic Polymer Resin Adsorption (Reference (1)))
- Monolithic honeycomb adsorption

The purpose of the BAMRT analysis was to determine if the 72% mercury emissions reduction required by Minn. R. 7007.0502, subp. 6, was technically achievable by any of the proposed reduction technologies. According to Minnesota Pollution Control Agency (MPCA) guidance, "technically achievable" means a technology that meets the four adaptive management criteria from the Total Maximum Daily Load (TMDL) Implementation Plan (Reference (2)). The results of the BAMRT analysis are further discussed in Section 2.1.3 and are summarized in Table ES-1 below. The BAMRT analysis also considered the environmental impacts of each proposed technology. Full details of the BAMRT analysis are included in Section 4 and Figure 4-1 illustrates the steps in both the BAMRT analysis and the alternative mercury emissions reduction evaluation.

Minorca determined that the 72% mercury emissions reduction for the indurating furnace was not technically achievable or without unacceptable environmental impacts by any of the potentially available mercury emissions reduction technologies evaluated in the BAMRT analysis. Minorca selected two reduction technologies, mercury capture by existing MACT wet scrubbers with solids removal and GORE, for further evaluation in the alternative mercury emissions reduction evaluation.

The purpose of the alternative mercury emissions reduction evaluation was to determine what level of mercury emissions reduction is technically achievable under the four established criteria without causing unacceptable environmental impacts. Full details of the alternative mercury emissions reduction evaluation are included in Section 5.

Minorca determined that mercury emissions reduction of 22% is technically achievable without unacceptable environmental impacts. In addition, Minorca will conduct a literature review and/or vendor screening to determine if any new mercury emissions reduction technologies are available and complete a supplemental BAMRT analysis as needed. Minorca's AMERP was prepared in accordance with Minn. R. 7007.052, subp. 5(A)(2), with full details included in Section 6. Appendix A includes the completed MPCA Form aq-ei2-04a (referred to as MPCA's Ferrous Mercury Reduction Plan Form in the remainder of this document).

**Table ES-1 Summary of the BAMRT Analysis Results**

| Step 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 |
|---|---|---|---|---|---|---|
| List available reduction technologies | Is the technology commercially available? | Does the technology operate without impairing pellet quality or production? | Does the technology cause excessive corrosion to pellet furnaces or associated ducting or emission control equipment? | Does the technology present unacceptable environmental impacts? | Can the technology consistently meet the 72% reduction per the rule? | Is the technology cost effective? |
| Mercury capture by existing wet scrubbers with solids removal | Yes | Yes | No | No | No - Technology proceeds to alternative mercury emissions reduction evaluation (refer to Section 5) | NA - see Step 6 |
| Halide Injection | Yes | Yes | No | Yes - Increased likelihood of local mercury deposition, eliminated from further consideration | NA - see Step 5 | NA - see Step 5 |
| In-scrubber oxidation – Not considered a potential technology based on previous industry testing | NA – See Step 1 | NA – See Step 1 | NA – See Step 1 | NA – See Step 1 | NA – See Step 1 | NA – See Step 1 |
| High Energy Dissociation Technology (HEDT) | No, eliminated from further consideration | NA - see Step 2 | NA - see Step 2 | NA - see Step 2 | NA - see Step 2 | NA - see Step 2 |
| ACI with existing scrubbers | Yes | Yes | No | Yes - Increased likelihood of local mercury deposition, eliminated from further consideration | NA - see Step 5 | NA - see Step 5 |

| Step 1 | Step 2 | Step 3 | Step 4 | Step 5 | Step 6 | Step 7 |
|---|---|---|---|---|---|---|
| **List available reduction technologies** | **Is the technology commercially available?** | **Does the technology operate without impairing pellet quality or production?** | **Does the technology cause excessive corrosion to pellet furnaces or associated ducting or emission control equipment?** | **Does the technology present unacceptable environmental impacts?** | **Can the technology consistently meet the 72% reduction per the rule?** | **Is the technology cost effective?** |
| ACI at lower injection rate with existing wet scrubbers – Not considered a potential technology, does not reduce mercury emissions if accounting for mercury entering the furnace with the greenballs | NA – See Step 1 | NA – See Step 1 | NA – See Step 1 | NA – See Step 1 | NA – See Step 1 | NA – See Step 1 |
| ACI with baghouse | Yes | Yes | No | No | Yes | No, eliminated from further consideration |
| ACI with replacement high efficiency scrubber | Yes | Yes | No | No | Yes | No, eliminated from further consideration |
| Fixed carbon bed | Yes | Yes | No | No | Yes | No, eliminated from further consideration |
| GORE$^{TM}$ | Yes | Yes | No | No | No - Technology proceeds to alternative mercury emissions reduction evaluation (refer to Section 5) | NA – see Step 6 |
| Monolithic honeycomb adsorption | No, eliminated from further consideration (refer to Section 4.2.1) | NA - See Step 2 | NA -See Step 2 | NA - See Step 2 | NA - See Step 2 | NA -See Step 2 |

# 2 Introduction

This section discusses the purpose of and background information for the BAMRT analysis and alternative mercury emissions reduction evaluation. In addition, a description of Minorca's taconite production process is included for context in the potentially available mercury emissions reduction technology evaluations in Section 4.

## 2.1 Purpose

This section outlines the history of the Minnesota TMDL, mercury reduction research, and rulemaking for the taconite processing industry. The background information explains why the BAMRT analysis and alternative mercury emissions reduction evaluation were completed.

### 2.1.1 Mercury Reduction Research in Minnesota Taconite Processing

The taconite processing industry in northeastern Minnesota has actively researched methods to reduce mercury emissions from processing taconite ore, which produces taconite pellets for use in blast furnaces. Facilities that have participated in the ongoing efforts to reduce mercury emissions from operations include Minorca, Hibbing Taconite Company (HTC), Northshore Mining Company, U. S. Steel – Keetac (Keetac), U. S. Steel – Minntac (Minntac), and United Taconite (UTAC).

Mercury is a naturally occurring element in taconite ore and certain indurating furnace fuels. During the development of the Minnesota statewide mercury emissions reduction goals, the taconite processing facilities, the MPCA, and the Minnesota Department of Natural Resources (DNR) focused research on mercury emissions from Minnesota taconite processing facilities and ways to reduce these emissions. In 2003, efforts focused on the speciation of mercury from taconite processing and total mercury levels being emitted from taconite processing operations. Research conducted in 2005 studied the generation, distribution, and fate of mercury emissions from taconite processing facilities. Between 2006 and 2009, research focused on the capture of mercury from taconite processing combustion streams. Facilities actively tested several methods to capture mercury released from the induration process by existing wet scrubbers. These tests showed mixed results for mercury capture and reduction, identifying data gaps that would benefit from a more complete evaluation of the technology. The State of Minnesota continued to move forward with statewide mercury emissions reduction goals through the development and implementation of a statewide mercury TMDL.

### 2.1.2 Minnesota Statewide Mercury Total Maximum Daily Load

MPCA developed a statewide mercury TMDL to address mercury concentrations in fish tissue in Minnesota's lakes and streams, which was approved by the EPA in March 2007. The TMDL (authorized by MN Statute 114D.25) addresses impaired waters by evaluating the sources of mercury pollution, the reduction necessary to meet water quality standards (in Minnesota, the water quality standard is a fish tissue mercury concentration of 0.2 milligrams per kilogram [mg/kg]), and the allowable levels of mercury emissions in the future. According to MPCA's findings in Minnesota, mercury is primarily introduced to surface waters through atmospheric deposition, the majority of which originates from sources outside of Minnesota. See Figure 2-1 below for details.

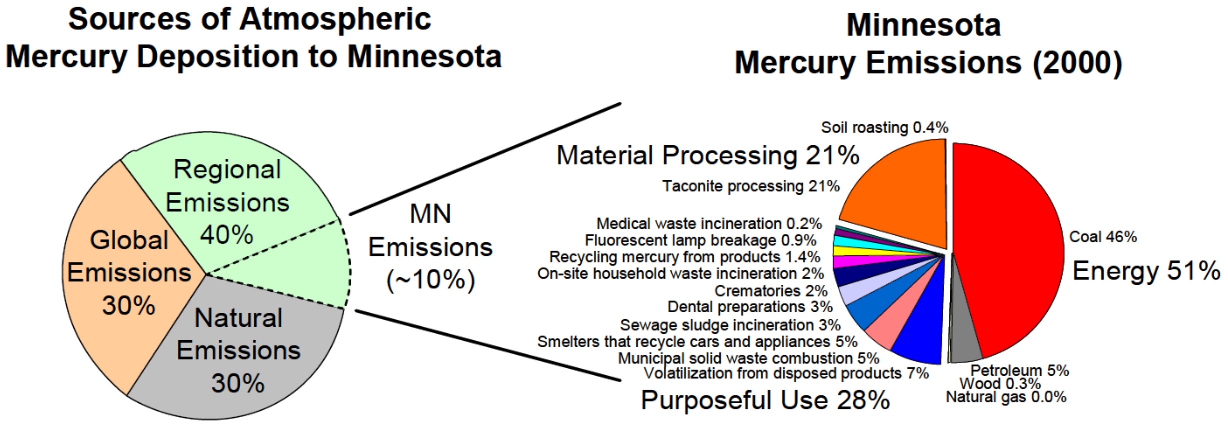


**Figure 2-1** **Sources of Mercury Deposition and Estimated Mercury Emission Sources in Minnesota (Reference (3))**

The TMDL specifies that, in order to meet water quality standards, a 93% reduction from 1990 human-caused, air-deposited mercury levels is required. As Figure 2-1 makes clear, attainment of this goal is only possible through global and national reductions because 90% of mercury deposition in Minnesota is from sources outside of Minnesota (Reference (3)). Even if all reduction goals in Minnesota are met, the mercury impairment will still exist in many water bodies throughout the state. In accordance with the TMDL, the Minnesota taconite processing sector endeavored to research mercury reduction technologies with a goal of a 75% reduction of mercury emissions by 2025 because mercury reduction technologies did not exist for the taconite industry. The MPCA later reduced the taconite processing sector's mercury reduction goal to 72% under Minn. R. 7007.0502, as discussed in more detail in Section 2.1.3.

The MPCA's 2016 emission estimates show that regional sources have reduced mercury emissions beyond the 2018 emission projections of the TMDL implementation plan (References (4), (5)). Specifically, the energy production sector's 2016 emission estimates (357.5 lb) show that the sector has already reduced mercury emissions beyond the 2018 emission projections (365.4 lb). The energy production sector represented over 51-56% of statewide mercury emissions in 2005 and 2008, while the taconite industry only represented 22-23% of statewide mercury emissions in those years. Mercury emissions reductions from the energy production sector are more significant than reductions from the taconite processing sector because they represent a larger portion of the state's emission inventory.

The MPCA has estimated mercury air emissions for the taconite industry as 734.8 pounds per year for 2005, 648.5 pounds per year for 2008, 745.4 pounds per year for 2011, 651.9 pounds per year for 2014, and 509 pounds per year for 2015 (Reference (4)). The estimated emissions from the taconite industry represent approximately 26% of statewide emissions for the cited years. In addition, the taconite industry only accounts for 3% of the total, 4% of anthropogenic, and 6% of regional atmospheric mercury deposition sources to Minnesota.

Under current operating conditions, nearly all of the mercury emitted to the air from taconite processing is elemental (93.3%), along with a small amount of oxidized (6.6%) and particulate-bound (0.1%) mercury (Reference (6)). Elemental mercury emissions are widely dispersed, travel thousands of miles, and remain in the atmosphere for several months to a year (Reference (7)). Accordingly, very little of the elemental mercury emitted to the air is deposited locally, which is why 90% of mercury deposited in Minnesota comes from external sources, and mercury in the atmosphere is largely (95%) elemental mercury (Reference (8)). Both oxidized and particulate-bound mercury have a higher probability of being deposited to the local environment than elemental mercury (References (9), (10)). Mercury deposition to land and water is predominantly in the form of oxidized mercury compounds (gaseous oxidized mercury or oxidized mercury attached to particles); land and water deposition occurs through either direct deposition of gas phase species or wet deposition of oxidized mercury in precipitation (Reference (11)). Particulate-bound mercury is generally thought to be deposited in a range of 30-50 miles from the point of emission to the atmosphere and oxidized mercury reacts with other environmental constituents within a few miles of the emission location (Reference (7)). Additional discussion on the potential impacts of mercury local deposition from reduction technologies are addressed in Section 4.5 and in the Local Deposition Evaluation (refer to Appendix B).

Mercury pollution is a global phenomenon with air emissions from international sources travelling thousands of miles and ultimately impacting Minnesota's water bodies. The MPCA, in its 2007 TMDL Executive summary, noted that "99 percent of mercury load to Minnesota's lakes and streams is from atmospheric deposition" (Reference (3)). Total international global mercury emissions are estimated between 12,100,000 and 13,200,00 pounds per year, of which between 4,000,000 and 4,800,000 pounds are anthropogenic sources (Reference (12)). Minnesota's total air emissions account for less than 0.03% of total international, anthropogenic mercury emissions.

As MPCA recognized in its February 2013 factsheet, *Sources of Mercury Pollution and the Methylmercury contamination of fish in Minnesota*, mercury contamination of lakes and streams in Minnesota "will not be solved until the United States and other countries greatly reduce mercury releases from all sources including mining, product disposal, and coal-fired power plants" (Reference (13)). More specifically, a 50% reduction in anthropogenic mercury emissions from Minnesota sources will only reduce deposition in Minnesota by 5% and a 50% reduction in U.S. emissions will only reduce deposition in Minnesota by 21% (Reference (14)).

The TMDL Implementation Plan (Reference (5)) notes "mercury-reduction technology does not currently exist for use on taconite pellet furnaces. Therefore, achieving the 75% mercury reduction target will incorporate the concept of adaptive management by focusing on research to develop the technology in the near term and installation of mercury emission control equipment thereafter."

The TMDL Implementation Plan defined the adaptive management criteria as reduction technology that is technically and economically feasible, does not impair pellet quality, and does not cause excessive corrosion to pellet furnaces or associated ducting or emission control equipment. As part of the BAMRT analysis and in keeping with the TMDL Implementation Plan and later MPCA rulemaking, all adaptive management criteria discussed above were evaluated to ensure that a suitable technology could be identified.

### 2.1.3 State of Minnesota Air Quality Rules for Mercury Air Emissions Reduction and Reporting Requirements

On September 29, 2014, the State of Minnesota amended the air quality rules related to mercury air emissions reporting and reductions requirements. During the rulemaking process, MPCA indicated that the rule must be considered in concert with the TMDL and use the adaptive management criteria (the technology must be technically feasible; it must be economically feasible; it must not impair pellet quality; and it must not cause excessive corrosion to pellet furnaces or associated ducting or emission control equipment) when evaluating whether mercury reduction technologies are "technically achievable" under the rules. As part of the BAMRT analysis for Minorca, all adaptive management criteria discussed above are evaluated to ensure that a suitable technology can be identified. In addition, the mercury rules were crafted because of the creation of the TMDL. Therefore, the implementation of a reduction technology must not create environmental impacts contrary to the goals of the TMDL (i.e., the technology must not have unacceptable environmental impacts). If a technology cannot be identified that will satisfy the adaptive management and acceptable environmental impacts criteria while also reducing emissions by 72% of the baseline as required by the rule, then Minorca will propose an AMERP to reduce mercury emissions, according to Minn. R. 7007.0502, subp. 5(A)(2). Note, the taconite processing industry originally endeavored to research mercury reduction technologies with a goal of a 75% reduction of mercury emissions by 2025 compared to 2010 estimates as part of the TMDL implementation plan. However, the actual MPCA rulemaking required a 72% reduction of 2008 or 2010 emissions, whichever is higher.

In addition, Minn. R. 7007.0502, subp. 4(B) requires the submittal of a Mercury Emissions Reduction Plan by December 30, 2018, for approval and inclusion in a permit or other enforceable document. Further, the Mercury Emissions Reduction Plan must include the following:

> ***7007.0502 Subp. 5. Mercury Emissions Reduction Plan Elements and Format***
>
> *A. The owners or operators of an existing mercury emission source must submit a mercury emissions reduction plan that complies with this item:*
>
> *(1) The plan must be submitted in a format specified by the commissioner and must contain:*
>
> *a. description of the specific control equipment, processes, materials, or work practices that will be employed to achieve the applicable control efficiencies, reductions, or allowable emissions and work practices listed in subpart 6 and a schedule for adopting the processes or installation of equipment;*
>
> *b. the mercury reduction, control efficiency, or emission rate that each emissions unit will achieve once the plan for that emissions unit is fully implemented;*

c. *a description of how operating parameters will be optimized to maintain the mercury control efficiency in the plan;*

d. *a proposed periodic monitoring and record-keeping system for proposed control equipment, processes, materials, or work practices or citation to an applicable requirement for monitoring and record keeping consistent with chapter 7017. An evaluation of the use of a continuous mercury emission monitoring system must be included in the plan;*

e. *if the plan includes elements that meet the definition of a modification under part 7007.0100, subpart 14, or requires an air permit amendment or notification under part 7007.1150, a projected schedule for submitting the appropriate permit applications; and*

f. *the date that the mercury reductions proposed in the plan will be demonstrated. This date must be no later than January 1, 2025, or as specified in subpart 6; or*

(2) *if the owner or operator determines that the mercury reductions listed in subpart 6, if applicable, are not technically achievable by the identified compliance date, the owners or operators may submit an alternative plan to reduce mercury emissions, in a format specified by the commissioner. The alternative plan must contain:*

a. *the plan elements in item A, substituting the owners' or operators' proposed reduction for the requirements under subpart 6;*

b. *a detailed explanation of why the mercury reductions listed in subpart 6 are not technically achievable;*

c. *a demonstration that air pollution control equipment, work practices, or the use of alternative fuels or raw materials have been optimized such that the source is using the best controls for mercury that are technically feasible; and*

d. *an estimate of the annual mass of mercury emitted under the requirements of subpart 6 and the proposed alternative plan.*

B. *The commissioner shall identify plan deficiencies and notify the owners or operators of the deficiencies.*

Minnesota’s taconite industry must include in the Mercury Emissions Reduction Plan the minimum mercury control requirements for source categories listed in Minn. R. 7007.0502, subp. 6(A):

***7007.0502 Subp. 6. Mercury Control and Work Practices***

A. *For ferrous mining or processing:*

> (1) *the plan must address the indurating furnace or kiln of a taconite processing facility or the rotary hearth furnace of a direct-reduced iron facility and must demonstrate that by January 1, 2025, mercury emissions from the indurating furnace or kiln or rotary hearth furnace do not exceed 28 percent of the mercury emitted in 2008 or 2010, whichever is greater. The commissioner shall determine the mercury emitted in 2008 and 2010. If the facility held a Minnesota Pollution Control Agency construction permit but was operating in 2010 at less than 75 percent of full capacity, the operating furnace must not exceed 28 percent of the mercury potential to emit included in the permit authorizing construction; and*
>
> (2) *the plan may accomplish reductions as:*
>
> a. *28 percent of 2008 or 2010 emissions for each furnace;*
>
> b. *28 percent of 2008 or 2010 emissions across all furnaces at a single stationary source; or*
>
> c. *28 percent of 2008 or 2010 emissions across furnaces at multiple stationary sources.*
>
> *Owners of the stationary sources must enter into an enforceable agreement as provided by Minnesota Statutes, section 115.071, subdivision 1, to reduce mercury emissions between the stationary sources. If this option is selected, the reduction plan must include the enforceable agreement. Execution of an enforceable agreement under this part does not relieve the owner or operator of the obligation to obtain a permit or permit amendment if otherwise required under this chapter.*

The BAMRT analysis helps Minorca develop the Facility's Mercury Emissions Reduction Plan by determining if a potential mercury emissions reduction technology is suitable for application at Minorca to achieve the required 72% reduction from baseline levels. If no technology can be identified that reduces mercury emissions by 72% while also satisfying the adaptive management and acceptable environmental impacts criteria, then Minorca will propose an alternative plan to reduce mercury emissions, according to Minn. R. 7007.0502, subp. 5(A)(2). The details of the BAMRT analysis process are described in Section 4.

## 2.2 Facility Description

The Facility mines taconite ore (magnetite) and produces taconite pellets that are shipped to an ArcelorMittal blast furnace in Indiana.

Concentrate slurry flows to a storage tank where fluxstone is added to make flux pellets. The concentrate is dewatered by vacuum disk filters, mixed with bentonite, and conveyed to balling discs. Greenballs produced on the balling discs are transferred to a roll conveyor for additional removal of over- and undersized material.

The greenballs are distributed evenly across pallet cars prior to entry into the pellet furnace. The pallet cars have a layer of fired pellets, called the hearth layer, on the bottom and sides of the car. The hearth layer acts as a buffer between the pallet car and the heat generated through the exothermic conversion of magnetite to hematite.

There is only one indurating furnace (EU 026) that is natural gas-fired at the Facility, with ultra-low sulfur diesel fuel as a back-up for emergency purposes only. The indurating furnace is a straight grate furnace with several distinct zones. The first two stages are updraft and downdraft drying zones. The next zones are the preheat zone and firing zone. The temperature increases as the pellets pass through each zone, reaching a peak in the firing zone. The pellets enter the after-firing zone, where the conversion of magnetite to hematite is completed. The last two zones are cooling zones that allow the pellets to be discharged at a temperature of around 120 degrees Fahrenheit.

Heated air discharged from the two cooling zones is recirculated to the drying, preheat and firing zones. Off-gases from the furnace are vented primarily through two ducts, the hood exhaust that handles the updraft drying and recirculated second cooling gases, and the windbox exhaust, which handles the preheat, firing, after-firing, and downdraft drying gases. The windbox exhaust flows through a multiclone dust collector, which protects the downstream fan, and then enters a common header shared with the hood exhaust stream. The exhaust gases are subsequently divided into four streams, which lead to four venturi rod scrubbers that exhaust from individual stacks (Furnace Stacks A-D, SV 014-017). Under normal operations, the captured scrubber solids from each of the four scrubbers are routed back to the concentrate thickener. An overview of the furnace design is provided on Figure 2-2.

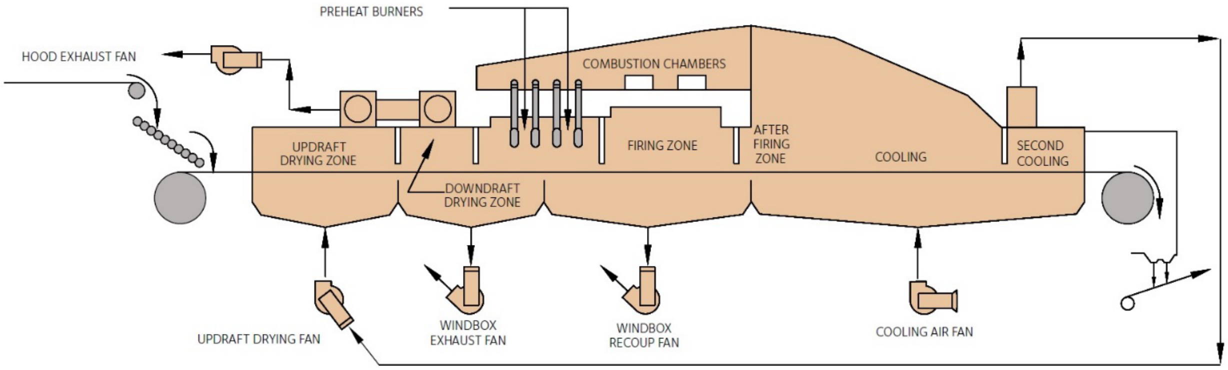


**Figure 2-2 Straight Grate Furnace Diagram**

The majority of mercury entering the process comes from the ore. Mercury is removed from the process in tailings streams or stack emissions from the indurating furnace. Stack emissions are dependent on the mercury content of the greenballs and the rate that the greenballs are fed to the furnace. The portion of mercury that is not captured by the four existing wet scrubbers is emitted to the atmosphere through each of the exhaust stacks mentioned above as mercury is liberated from the greenballs during the induration process. Mercury emissions out the stack can be in several different forms: gas phase mercury (in the form of elemental or oxidized mercury) or particulate-bound mercury. However, as stated in Section 2.1.2, the majority of the emissions are in the form of elemental mercury.

Fuel combustion is another potential source of mercury emissions. Minorca already fires natural gas in the indurating furnace, resulting in lower fuel combustion mercury emissions than multi fuel-fired furnaces.

# 3 Analysis of Baseline Mercury Emissions

This section describes how the annual mass of mercury emitted (i.e. baseline emissions) was calculated per the requirements of Minn. R. 7007.0502, subp. 6 (question 3b on the MPCA's Ferrous Mercury Reduction Plan Form).

The TMDL Implementation Plan estimated the Facility's mercury emissions to be 33.4 pounds per year for 2005, 2010, and 2018 (Reference (5)). These estimates were based on mercury volatilization emission factors from historic emission testing to derive emission factors and pellet production from 1995-1997 as reported in *Mercury Emissions from Induration of Taconite Concentrate Pellets – Stack Testing Results from Facilities in Minnesota* (Reference (15)). However, results from more recent emission testing conducted in 2015 (required by Minn. R. 7019.3050) varied from the TMDL emissions estimates (Reference (16)). The stack testing conducted in 2015 was in accordance with EPA-approved Method 29 and is more representative of current operations; therefore, the emission rate from the 2015 emission test is more representative than the TMDL emission rate estimate. The emission factor from the 2015 emission test (pounds of mercury per long ton of pellet production) was applied to 2008 and 2010 pellet production quantities (calculated as described below) per the requirements of Minn. R. 7007.0502, subp. 6 to find the annual mass of mercury emitted.

The Facility does not always operate at high production rates due to changing market conditions. It is inappropriate to use actual pellet production data from 2008 and 2010 because it would underestimate baseline emissions if the furnace were to operate for an extended duration at production rates closer to capacity. Therefore, looking exclusively at 2008 or 2010 actual production and associated mercury emissions would risk generating unrealistic baseline values for Minorca. This is because Minorca was not at full production (due to market or other conditions). As a result, Minorca determined baseline emissions using concepts from Step 1 of a New Source Review (NSR) Prevention of Significant Deterioration (PSD) analysis and EPA PSD guidance. Minorca annualized the highest demonstrated monthly pellet throughput (24-month rolling maximum) during 2008 and 2010 as an approximation of the annual level of production that unit was capable of accommodating. Supporting information is included in Appendix C.

Example calculation for 2008:

Minorca was capable of accommodating production of 3,467,064 long tons of pellets in 2008. This is based on the maximum month of actual pellet production from January 2006-December 2008 (maximum actual production in this period was 288,922 long tons in July 2006). Minorca's 2008 baseline emissions (85 lb/yr) were calculated using Minorca's emission factor (2.44E-05 lb/Lton) and the 2008 capable of accommodating production rate.

This method ensures that the baseline emissions account for varying production rates due to changing market conditions. Refer to Table 3-1 for details.

### Table 3-1 Summary of Mercury Emissions for Each Baseline Period

| Parameter | 2008 | 2010 |
|---|---|---|
| Emission Factor (lb mercury per long ton of pellets)(1) | 2.44E-05 | |
| Actual Production (long ton per year)(2) | 2,794,000 | 2,798,000 |
| Actual Emissions (lb mercury per year) | 68 | 68 |
| Capable of Accommodating Production (long ton per year) | 3,467,000 | 3,397,000 |
| Capable of Accommodating Emissions (lb mercury per year) | 85 | 83 |

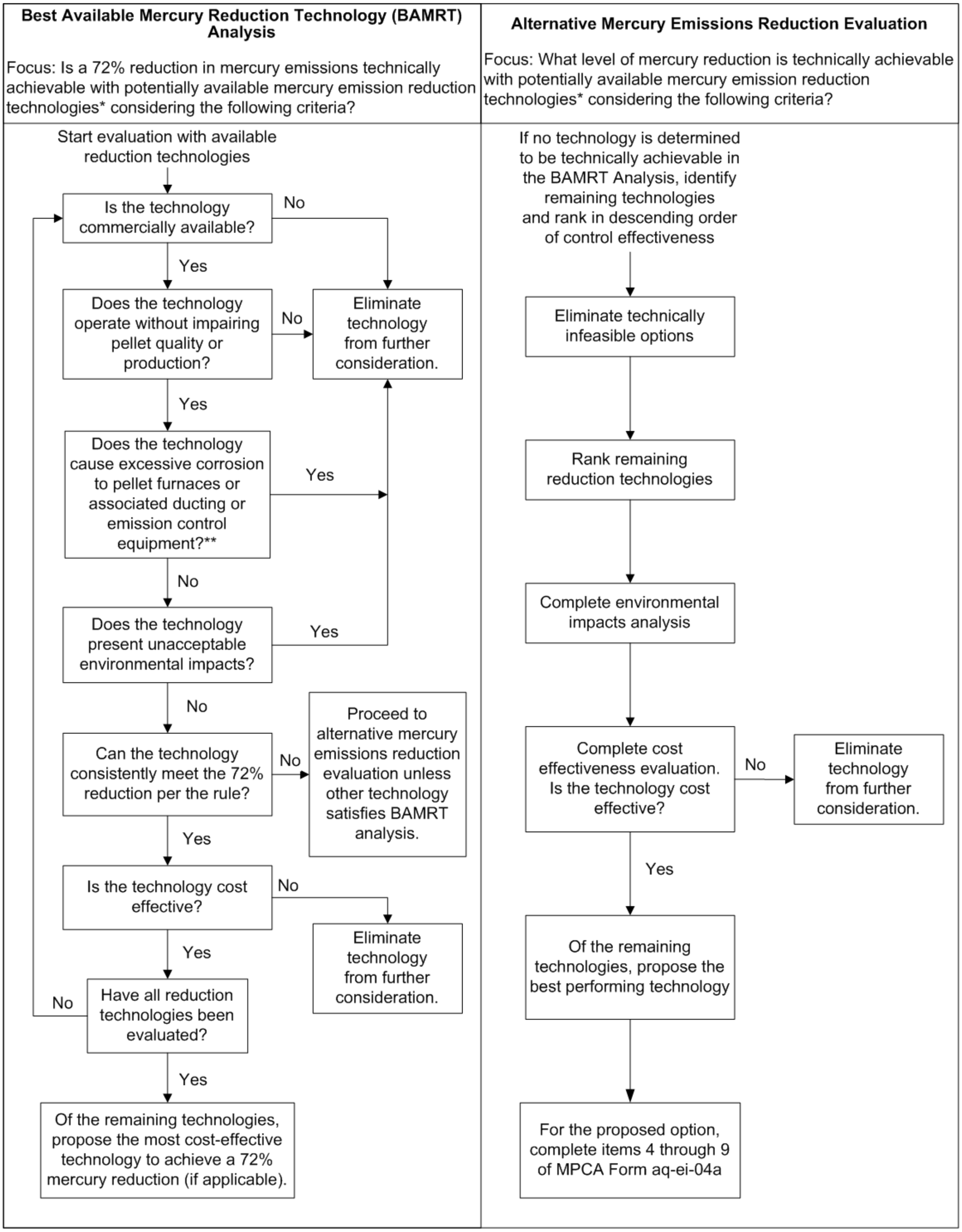
(1) Based on the 2015 Method 29 emission test (Reference (16))

(2) Production includes flux pellets, acid pellets, chips, and minroy.

Based on the approach to the baseline calculations described above, the annual mass of mercury emitted calculated per the requirements of Minn. R. 7007.0502, subp. 6 is 85 lb per year.

# 4 Best Available Mercury Reduction Technology Analysis

The purpose of the BAMRT analysis was to determine if the 72% mercury emissions reduction required by Minn. R. 7007.0502, subp. 6, was technically achievable by any of the potentially available mercury emissions reduction technologies and that none of the technologies caused unacceptable environmental impacts. Technically achievable, as discussed in Section 2.1.3, means the reduction technology meets the four adaptive management criteria from the TMDL Implementation Plan. Any technologies that cannot meet the mercury reduction percentage required by Minn. R. 7007.0502, subp. 6, are evaluated in the alternative mercury emissions reduction evaluation if they satisfy the adaptive management and the acceptable environmental impacts criteria. Figure 4-1 below provides additional detail on the process used to evaluate mercury reduction technologies.



*Potentially available mercury emission reduction technologies include specific control equipment, processes, materials or work practice standards that may be considered to achieve the required mercury reduction.

**Excessive corrosion is to be defined by the owner or operator.

**Figure 4-1 Determination of Technically Achievable Mercury Reductions**

Minorca completed an evaluation of potentially available mercury reduction technologies by adapting an approach similar to the EPA-approved BART analysis and top-down BACT analysis as a benchmark methodology to develop the BAMRT analysis. The BAMRT analysis sought to determine if mercury reductions required by Minn. R. 7007.0502, subp. 6, are technically achievable using the adaptive management criteria and acceptable environmental impacts criteria. The steps of the BAMRT analysis are outlined below. The details of each step, including the methods used to analyze a technology's acceptability under each step, are discussed further in Sections 4.1 through 4.8.

The sequence of the analysis was established by ordering the evaluation criteria such that the majority of potentially available mercury emissions reduction technologies proceed through the detailed analysis. Considerable effort was required to conduct site-specific evaluations for technologies as well as cost analyses. In addition, the MPCA expressed interest in evaluating how certain technologies performed (ACI with existing wet scrubbers and halide injection) and the existing structure allows for a direct evaluation of the adaptive management and environmental impacts criteria. Adjusting the sequence would increase the level of effort and cost of this analysis while having no effect on the conclusions. For example, if Step 6 were placed before Step 5 (environmental impacts), additional technologies would be carried to the alternative mercury emissions reduction evaluation in Section 5, while having no effect on the conclusions because the unacceptable environmental impacts still remain.

Step 1 – Identification of potentially available mercury reduction technologies

The first step in the BAMRT analysis was to identify all potentially available mercury reduction technologies for the taconite processing industry as the first stage of evaluating the technical feasibility of reduction technologies. Unlike BART, where only technologies that have been permitted and installed need to be evaluated, the industry included any known technology that may have conducted bench or pilot scale testing because mercury reduction technologies did not exist in the taconite processing sector when the industry began its analysis. Reduction technologies include specific control equipment, processes, materials, or work practice standards that may achieve the required mercury reduction. Details on each mercury reduction technology identified can be found in Section 4.1.

Step 2 – Determine if the technology is commercially available

The second step in the BAMRT analysis was to determine if the potentially available mercury reduction technologies identified in Step 1 were commercially available as the second stage of evaluation the technical feasibility of reduction technologies. Details on how commercial availability for each technology was determined can be found in Section 4.1.8. Any technology that was not commercially available was eliminated from further consideration.

Step 3 – Determine if the technology can operate without impairing pellet quality or production

The third step in the BAMRT analysis was to eliminate technologies that would impair pellet quality or production. Pellet quality parameters must be acceptable to produce marketable pellets and must not be adversely impacted by the mercury reduction technology. Details can be found in Section 4.2.2. Any technology that impairs pellet quality or production was eliminated from further consideration.

### Step 4 – Determine if the technology causes excessive corrosion

The fourth step in the BAMRT analysis was to determine if the technology causes excessive corrosion to pellet furnaces or associated ducting or emission control equipment, in accordance with the adaptive management criteria. Details on how corrosion was evaluated can be found in Section 4.4. Any technology that causes excessive corrosion was eliminated from further consideration.

### Step 5 – Determine if the technology presents unacceptable environmental impacts

The fifth step of the BAMRT analysis was to determine if the technology presents unacceptable environmental impacts. Most technologies will have some environmental impact (i.e., waste disposal, water, or air implications). Impacts that can be mitigated through other treatment methods were not used to eliminate a technology from further consideration. Rather, an unacceptable environmental impact was considered something that contradicts the goals of the TMDL or other state or federal regulations. For example, a reduction technology that increases particulate-bound mercury emissions would be unacceptable because mercury is more likely to be deposited locally, which is contrary to the goals of the TMDL. Refer to the Local Deposition Evaluation in Appendix B (Reference (17)). Details on how each technology was evaluated for environmental impacts can be found in Section 4.5. Any technology that causes unacceptable environmental impacts was eliminated from further consideration.

### Step 6 – Determine if the technology can consistently meet the 72% reduction per the MN rule

Any technology that cannot consistently achieve a 72% reduction per the rule was not carried into the next step of the BAMRT analysis. Details on the determination of percent reduction for each technology can be found in Section 4.6. Any technology that makes it to Step 6 of the BAMRT analysis but cannot consistently achieve a 72% reduction (required in Minn. R. 7007.0502, subp. 6(A)(1)) is evaluated in the alternative mercury emissions reduction evaluation (Minn. R. 7007.0502, subp. 5(A)(2)) if it is needed, as determined in Step 8.

### Step 7 – Determine if the technology is cost effective

The seventh step of the BAMRT analysis documented the cost effectiveness of each mercury reduction technology not eliminated in Steps 1 through 6, pursuant to the adaptive management criteria. This step compared the annualized cost per pound of mercury ($/lb) removed for the remaining technologies, consistent with the EPA’s approach to determining if reduction technologies are cost effective. Details on the cost effectiveness procedure can be found in Section 4.7.

If the control cost exceeded the established cost effectiveness threshold, then the technology was not considered cost effective. Any technology that was not considered cost effective was eliminated from future consideration.

Step 8 – Determination of Best Available Mercury Reduction Technology

The final step in the BAMRT analysis selects the best technology by using the results from Steps 1 through 7 or determines if an alternative mercury emissions reduction evaluation is required, pursuant to Minn. R. 7007.0502, subp. 5(A)(2). If, after completing Steps 1 through 7, Minorca determines that the 72% reduction in mercury emissions is not technically achievable and achievable without unacceptable environmental impacts with the potentially available mercury emissions reduction technologies, an alternative mercury emissions reduction evaluation is completed. The alternative mercury emissions reduction evaluation only includes remaining technologies that are not eliminated from further consideration in any of the above steps.

## 4.1 Step 1 – Identification of Potentially Available Mercury Reduction Technologies

Technologies identified for evaluation in the BAMRT analysis are discussed in the following sections.

### 4.1.1 Mercury Emissions Reduction Technology Selection Process

The BAMRT analysis contains a high-level evaluation of potentially available mercury reduction technologies. The list of technologies was compiled based on a review of historical research and testing that has been completed at both industry and site-specific levels. Minorca has invested significant resources and thousands of staff hours on technology evaluation efforts. The historical review covered each of the following “stages” of mercury reduction studies:

- Pre-TMDL Implementation Plan DNR Research (Pre-TMDL research)
- Phase I – Minnesota Taconite Mercury Control Advisory Committee (Phase I)
- Phase II – Extended Testing of ACI (Phase II)
- Gore Technology Demonstrations (GORE$^{TM}$)
- Site-specific Evaluations

Each of the stages listed above included a number of individual research projects that were reviewed as part of this analysis. The reports for each project have been included in Appendix B.

Pre-TMDL research evaluated potential mercury controls for the taconite processing industry and was coordinated with the DNR. This stage of research sought to conduct a broad review of all potential reduction technologies utilized in other industries. It concluded that chemical oxidation and sorbent injection methods used by or considered for the power industry might be adapted by the taconite processing industry (Reference (18)). Therefore, the taconite processing industry, including Minorca, focused on these technologies during Phase I.

Testing from Phase I research projects showed that ACI had the highest potential to control mercury emissions from the taconite processing industry. This led to Phase II ACI testing at several taconite facilities, including Minorca. However, Phase II testing did not achieve anticipated reductions and it revealed issues such as increased particulate emissions (i.e., unacceptable environmental impacts) from the wet scrubbers during ACI. During Phase II testing, the taconite processing industry became aware of an emerging sorbent technology known as GORE$^{TM}$. Pilot studies of this technology were conducted at Minorca, UTAC, and Minntac. GORE$^{TM}$ demonstrated that it had the potential to reduce mercury emissions by 72% under specific conditions, but presented additional concerns such as mercury- and sulfate-laden wash water. However, GORE technology did not reduce emissions consistently by 72% during testing at Minorca.

The testing discussed above left several unanswered questions and data gaps. In order to address these issues, additional sorbent injection and mercury capture by existing wet scrubbers with solids removal process sampling were conducted.

### 4.1.2 Potentially Available Mercury Emissions Reduction Technologies

Table 4-1 lists all potentially available mercury emissions reduction technologies that were evaluated as part of the BAMRT analysis along with a short summary of how mercury reduction could work. This summary also includes background information and considerations from the testing discussed above that will be addressed in later steps of the BAMRT analysis. Sections 4.1.3 through 4.1.7 summarize each technology in more detail.

**Table 4-1 Potentially Available Mercury Emissions Reduction Technologies**

| Reduction Technology | | Basis of Technology | Section # |
|---|---|---|---|
| Mercury capture by existing wet scrubbers with solids removal | | Oxidized mercury can be captured in wet scrubbers. To prevent captured mercury from re-entering the system, the scrubber solids can be removed from the process. | 4.1.3 |
| Mercury oxidation for capture by wet scrubbers | Halide injection | Halide injection increases mercury oxidation and subsequent capture. | 4.1.4.1 |
| | In-scrubber oxidation | Addition of oxidation chemicals to the scrubber to increase mercury oxidation and subsequent capture. | 4.1.4.2 |
| | High energy dissociation technology (HEDT) | Generation of reactive halogens at high temperatures outside of the process prior to injection downstream of the furnace, which aids in mercury oxidation and subsequent capture. | 4.1.4.3 |
| Activated carbon injection | With existing wet scrubbers | Powdered activated carbon (PAC) adsorbs mercury and is then removed in the wet scrubber or baghouse. Injection at a lower rate with the existing scrubbers may still achieve mercury reduction while reducing environmental impacts. | 4.1.5.1 |
| | At lower injection rate with existing wet scrubbers | | 4.1.5.2 |
| | With baghouse | | 4.1.5.3 |
| | With replacement high efficiency scrubber | | 4.1.5.4 |
| Fixed carbon bed | | Flue gas is routed through a carbon bed, which adsorbs the mercury. | 4.1.6 |
| GORE$^{\text{TM}}$ | | GORE$^{\text{TM}}$ technology is a fixed sorbent polymer composite, which doesn't require injection of powder sorbents or chemicals, capturing both elemental and oxidized mercury in particulate and gas phase. | 4.1.7 |
| Monolithic Honeycomb Adsorption | | Activated carbon and elemental sulfur are mechanically fixed into a honeycomb structure that may include additives to enhance mercury capture. The cells of the monolith are plugged at their ends intermittently to force gas flow through the walls of the structure. | 4.1.8 |

### 4.1.3 Mercury Capture by Existing Wet Scrubbers with Solids Removal

The majority of mercury contained in greenballs is vaporized during the indurating process and becomes entrained in the furnace flue gas. Flue gas mercury is naturally present as either elemental (majority) or oxidized (minority) mercury. Oxidized mercury can be more readily captured in Minorca's four existing wet scrubbers due to the scrubbers' ability to reduce particulate emissions. This is because oxidized mercury is water soluble and adsorbs (or adheres) to particles (Reference (19)). Any mercury captured in the four wet scrubbers is currently recirculated within the process due to the recycling of the scrubber effluent. However, removing the scrubber solids from the process can reduce the amount of mercury entering the indurating furnace and thus reduce mercury air emissions. The Pre-TMDL research and testing evaluated this method of mercury reduction (Reference (19)) and found that the mercury would remain with the solids for permanent sequestration (i.e. the mercury would not leach if sent to the tailings basin).

The effluent from the four existing wet scrubbers contains a combination of liquid and solids during current operations. This scrubber effluent is returned to the process scrubber recirculation tank. A large portion of the scrubber effluent that reports to the process scrubber recirculation tank is recycled back to the waste gas scrubbers. Approximately 75% of the scrubber effluent that flows from the waste gas scrubbers is recycled as makeup water back to the process scrubber recirculation pumps. The remaining 25% of the scrubber effluent flow is removed from the process scrubber recirculation tank by the scrubber blowdown pump system.

The scrubber blowdown stream flow that is removed from the process scrubber recirculation tank is replaced with water from the plant process system. Under normal operating conditions, this scrubber blowdown stream is sent to the concentrate lower splitter box, which divides the flow between two concentrate thickeners. The concentrate thickeners recover water and the potential iron units captured by the four waste gas scrubbers. Any mercury that is captured in the scrubber solids is currently recycled back with iron units into the greenballs because it is returned to the concentrate. Therefore, to be an effective mercury reduction technique, the solids from the scrubbers would have to be removed from the process for disposal to prevent captured mercury from being recycled back into the process. However, this will come with a cost penalty because the iron units contained in the scrubber solids will no longer be recycled.

The Pre-TMDL research and recent testing indicated that the removal of scrubber solids from the process can provide some benefit of reducing mercury emissions (Reference (20)). In addition, other taconite facilities currently use this mercury reduction technology (e.g., Keetac and UTAC). Therefore, Minorca evaluated this as a potential mercury emissions reduction technology.

### 4.1.4 Mercury Oxidation for Capture by Existing Wet Scrubbers

Oxidized mercury has the potential to be captured in a wet scrubber because it is water-soluble and adsorbs to particles (Reference (19)). Therefore, in principle, increased mercury oxidation of the flue gas should result in an increased proportion of mercury that is able to be captured at the wet scrubber.

A number of methods to increase mercury oxidation are available, including halide injection, in-scrubber oxidation, and HEDT. The majority of the Pre-TMDL research focused on these methods, while Phase I work elaborated on halide injection and in-scrubber oxidation. In addition, HTC (a similar straight grate type furnace) conducted additional halide injection testing in 2017 (Reference (21)).

#### 4.1.4.1 Halide Injection

Oxidizing agents, typically halogens, convert elemental mercury to oxidized mercury through an oxidation reaction. Oxidizing agents can be applied directly to the greenballs before the indurating process or they can be injected into the flue gas stream. A number of chloride and bromide salts have been tested in the taconite industry. Injection locations and halide compounds that were tested at Minorca and other taconite processing facilities are listed below. Note, the term “halide injection” encompasses all chemicals and injection (or addition) locations that have been tested to reduce mercury emissions in the taconite industry discussed below:

- Sodium chloride (NaCl) addition to greenballs - This potential mercury reduction method was tested at HTC Line 3 and at UTAC Line 2 (Reference (22)). Both continuous mercury monitors (CMMs) and flue-gas absorbent-trap mercury speciation (FAMS) traps were placed in the stacks to measure the mercury concentration. The decrease in mercury concentration recorded by the monitor at the stack was used to calculate to the total mercury reduction assuming a constant greenball mercury concentration. Injection rates were 0.5 and 1 lb/long ton of greenballs.
- NaCl addition to preheat zone - This potential mercury reduction method was tested at HTC Line 3 (Reference (22)). A CMM was used to monitor mercury stack emissions. The decrease in mercury concentration recorded by the monitor at the stack was used to calculate to the total mercury reduction assuming a constant greenball mercury concentration. The NaCl injection rate tested was 50 lb/hr.
- Sodium bromide (NaBr) addition to greenballs - This potential mercury reduction method was tested at Minntac Line 3 and Minorca (Reference (23)). Mercury reduction efficiencies were based on CMMs placed in the scrubber feed duct and on the stack.
- NaBr addition to preheat zone - This potential mercury reduction method was tested at HTC Line 3 (Reference (22)). A CMM was used to monitor mercury stack emissions. The decrease in mercury concentration recorded by the monitor at the stack was used to calculate to the total mercury reduction assuming a constant greenball mercury concentration. The NaBr injection rate tested was 50 lb/hr.
- Calcium chloride ($CaCl_2$) addition to preheat zone - This potential mercury reduction method was tested at HTC Line 3 (Reference (22)). A CMM was used to monitor mercury stack emissions. The decrease in mercury concentration recorded by the monitor at the stack was used to calculate to the total mercury reduction assuming a constant greenball mercury concentration. The $CaCl_2$ injection rate tested was 50 lb/hr.
- Hydrogen bromide (HBr) addition to preheat zone - This potential mercury reduction method was tested at HTC during the recent halide injection testing in late 2017 (Reference (21)). The reduction in mercury emissions was determined using EPA 30B during screening trials. The injection rate was 2 gal/hr of HBr solution.
- HBr addition to the windbox exhaust - This potential mercury reduction method was tested at HTC during the recent halide injection testing in late 2017 (Reference (21)). The reduction in mercury emissions was determined using EPA 30B during screening trials. The injection rate was 2 gal/hr of HBr solution.
- Calcium bromide ($CaBr_2$) addition to preheat zone - This potential mercury reduction method was tested at HTC Line 3 and Minorca during the pre-TMDL research (References (22), (24)). A CMM was used to monitor mercury stack emissions. The decrease in mercury concentration recorded by

the monitor at the stack was used to calculate to the total mercury reduction assuming a constant greenball mercury concentration. The $CaBr_2$ injection rates tested were 50 lb/hr at HTC and 0.09 gallons per minute (gpm) at 48 wt% solution of $CaBr_2$ at Minorca. In addition, $CaBr_2$ was tested at HTC during the recent halide injection testing in late 2017 (Reference (21)). The reduction in mercury emissions was determined using EPA 30B during screening trials. The injection rate was 2 gal/hr of $CaBr_2$ solution. HTC also performed screening tests at injection rates of 1, 2, 3, and 4 gal/hr to determine what injection rate would be needed to provide the optimal mercury reduction. HTC proceeded to test $CaBr_2$ injection to the preheat zone at 2 gal/hr for a trial of 52 days. Mercury reductions were determined by comparing the baseline (no halide injection) to halide injection Ontario Hydro stack tests (which provide total and speciated mercury emission rates).

- $CaBr_2$ addition to the windbox exhaust - This potential mercury reduction method was tested at HTC during the recent halide injection testing in late 2017 (Reference (21)). The reduction in mercury emissions was determined using EPA 30B during screening trials. The injection rate was 2 gal/hr of $CaBr_2$ solution.

Halide injection testing has demonstrated that halide injection to the greenballs is an inferior control method compared to direct injection into the induration furnaces (preheat zone for Minorca, Reference (24)). Of the evaluated chemicals, NaCl and $CaCl_2$ consistently resulted in less mercury reductions compared to brominated salts such as $CaBr_2$, NaBr, and HBr (Reference (22)). Of those, $CaBr_2$ achieved the highest reductions (Reference (24)). Additionally, HBr is a highly toxic chemical that presents significant safety concerns for handling and use. Therefore, only $CaBr_2$ injection into the preheat zone was used for evaluation throughout the BAMRT analysis.

Halide injection has the added concerns of potential pellet quality degradation and/or excess corrosion to plant equipment (which are two of the adaptive management criteria). Oxidizing chemicals may oxidize plant equipment rather than the mercury in the flue gas, decreasing the effective life of furnace equipment. Due to these concerns, corrosion was evaluated by the taconite processing sector, as discussed in more detail in the Step 4 analysis in Section 4.4.

During the Pre-TMDL research work, the University of North Dakota’s Energy & Environmental Research Center (EERC) working in conjunction with the DNR completed bench-scale exposure experiments in simulated taconite flue gases to help understand if and how bromine-induced corrosion occurs. Testing was completed in environments that mimicked the preheat zone, the drying/cooling zone, and the discharge zone. The final report from August 28, 2009 is entitled *Assessment of Potential Corrosion Induced by Bromine Species used for Mercury Reduction in a Taconite Facility* (Reference (25)). The short-term small scale testing showed that 40 ppm HBr in a simulated taconite process flue gas environment caused slight surface corrosion, with bromine deposition and losses of Fe, Ni, and Cr mainly confined to the surface. However, the testing was time-limited (30 days) and was carried out in simulated flue gas environments that did not necessarily represent actual operating conditions of the taconite process. In addition, testing lacked a control sample to compare the corrosion from temperature and simulated flue gas constituents.

Other Pre-TMDL research reports discuss potential corrosion impacts from chemical injection to oxidize mercury, but they do not provide detailed technical concerns, nor do they demonstrate actual test results that indicate excessive corrosion or equipment degradation is an issue of concern.

Only one report discusses the potential impacts to pellet quality. The *Mercury Transport in Taconite Processing Facilities: (I) Release and Capture During Induration* report from August 15, 2005 (Reference (26)) noted that it is "unlikely the iron-oxide mineralogy would be strongly affected by the presence or absence of small amounts of HCl in process gases." However, "small amounts" is a general term and is not quantified.

As part of the Phase I – Minnesota Taconite Mercury Control Advisory Committee work, one of the research projects *Continuation of Corrosion Potential of Bromide Injection Under Taconite Operating Conditions* (Reference (27)) focused on the evaluation of bromine- and chlorine-induced metal corrosion under simulated taconite operating conditions. The research project found temperature is very critical to corrosion, and under elevated temperatures (500°– 950°C), active oxidation is a main corrosion mechanism. This temperature range is within Minorca's indurating furnace operating range of the downdraft drying zone. HBr showed a higher rate of corrosion when compared to hydrogen chloride (HCl).

Potential corrosion impacts of halide injection were further studied during recent HTC testing in 2017. The results from the corrosion laboratory analysis show increased corrosion of the grate bars and furnace ducting coupons (Reference (21)). While the laboratory analysis showed a higher rate of corrosion compared to baseline conditions, it could not be seen with the naked eye. Higher rates of corrosion nevertheless remain an operational concern with long-term halide injection.

In addition, the furnace, ducting, and pollution-control equipment were visually inspected for signs of additional buildup, wear, and corrosion during the 2017 HTC halide testing, with no additional buildup or visual corrosion of the equipment observed.

Corrosion observations were based on a 52 day halide injection test. Although there was no evidence from testing to determine if halide injection caused excessive corrosion, testing to date has not been long enough in duration to observe all possible process or equipment impacts. Full-scale installation may demonstrate that corrosion is a serious concern.

Halide injection was evaluated as a potential mercury emissions reduction technology in the BAMRT analysis.

#### 4.1.4.2 In-scrubber Oxidation

In-scrubber oxidation consists of adding oxidizing chemicals directly to the scrubber water (rather than to the flue gas) as an alternative way of oxidizing flue gas elemental mercury for capture in a wet scrubber. As part of the Pre-TMDL research and portions of the Phase I work, three different oxidizing chemicals were evaluated at taconite processing facilities: hydrogen peroxide ($H_2O_2$), diethyl dithiocarbamate

(DEDTC) and a proprietary reagent (sodium chlorite – $NaClO_2$) on slip-stream furnace off-gases as discussed below:

$H_2O_2$ Testing at Keetac: Keetac conducted slip-stream testing using $H_2O_2$. This test demonstrated that $H_2O_2$ decreased the simulated scrubber solution's ability to oxidize and capture mercury compared to baseline conditions. As a result, the report stated "$H_2O_2$ is not a likely candidate for in-scrubber oxidation at taconite processing plants and that, perhaps, it even interferes with the background mercury oxidation process that takes place when no oxidant is added to the water" (Reference (22)). $H_2O_2$ was not further developed or tested again for the taconite processing industry. Therefore, the addition of $H_2O_2$ to scrubber water was not considered to be a potential reduction technology.

DEDTC Testing at Minntac: Minntac tested DEDTC by dosing scrubber water. However, there was no observable reduction in mercury emissions at the stack during the test (Reference (28)). The report stated "Addition of the scrubber additive, DEDTC to the scrubber waters resulted in no observable effects on the mercury concentration/speciation in either the taconite process flue gases or the dissolved mercury concentration in the scrubber slurry." Therefore, the addition of DEDTC to scrubber water was not considered to be a potential reduction technology.

$NaClO_2$ Testing

- $NaClO_2$ Testing at Keetac: Keetac conducted slip-stream testing using $NaClO_2$. This test demonstrated that $NaClO_2$ had the potential to be effective as a scrubber additive to reduce mercury emissions (Reference (22)).
- $NaClO_2$ Testing at Minntac: Minntac added $NaClO_2$ to its wet scrubber on Line 3. Minntac used CMMs to determine a reduction efficiency. Based on Figure 1 in the Pre-TMDL research report "On the Measurement of Stack Emissions at Taconite Processing Plants" (Reference (23)), $NaClO_2$ reduced mercury emissions by approximately 20% (5,000 $ng/m^3$ to 4,000 $ng/m^3$). The report postulated that the oxidant addition interfered with the particulate's ability to adsorb mercury.
- $NaClO_2$ Testing at Minorca: $NaClO_2$ was added to the wet scrubber water. CMMs were used to determine a reduction efficiency. Mercury emissions actually increased by approximately 25% during this test and decreased back to baseline after injection ceased (Reference (29)).

As demonstrated by the testing discussed above, mercury control with the use of $NaClO_2$ is unpredictable and as seen at Minorca, may even increase mercury emissions out of the stack by hampering the existing scrubbers' ability to capture any mercury from the flue gas.

For the reasons discussed above, in-scrubber oxidation was not considered as a potential control technology for Minorca, and, therefore, was not evaluated throughout the remainder of the BAMRT analysis.

### 4.1.4.3 High Energy Dissociation Technology

HEDT is an EERC proprietary technology in which reactive halogens are generated at high temperatures outside of the taconite process and injected downstream of the furnace. The technology works by dissociating halogen salts, allowing the use of benign compounds to create halogen radicals that oxidize flue gas mercury (Reference (30)). This technology was tested during the Pre-TMDL research..

Excessive corrosion concerns associated with halide injection are still a concern with HEDT. However, due to the fact the halides with HEDT are injected after the furnace, corrosion impacts may be mitigated because the chemicals are less likely to encounter the high temperatures of the furnace.

HEDT was evaluated as a potential mercury emissions reduction technology in the BAMRT analysis.

## 4.1.5 Activated Carbon Injection

### 4.1.5.1 ACI with Existing Wet Scrubbers

ACI works by introducing powdered activated carbon (PAC) into the flue gas stream where it adsorbs gas phase mercury. The PAC is then captured, along with the mercury, downstream in the wet scrubbers. Both elemental and oxidized forms of mercury can be adsorbed onto the carbon particles. Since mercury is adsorbed onto the PAC in the ductwork, prior to the particulate control device, the distance from the PAC injection point to the particulate control device (i.e., the residence time) has a significant impact on the level of achievable control. This depends on the specific configuration of each individual facility. Adding halogens, such as bromine, iodine, or chlorine, to the activated carbon can increase the mercury oxidation, which in turn increases capture in the particulate control device (Section 4.1.4.1).

As part of the Phase I and Phase II research and testing, both PAC and brominated PAC were evaluated for effectiveness at taconite processing facilities. Injection locations tested included:

- Greenball (brominated PAC only) - This potential mercury reduction method was not actually tested at a taconite facility. Rather, greenball samples from HTC, UTAC, Minntac, Keetac, and Minorca were studied to determine if brominated PAC affects the oxidation characteristics of mercury during induration (Reference (31)). Oxidized mercury was measured using the Ontario Hydro Method (OHM) and a Horiba mercury analyzer. The reported bench-scale reduction efficiency assumes that 100% of the oxidized mercury would be captured by the wet scrubber, if this method were applied at the full scale. Additional evaluations of this injection method were ceased because the addition of carbon to the greenballs decreased the compression strength of the fired pellet and thus, impairing the pellet quality (Reference (32)).

- Preheat zone - Minntac's Line 3 was used to test PAC and brominated PAC injection into the furnace preheat zone (Reference (28)). A CMM and the OHM were used to determine the mercury reduction efficiency. Standard PAC injection rates tested were 50, 100, and 150 lb/hr. Brominated PAC injection rates tested were 50, 75, 100, and 150 lb/hr. Brominated PAC was injected in two separate locations: the preheat fans and the preheat grate. Higher reductions were achieved by injecting the brominated PAC at the preheat grate. As part of the testing, it was identified that PAC was slipping through the scrubber exhaust. Finally, it is important to note that the mercury reductions achieved during standard PAC injection were believed to be due to fluctuations in baseline values and not due to the PAC injection.

- Flue gas - This potential mercury reduction method was tested during Phases I and II (References (33), (34)). HTC Line 1 was tested during Phase I using PAC and brominated PAC. Phase II only tested brominated PAC injection and included UTAC Line 2, Minorca, Keetac, Minntac Line 7, and HTC Line 3. Mercury reduction efficiency was monitored using a continuous emission monitoring system (CEMS) and sorbent traps. Phase I PAC injection rates tested were 1 and 5 lb/MMacf and 1, 2, 3, 4, and 5 lb/MMacf for brominated PAC. Phase II brominated PAC injection rates in lb/MMacf are as follows: HTC - 3, Keetac - 3.6 and 7, Minntac - 7 and 9, Minorca - 3, and UTAC - 5 and 8. Testing at several of the facilities showed that particulates from the PAC injection were passing through the wet scrubbers. An additional test of this injection location was conducted at Minorca in 2017 (Section 4.1.5.2).

Brominated PACs achieved a greater reduction in mercury (Reference (33)). Therefore, all subsequent testing was with brominated PACs.

ACI increases the particulate loading at the wet scrubbers, which, depending on equipment parameters and facility operations, may result in reduced particulate matter control and possible exceedances of particulate limits under Minorca's existing Title V operating permit (TVOP). ACI may also lead to increased local deposition due to the increase in particulate-bound mercury emissions. Both oxidized and particulate-bound mercury have a higher probability of being deposited to the local environment than elemental mercury (References (9), (10)). The potential environmental impacts of ACI with wet scrubbers is discussed in more detail in Section 4.5.2.

ACI with existing wet scrubbers was evaluated as a potential mercury emissions reduction technology in the BAMRT analysis.

#### 4.1.5.2 ACI at a Lower Injection Rate with Existing Wet Scrubbers

ACI at a lower injection rate is similar to the process described in Section 4.1.5.1 with the exception that the PAC injection is reduced. This is to comply with existing TVOP and 40 CFR 63 Subpart RRRRR (Taconite MACT) filterable particulate limits (0.01 gr/dscf) and mitigate the adverse environmental impacts associated with increased particulate-bound mercury emissions. The 2017 test of this technology at Minorca (Reference (35)) injected PAC at a lower rate compared to the Phase II research (1 lb/MMacf).

Testing showed that ACI reduced gas phase mercury emissions. However, unlike Phase II testing, the calculations accounted for the amount of mercury entering the furnace with the greenball feed to calculate the total mercury reduction. Changes in stack emissions are directly related to the amount of mercury in the greenball feed. Accounting for greenball mercury showed that ACI did not reduce total mercury emissions. The decrease in gas phase mercury instead is attributed to a smaller amount of mercury entering the furnace with the greenballs. In addition, the particulate-bound mercury emissions represented a higher fraction of the mercury emitted out the stack compared to normal operating conditions. This demonstrates that ACI was effective at adsorbing some gas phase mercury. However, due to differences in particle size and density, PAC with mercury cannot be captured as readily as process dust. This explains why particulate-bound mercury was elevated compared to normal operating conditions. The four wet scrubbers operated normally during ACI testing and stack testing showed that particulate emissions rates were at or below prior stack test results with no ACI. Increased particulate-bound mercury is more likely to be deposited locally, which is contrary to the goals of the TMDL. Refer to Section 4.5 for details.

ACI at a lower injection rate with the four existing wet scrubbers was not considered to be a potential reduction technology because it did not reduce total mercury emissions (Reference (35)). Therefore, this technology was eliminated from further consideration.

#### 4.1.5.3 ACI with Baghouse

As discussed in Section 4.1.5.1, ACI can adsorb elemental and oxidized mercury from the flue gas to form particulate-bound mercury. However, smaller and less dense PAC particulates are less likely to be captured by the existing wet scrubbers. Therefore, smaller PAC particles containing adsorbed mercury have the potential to be emitted as particulate-bound mercury. The existing wet scrubbers can operate and maintain compliance with existing limits under current operations. However, the same level of control for PAC particulates cannot be maintained because the existing wet scrubbers were not designed to control PAC. To address this issue, enhanced particulate controls may be considered to replace the four existing wet scrubbers. The net effect of installing new controls is to increase the capture efficiency of particulates and thereby increase the overall mercury reduction of ACI. This evaluation is based on replacing the four existing wet scrubbers with a single stack and baghouse.

A study from Phase I, *Project 4: Evaluation of a Slipstream Baghouse for the Taconite Industry* (Reference (36)) evaluated the possibility of using enhanced particulate control with a baghouse to capture the PAC. CMMs and sorbent traps were used to measure mercury reduction efficiency. PAC injection rates tested at Keetac were 1.1, 2, and 2.2 lb/MMacf with mercury reductions of 76.3%, 84.5%, and 91% respectively. Brominated PAC injection rates tested at Keetac were 0.6 and 1.1 lb/MMacf with reductions of 82.9% and 88.1% while firing natural gas, respectively.

ACI with a baghouse was evaluated as a potential mercury emissions reduction technology in the BAMRT analysis.

#### 4.1.5.4 ACI with Replacement High Efficiency Scrubber

Similar to Section 4.1.5.3, enhanced particulate controls can increase the overall mercury reduction of ACI. Therefore, this technology evaluates the possibility of replacing the four existing wet scrubbers with a single new stack and new high efficiency scrubber to accommodate the additional PAC particulate loading.

Although industry did not test a high efficiency scrubber, this technology was considered a potential technology for completeness because the technology may have been developed further in recent years.

ACI with a replacement high efficiency scrubber was evaluated as a potential mercury emissions reduction technology in the BAMRT analysis.

### 4.1.6 Fixed Bed Carbon Adsorption

Fixed bed carbon adsorption consists of routing flue gases through a vessel packed with activated carbon. The flue gas passes through a series of vessels where the fixed carbon beds remove the mercury from the flue gas. The carbon contains many pores with active adsorption sites, which capture mercury as the flue gas flows through.

Although a fixed carbon bed would be installed after all existing processing equipment, there is still a concern that implementation has the potential to negatively impact the process due to the expected large differential pressure across the adsorption bed. The induced back pressure has the potential to cause reduced indurating airflow, which could jeopardize pellet quality and/or production. Considerable Facility-specific mechanical upgrades would be needed in order to design and install the required equipment in a way that overcomes the resistance through the adsorption beds. In addition to the resistance of the beds, the space constraints around the furnace present significant installation challenges due to the large footprint required. Installing a fixed carbon bed downstream of the four existing wet scrubbers is not appropriate because a water-saturated waste gas stream would block adsorption sites with moisture and reduce the carbon bed's ability to control mercury. In addition, this reduction technology requires enhanced particulate control to avoid plugging the carbon beds. Plugging carbon beds would reduce indurating airflow and jeopardize pellet quality and production. This analysis assumes that a single baghouse would replace the four existing wet scrubbers to maximize the filterable particulate control.

Based on the Pre-TMDL research of bench scale results from the June 17, 2009 EERC testing ("*Demonstration of Mercury Capture in a Fixed Bed*", Reference (37)), fixed bed carbon adsorption is an effective method of removing mercury from flue gas. However, the testing was carried out on a small scale and in simulated flue gas environments that do not necessarily represent actual operating conditions of the taconite process. In August 2012, as part of the Phase I work, additional testing was completed at HTC, Minorca, and UTAC; see "*Developing Cost-Effective Solutions to Reduce Mercury Emissions from Minnesota Taconite Plants*" (Reference (38)) to further review a fixed bed carbon adsorption system. 2012 results indicated a high level (>75%) of control was achievable based on laboratory scale slip stream testing. However, on a full-scale operation, costs and other site-specific factors may be too large to overcome in order for fixed carbon beds to be a viable reduction technology and therefore require further evaluation.

Fixed carbon bed adsorption was evaluated as a potential mercury emissions reduction technology in the BAMRT analysis.

### 4.1.7 GORE™

The GORE™ technology is a fixed sorbent polymer composite, which does not require injection of powder sorbents or chemicals, capturing both elemental and oxidized mercury, and removing sulfur dioxide ($SO_2$) as a co-benefit. During the Phase I evaluations, this technology was previously referred to as Monolithic

Polymer Resin Adsorption (Reference (1)). The system includes wash equipment to remove particulate material from the pleated sorbent panels. When used in high $SO_2$ environments, the $SO_2$ converts to sulfuric acid mist (SAM) which helps to clean the filter/panels and prevent plugging. However, material build-up in the GORE$^{TM}$ unit is expected when $SO_2$ levels are low, resulting in lower mercury reductions and more frequent wash cycle requirements. The panels are housed in modules that may be placed in series to increase the removal efficiency of the system. This potential reduction technology was evaluated after the Phase II research.

GORE$^{TM}$ pilot testing pulled a slip stream of air through the test skid modules (updraft) and through a fan, which returned the slip stream into the waste gas stack. Demonstrations took place on three different induration furnaces: Minorca, Minntac – Line 7, and UTAC – Line 2. The facilities where the demonstration took place contracted with TRC Solutions Emissions Testing Services to perform the mercury and $SO_2$ analysis. Samples for mercury and $SO_2$ were taken before and after the test skid modules to determine the amount of reduction. The mercury samples were analyzed using Method 30B. All results were excluded from testing if the paired traps were not within 10% of each other. $SO_2$ was analyzed using a CEMS. Process water was used in the system to spray the GORE$^{TM}$ modules to remove particulate and any other build-up. The long-term effects of increased build-up could cause unacceptable differential pressure increases across the GORE$^{TM}$ unit, thereby reducing indurating airflow and jeopardizing pellet quality and production. In addition, results from all three facilities of mercury concentration in the GORE$^{TM}$ membrane wash water effluent ranged from 2,460 ng/L – 30,300 ng/L. The wash water influent mercury concentrations ranged from non-detect to approximately 10 ng/L (Reference (39)). This represents a significant increase in mercury loading to the plants' process water systems. Coupled with an increase in the plant water system (TDS, sulfate), consideration of a full-scale implementation of the GORE$^{TM}$ technology for mercury reduction requires the evaluation of additional wastewater treatment for the increased loading of mercury, sulfate, TDS and other constituents that may be captured by the wash water.

To meet market and operating demands, Minorca can produce two distinct types of pellets: flux pellets and acid pellets. The primary distinction between these types of pellets is the amount of fluxstone added. Acid pellets do not contain fluxstone, while Minorca's flux pellets typically contain 10.5% fluxstone. That composition difference results in changes to process chemistry that impact $SO_2$ emissions.

Sulfur dioxide scrubbing efficiency is affected by the addition of limestone to the pre-fired pellets (Reference (40)). The taconite pelletizing process produces from 2 to 8 pounds of dust per gross ton of pellets produced. The four existing wet scrubbers remove this dust from the waste gas. The acid neutralizing capacity of this "scrubber dust" during the production of a 1% limestone pellet is about 0.2 to 0.8 millimoles for each ton of standard pellets produced. The acid neutralizing capacity of "scrubber dust" during the production of 10% limestone pellets is about 2 to 8 millimoles for each ton of pellets produced.

That fluxstone dust provides additional incidental $SO_2$ scrubbing capacity to the four existing wet scrubbers. The order of magnitude difference in fluxstone content between flux pellets and acid pellets means that there is additional $SO_2$ scrubbing capacity while producing flux pellets. Thus, higher $SO_2$ emissions are inherent to acid pellet production.

The GORE$^{TM}$ modules' mercury control effectiveness decreases with decreasing $SO_2$ concentrations as demonstrated by the lower mercury reduction effectiveness from the Minorca pilot test results (lower $SO_2$ concentrations) and UTAC and Minntac test results (higher $SO_2$ concentrations) (Reference (39)). The furnace at Minorca combusts inherently low sulfur natural gas in its indurating furnace and was producing flux pellets ($SO_2$ scrubbing) during the GORE$^{TM}$ pilot testing to be representative of normal operation. The use of multi fuel-fired furnaces (i.e. higher $SO_2$ concentrations in the flue gas) at UTAC and Minntac may have contributed to their higher mercury control effectiveness.

The taconite industry has been in frequent discussions with GORE$^{TM}$ after the industry pilot tested GORE$^{TM}$ GEN2 modules in 2015. Those discussions included follow up questions and observed concerns regarding such things as wash water contamination, plugging, and pressure drop. GORE$^{TM}$ recently released GEN3 modules, which have a higher control efficiency per module, thus reducing the overall footprint and capital cost. In September 2018, the taconite industry met with GORE$^{TM}$ representatives to discuss recent developments with their technology. Comments and information from this meeting have been incorporated into the full-scale design and cost evaluation for the BAMRT analysis along with an updated quote.

GORE$^{TM}$ was evaluated as a potential mercury emissions reduction technology in the BAMRT analysis.

### 4.1.8 Monolithic Honeycomb Adsorption

Monolithic honeycomb adsorption was never tested at a taconite facility but was previously reviewed during Phase I as a potential reduction technology. Activated carbon and elemental sulfur are mechanically fixed into a honeycomb structure that may include additives to enhance mercury capture. The cells of the monolith are plugged at their ends intermittently to force gas flow through the walls of the structure (Reference (1)). This plugging configuration improves contact between the flue gas and the porous wall of the monolith.

Monolithic honeycomb adsorption was evaluated as a potential mercury emissions reduction technology in the BAMRT analysis.

## 4.2 Step 2 – Determine if the Technologies are Commercially Available

Commercial availability was determined by contacting vendors to determine whether the materials needed to implement each technology were readily available for purchase at the time this report was created (2018). The commercial availability of potentially available mercury emissions reduction technologies is summarized in Table 4-2.

**Table 4-2 Commercial Availability of Potentially Available Mercury Emissions Reduction Technologies**

| Reduction Technology | | Commercially Available? |
|---|---|---|
| Mercury capture by existing wet scrubbers with solids removal | | Yes |
| Mercury oxidation for capture by existing wet scrubbers | Halide injection | Yes |
| | HEDT | No |
| Activated carbon injection | With existing wet scrubbers | Yes |
| | With baghouse | Yes |
| | With replacement high efficiency scrubber | Yes |
| Fixed carbon bed | | Yes |
| GORE$^{\text{TM}}$ | | Yes |
| Monolithic honeycomb adsorption | | No |

HEDT and monolithic honeycomb adsorption were not commercially available and were therefore eliminated from further consideration, as discussed in Sections 4.2.1 and 4.2.2.

### 4.2.1 High Energy Dissociation Technology

Testing of this technology by the EERC in 2008 was based on a prototype design. EERC sold the patent rights to Midwest Energy Emissions Corporation (ME2C). However, ME2C confirmed that this technology was not commercially available at the time of the BAMRT analysis (2018). Therefore, HEDT was eliminated from further consideration.

### 4.2.2 Monolithic Honeycomb Adsorption

This technology was previously under development by MeadWestvaco and Corning Incorporated. However, development was halted prior to becoming commercially available (Reference (1)). Therefore, monolithic honeycomb adsorption was eliminated from further consideration.

## 4.3 Step 3 – Determine if the Technology Can Operate without Impairing Pellet Quality or Production

The expected impact on pellet quality of each potentially available mercury reduction technology is summarized in Table 4-3.

**Table 4-3 Impact on Pellet Quality or Production from Potentially Available Mercury Emissions Reduction Technologies**

| Reduction Technology | | Impair Pellet Quality or Production? |
|---|---|---|
| Mercury capture by existing wet scrubbers with solids removal | | No |
| Mercury oxidation for capture by existing wet scrubbers | Halide injection | No |
| Activated carbon injection | With existing wet scrubbers | No |
| | With baghouse | No |
| | With replacement high efficiency scrubber | No |
| Fixed carbon bed | | No |
| GORE$^{\text{TM}}$ | | No |

There was no evidence from previous testing to suggest that the remaining reduction technologies impaired pellet quality parameters or production. However, testing has not been long enough in duration to observe all possible process impacts and should any of these potentially available mercury emissions reduction technologies be considered for full-scale installation, this criterion would need to be further evaluated. Minorca reserves the right to revisit this evaluation and subsequent resulting conclusion when new information becomes available. Therefore, for the purposes of the analysis, all remaining technologies proceeded to Step 4.

## 4.4 Step 4 – Determine if the Technology Causes Excessive Corrosion to Pellet Furnaces or Associated Ducting or Emission Control Equipment

Prior to testing each technology, research was conducted to determine if the potential for increased corrosion existed. Both ACI and halide injection were thought to have the potential to create additional corrosion. ACI testing at Minorca (approximately 77 days) did not reveal any visible corrosion concerns beyond normal operations (Reference (35)). As discussed in Section 4.1.4.1 for halide injection, HTC test data showed a higher rate of corrosion compared to baseline conditions based on laboratory analysis, but corrosion was not visible to the naked eye (Reference (21)). There is no evidence to indicate that excessive corrosion to pellet furnaces or associated ducting induced corrosion from ACI or halide injection is considered to be excessive. The higher rates of corrosion are an operational concern with long-term halide injection. Corrosion testing was relatively short-term. Thus, it is nearly impossible to determine all the long-term impacts.

**Table 4-4 Potential for Corrosion from Potentially Available Mercury Emissions Reduction Technologies**

| Reduction Technology | | Potentially Cause Corrosion? |
|---|---|---|
| Mercury capture by existing wet scrubbers with solids removal | | No |
| Mercury oxidation for capture by existing wet scrubbers | Halide injection | Possibly |
| Activated carbon injection | With existing wet scrubbers | No |
| | With baghouse | No |
| | With replacement high efficiency scrubber | No |
| Fixed carbon bed | | No |
| GORE$^{\text{TM}}$ | | No |

None of the remaining reduction technologies, except possibly halide injection, are expected to induce corrosion to production equipment above an acceptable threshold. This threshold is pursuant to existing preventative maintenance practices (i.e. does the technology significantly increase the required preventative maintenance to plant equipment). However, testing has not been long enough in duration to observe all possible process or equipment impacts and should any of these potentially available mercury emissions reduction technologies be considered for full-scale installation, this criterion would need to be further evaluated. Minorca reserves the right to revisit this evaluation and subsequent resulting conclusion when new information becomes available. Therefore, for the purpose of the BAMRT analysis, all remaining technologies proceeded to Step 5.

## 4.5 Step 5 – Determine if the Technology Presents Unacceptable Environmental Impacts

Most reduction technologies have some limited environmental impacts (additional wastewater treatment, solid waste disposal, etc.). However, these impacts are not considered unacceptable because they are reasonably mitigated with well-established management techniques. However, the TMDL sought to reduce mercury concentrations in fish tissue (Reference (3)). Therefore, any technology that results in environmental impacts contrary to this goal is considered unacceptable. The results of Step 5 are summarized in Table 4-5.

**Table 4-5 Environmental Impacts of Remaining Mercury Emissions Reduction Technologies**

| Reduction Technology | | Unacceptable Environmental Impacts? | Continue to Next Step? |
|---|---|---|---|
| Mercury capture by existing wet scrubbers with solids removal | | No | Yes |
| Mercury oxidation for capture by existing wet scrubbers | Halide injection | Yes | No – See Section 4.5.1 |
| Activated carbon injection | With existing wet scrubbers | Yes | No – See Section 4.5.2 |
| | With baghouse | No | Yes |
| | With replacement high efficiency scrubber | No | Yes |
| Fixed carbon bed | | No | Yes |
| GORE™ | | No | Yes |

Halide injection and ACI with the existing wet scrubbers pose unacceptable environmental impacts. This is discussed in detail below.

### 4.5.1 Halide Injection

Halide injection testing did not occur at Minorca after the pre-TMDL research, but a site-specific evaluation was conducted at a similar straight grate furnace (HTC) in 2017. Using HTC data to support conclusions at Minorca is appropriate because the furnace configuration is similar, as described in Section 2.2, although process temperatures and flowrates will vary slightly from site to site.

HTC was able to achieve a reduction in total mercury emissions during the most recent halide injection testing at a reduced injection rate compared to the Pre-TMDL research. However, both oxidized and particulate-bound mercury emissions significantly increased (as shown by the Ontario Hydro stack test data) over baseline conditions (Reference (21)). This is because halide injection greatly impacted the speciation of particulate, elemental, and oxidized mercury, which results in unacceptable environmental impacts contrary to the goals of the TMDL.

The same speciation change and mercury reduction observed at HTC was applied to the proposed baseline emission rate in Section 3. This was used to estimate the increase in oxidized emissions if halide injection were applied to the indurating furnace at Minorca. Results are summarized in Table 4-6.

### Table 4-6 Mercury Emissions Reductions and Estimated Speciation Changes with Halide Injection

| Parameter | Total | Particulate | Elemental | Oxidized |
|---|---|---|---|---|
| **Potential Speciation Changes with Halide Injection at Minorca** | | | | |
| Baseline estimated particulate, elemental, and oxidized emissions with no halide injection, lb/year (% of total)(1) | 85 | 1.7 (2.0%) | 74.0 (87.0%) | 9.4 (11.0%) |
| Including halide injection, lb/year (% of total)(2) | 57.0 | 4.0 (7.0%) | 12.0 (21.0%) | 41.0 (72.0%) |
| Increase/Decrease in emissions, lb/year **(% of baseline)** | -28.1 | 2.3 **(134.5%)** | -62.0 **(-83.8%)** | 31.7 **(338.5%)** |

(1) Estimates apply the industry average particulate, elemental, and oxidized mercury speciation from Table 1 of the Local Deposition Evaluation of oxidized and particulate-bound mercury emissions (Reference (17)) to the baseline emission rate proposed in Section 3.

(2) A 33% control efficiency was applied to the total baseline emission rate to estimate the halide injection total emissions (Reference (21)). Particulate, elemental, and oxidized mercury was estimated by applying the observed speciation during HTC halide injection testing from Ontario Hydro stack test data (Reference (21)).

Third party technical experts reviewed the impact of mercury reduction technologies (halide injection and ACI) on local mercury deposition (refer to the Local Deposition Evaluation in Appendix B). Screening calculations indicate that increased particulate or oxidized mercury emissions from halide injection would increase local mercury deposition to the Northeast Region (defined by the TMDL, which includes the Iron Range) even if the technology decreased total mercury emissions (Reference (17)). Elemental mercury (the majority of mercury emissions under baseline conditions) can remain in the atmosphere for long periods of time and travel great distances. It is unlikely for elemental mercury to be deposited near the emission source (Reference (17)). Therefore, the estimated reductions of elemental mercury are unlikely to have any impact on local mercury deposition or improve the mercury impairment of Minnesota waters, even though the estimated decrease in elemental mercury emissions was more significant than the increase in oxidized mercury emissions. However, even a small increase in oxidized mercury emissions can increase local mercury deposition. In contrast to elemental mercury, oxidized mercury is water soluble and readily deposited through precipitation at the local level (i.e. within a few miles of the emission source) (Reference (17)). The local deposition of oxidized mercury and its role in elevated fish tissue mercury concentrations has been documented in several regions of the U.S., for example in the southeast (Reference (41)) and in New England (References (42), (43)). In the evaluation by Florida DEP (Reference (41)), oxidized mercury accounted for more than 50% of the emissions from the facilities being evaluated. King et al. found that local mercury deposition due to emissions of oxidized mercury was a factor of 4 to 10 times greater than rural background deposition (Reference (43)). Associated with increased local deposition of mercury, fish tissue mercury concentrations were elevated in nearby water bodies (References (41), (43)). As a result, an increase in oxidized mercury air emissions can result in increased local deposition and an associated increase in fish tissue mercury concentrations. As discussed above, this outcome is observed despite the elemental mercury emissions decrease. Table 2 of the Local Deposition Evaluation (Reference (17)) demonstrates that even a small increase in oxidized mercury emissions can increase local deposition of mercury and loading the environment. As demonstrated by and Table 4-6, halide injection is expected to increase oxidized mercury emissions and thus local mercury deposition.

Since the environmental impacts at a reduced halide injection rate were considered unacceptable, then the increased halide injection rates used during the Pre-TMDL research would yield similar or more severe environmental impacts.

In addition, the increase in particulate-bound mercury emissions (Table 4-6) estimated with halide injection testing is an unacceptable environmental impact because particulate-bound mercury has a higher likelihood of being deposited locally, similar to oxidized mercury (Reference (17)). Table 2 of the Local Deposition Evaluation demonstrates that even a small increase in particulate mercury speciation may increase local deposition (see Appendix B). Increased local deposition of any kind of mercury is expected to increase fish tissue mercury concentrations (Reference (17)).

The increase in oxidized and particulate mercury emissions from halide injection directly contradicts the purpose of the TMDL to reduce mercury concentrations in fish tissue. Therefore, this is an unacceptable environmental impact and halide injection was eliminated from further consideration.

### 4.5.2 ACI with Existing Wet Scrubbers

A reduction in mercury emissions during the Phase II ACI testing was achieved. However, particulate emissions out of the stack were elevated while injecting PAC at rates above 1 lb/MMacf. This indicates that the PAC was not completely captured by the wet scrubbers, which could result in an increase in particulate-bound mercury emissions. Refer to Table 4-7 for details.

**Table 4-7 Particulate Emission Rates and Vapor Phase Mercury Reductions during Minorca ACI Testing (References (34), (44), (45), (46), (47))**

| Parameter | Value | Vapor Phase Mercury Reduction (%)(1) |
|---|---|---|
| **Stack Filterable Particulate Concentration with no ACI (gr/dscf)(2)** | | N/A |
| 2013 compliance testing | 0.0063 | N/A |
| 2015 compliance testing | 0.0069 | N/A |
| 2017 compliance testing | 0.0059 | N/A |
| **Average of compliance testing** | **0.0063** | N/A |
| **Stack Filterable Particulate Concentration with ACI (gr/dscf)(2)** | | N/A |
| HPAC screening test (3 lb/MMacf) | 0.011 | 67% |
| HPAC screening test (6 lb/MMacf) | 0.019 | 75% |
| BPAC screening test (3 lb/MMacf) | 0.020 | 70% |
| BPAC screening test (5 lb/MMacf) | 0.021 | 71% |
| 2013N screening test (5 lb/MMacf) | 0.015 | 72% |
| 2013N screening test (7 lb/MMacf) | 0.018 | 71% |
| BPAC stack test #1 (3 lb/MMacf) | 0.016 | 81%(3) |
| BPAC stack test #2 (3 lb/MMacf) | 0.020 | |
| BPAC stack test #3 (3 lb/MMacf) | 0.014 | |
| **Average of all ACI testing** | **0.017(4)** | N/A |
| Stack particulate concentration increase with ACI (gr/dscf) | 0.011 | N/A |
| % increase with ACI | 170% | N/A |

(1) Screening test vapor phase mercury reduction are the average of Stacks B and D.

(2) Stack testing results are only from Stack D because PAC screening tests during Phase II did not test all four stacks. Therefore, to be an appropriate comparison, only Stack D compliance testing results are reported.

(3) Letter from the MPCA corrected an error in the Phase II report (Reference (48)).

(4) The Facility did not exceed the Maximum Achievable Control Technology (MACT) filterable particulate limit (0.01 gr/dscf) because compliance is based on an average of emissions from all four stacks. However, this table demonstrates the significant increase observed during testing. Stack D showed the largest increase because the majority of its flow comes from the windbox exhaust, where the PAC was injected.

As demonstrated by Table 4-7, particulate emission rates out of Stack D during Phase II testing were significantly elevated by 170%. This increases the amount of particulate-bound mercury emitted with ACI as a portion of the PAC passes through the wet scrubbers. The PAC that is not captured by the wet scrubbers contains adsorbed mercury from the furnace waste gas. As noted by DNR's review of the Phase II reports (Reference (49)), ACI increases the particulate loading to the wet scrubbers and mercury bound to PAC particles was slipping past the wet scrubbers. The DNR stated in reference to the Phase II reports "the reports do provide relatively strong evidence that re-emission of particulate-bound mercury is a pervasive issue that must be solved before brominated activated carbon injection methods can be considered suitable for the taconite industry." This is considered to be an unacceptable environmental impact because particulate-bound mercury emissions are more likely to be deposited locally compared to elemental mercury, similar to oxidized mercury and are expected to increase mercury concentrations in fish tissue (Reference (17)). This is contrary to the purpose of the TMDL, which seeks to reduce mercury concentrations in fish tissue from Minnesota waters. Table 4-7 shows that this adverse impact is true even at lower PAC injection rates.

Under normal operating conditions with no ACI, the existing wet scrubbers can consistently maintain compliance and stay well below their existing Taconite MACT filterable particulate limit (0.01 gr/dscf). During Phase II ACI testing, particulate loading to the existing wet scrubbers increased such that the filterable particulate concentration at the stack was close to exceeding the MACT limit. This demonstrated that ACI, in addition to the existing particulate concentration from the furnace operations, exceeded the existing scrubber's particulate loading capacity. Full-scale utilization of ACI would jeopardize the Facility's ability to consistently comply with its existing limit.

The potential for increased local mercury deposition and the increase in particulate emissions are considered to be unacceptable environmental impacts. This is because it directly contradicts the purpose of the TMDL and jeopardizes compliance with the Taconite MACT limit. Therefore, ACI with the four existing wet scrubbers was eliminated from further consideration.

## 4.6 Step 6 – Determine if the Technology Can Consistently Meet the 72% Reduction per the MN Rule

Table 4-8 summarizes the control effectiveness of the remaining mercury reduction technologies. Each technology must be able to consistently achieve its control efficiency in order to demonstrate compliance for potential future permit conditions.

### Table 4-8 Control Effectiveness of Remaining Mercury Emissions Reduction Technologies

| Reduction Technology | | Total Mercury Control Efficiency | Continue to Next Step? |
|---|---|---|---|
| Mercury capture by existing MACT wet scrubbers with solids removal | | 22%(1) | No |
| Activated carbon injection | With baghouse | 88.1%(2) | Yes |
| | With replacement high efficiency scrubber | 88.1%(2) | Yes |
| Fixed carbon bed | | 99%(3) | Yes |
| GORE™ | | 53.8%(4) | No |

(1) See Appendix B-5-3 Minorca Mine – Scrubber Solids Mass Balance Barr Technical Memo dated December 5, 2018. The basis of the twenty-two percent reduction target is based on actual testing at Minorca as documented by the Barr Memo (Reference (50)). Prior to establishing an enforceable limit, additional long-term data in excess of twelve months is necessary to compile sufficient data during implementation of the solids removal work practice to conduct a statistical evaluation, e.g., 99% upper predictive limit.

(2) Slip stream baghouse testing at Keetac (Reference (36)) indicated that brominated PAC could reduce mercury emissions by 88.1%. This technology was not tested at Minorca, but it is assumed for this analysis that an 88.1% reduction can be achieved. In addition, it is assumed that the same mercury control efficiency is achievable with a replacement high efficiency scrubber.

(3) Vendor estimated control efficiency and most literature for fixed bed controls cite a control efficiency greater than 99%. This has never been tested on a full-scale at a taconite facility. Therefore, Minorca assumed that a 99% control efficiency can be achieved.

(4) Pilot testing at Minorca indicated that a 72% reduction per the rule was not achieved (Reference (39)). The cited control efficiency is the average mercury reduction achieved during testing.

GORE™ and mercury capture by existing MACT wet scrubbers with solids removal cannot meet the reductions required by Minn. R. 7007.0502, subp. 6. Therefore, these technologies will be evaluated in the Facility’s alternative Mercury Emissions Reduction Plan, if no other technology satisfies all seven steps of the BAMRT analysis. All other mercury emissions reduction technologies listed in Table 4-8 can meet a 72% reduction in mercury emissions and proceeded onto the next step.

## 4.7 Step 7 – Determine if the Technology is Cost Effective

ACI with a baghouse, ACI with a replacement high efficiency scrubber, and fixed carbon beds are the only remaining technologies for the BAMRT analysis that were evaluated for cost effectiveness.

### 4.7.1 Cost Effectiveness Threshold

EPA has considered the cost effectiveness of mercury reductions while setting “beyond-the-floor” MACT standards in the rulemaking process for a variety of source categories under the National Emission Standards for Hazardous Air Pollutants (NESHAP) listed in Table 4-9. While developing these NESHAPs, EPA sets a MACT “floor” based on the best performing facilities within a source category and incorporates the technologies or work practices used at those facilities in the regulation. When EPA considers setting “beyond-the-floor” MACT standards, it is required to consider the cost effectiveness of these additional emissions reductions.

In rule development for the Mercury Cell Chlor-Alkali Plant MACT, EPA stated that “EPA has not established a clear cost effectiveness level for mercury reductions that are considered acceptable”

(Reference (51)). EPA stated that the cost effectiveness of brominated ACI and polishing baghouse for ferromanganese production was “within the range of cost effectivenesses we have determined are reasonable for mercury control in other rulemakings. Furthermore, no other significant economic factors were identified that would indicate these limits would be inappropriate or infeasible […]” (Reference (52)).

Following EPA’s approach for evaluating the economic acceptability of mercury reduction options, the taconite processing industry reviewed the cost effectiveness of mercury reduction options found to be acceptable in other regulations; see Table 4-9 with cost effectiveness values from federal MACT regulations.

### Table 4-9 Cost Effectiveness Values Considered by EPA in MACT Rule Development

| Cost Effectiveness ($ per lb mercury) | Accepted by EPA | Regulation | Standard Considered |
|---|---|---|---|
| $1,300<br>(Reference (53)) | Proposed | Gold Mining MACT<br>40 CFR 63 Subpart 7E | Beyond the floor, refrigeration unit (or condenser) and a carbon adsorber on autoclaves |
| $2,000<br>(Reference (54)) | Yes | Portland Cement MACT<br>40 CFR 63 Subpart LLL | Recalculated floor from 58 to 55 lb mercury/MMtons clinker |
| $7,100<br>(Reference (52)) | Yes | Ferroalloys Production MACT<br>40 CFR 63 Subpart XXX | Beyond the floor, brominated ACI and polishing baghouse; FeMn furnace operating 100% of year |
| $13,600<br>(Reference (52)) | Yes | Ferroalloys Production MACT<br>40 CFR 63 Subpart XXX | Beyond the floor, brominated ACI and polishing baghouse; FeMn furnace operating 50% of year |
| $20,000<br>(Reference (55)) | Proposed | Mercury Cell Chlor-Alkali Plant MACT<br>40 CFR 63 Subpart IIIII | Non-mercury technology option |
| $27,016<br>(Reference (56)) | Yes | Mercury and Air Toxics Standards (MATS) (existing Electrical Generating Units [EGUs])<br>40 CFR 63 Subpart UUUUU | Beyond the floor standard of 4 lb mercury/ TBtu using brominated ACI |
| $44,000<br>(Reference (53)) | No | Gold Mining MACT<br>40 CFR 63 Subpart 7E | Beyond the floor, non-carbon concentrate process with second carbon adsorber in series on melt furnaces |
| $74,000<br>(Reference (57)) | No | Brick and Structural Clay MACT<br>40 CFR 63 Subpart JJJJJ | Beyond the floor, make existing units meet limits for new units |
| $14,000 - $127,000<br>(Reference (58)) | No | Taconite MACT<br>40 CFR 63 Subpart RRRRR | Beyond the floor, wet scrubbers wasting |
| $61,000 - $183,500<br>(Reference (59)) | No | MATS (new EGUs)<br>40 CFR 63 Subpart UUUUU | Beyond the floor, hypothetical new plant with ACI and fabric filter |
| $80,000 - $100,000<br>(Reference (60)) | No | Sewage Sludge Incinerator MACT | Beyond the floor, afterburners, ACI, and fabric filters |
| $100,000<br>(Reference (53)) | No | Gold Mining MACT<br>40 CFR 63 Subpart 7E | Beyond the floor, carbon process with second carbon adsorber in series on autoclaves |
| $420,000-540,000<br>(Reference (61)) | No | Portland Cement MACT<br>40 CFR 63 Subpart LLL | Beyond the floor, additional ACI system |

The taconite processing industry considers $7,100 per pound of mercury reduced to be an acceptable cost effectiveness threshold for mercury reduction, based on the strong similarities between the taconite processing source category and the ferromanganese production source category regulated under the Ferroalloys Production MACT. The $7,100 cost effectiveness value is equal to the cost effectiveness value

EPA found to be acceptable for new and reconstructed ferromanganese production furnaces using brominated activated carbon injection with a polishing baghouse in the Ferroalloys Production MACT.

The taconite processing and the ferromanganese production source categories both serve niche markets and are not able to pass increased costs on to their customers because of the competitive nature of the commodity market. Both source categories have limited options to reduce mercury emissions because the main source of mercury is the variable mercury content of their respective raw materials (iron ore or manganese ore). Conversely, there are several different viable mercury reduction options for Industrial, Commercial, and Institutional (ICI) boilers which have a more constant mercury concentration in their raw materials. In addition, the cost effectiveness evaluation for the boiler industry is likely an upper-bound estimate based on what is likely to be the most expensive mercury reduction option (ACI retrofit).

From the review of MACT standards (Table 4-9), there are only two standards with EPA-accepted cost effectiveness values higher than those found in the Ferroalloys MACT. The $20,000 cost effectiveness value for the mercury cell chlor-alkali plant MACT is not an apt comparison because the mercury reduction option being considered was a completely new process that eliminated the use of mercury altogether. The $27,016 cost effectiveness value for the Mercury Air Toxics Standard at existing electric generating units also is not a clear analogue because power generation is a much larger market and cost increases can more readily be passed on to consumers, an option not available to the taconite industry.

### 4.7.2 Economic Evaluation of Remaining Mercury Reduction Technologies

The annualized cost includes both capital and operating costs. Economic impacts were analyzed using the procedures found in the EPA Air Pollution Control Cost Manual (CCM, References (62), (63)). The most up-to-date CCM sections were used whenever possible as new updates have been published since the release of the 6th edition of the CCM. Vendor cost estimates were used when available. If vendors did not respond to bid requests, capital costs were estimated using literature cost factors or data from other projects with adjustments for inflation and size.

Table 4-10 details the expected costs associated with the installation of the three mercury reduction technologies for the indurating furnace that satisfied Step 6. Equipment design is based on mercury control efficiencies outlined in Table 4-8, baseline values determined in Section 3, vendor estimates, and the CCM (References (62), (63)). Capital costs were based on recent vendor quotes, if available, or cost factors. Direct and indirect costs were estimated as a percentage of the fixed capital investment using the CCM (Reference (62)), unless provided by a vendor. Operating costs were based on 100% utilization and annual operating hours of 8,100 hours. Operating costs of consumable materials, such as electricity, water, and chemicals were established based on the CCM (References (62), (63)) and Barr's engineering experience. The detailed cost analysis and design assumptions are provided in Appendix D.

Due to space considerations, a 60% markup of the total capital investment (i.e. 1.6 retrofit factor) was included in the costs to account for the retrofit installation. Retrofit installations have increased difficulty in equipment handling and erection for many reasons. Access for transportation, laydown space, etc., for new equipment is significantly impeded or restricted. This is because the spaces surrounding the furnace are congested and the areas surrounding the building support frequent vehicle traffic or crane access for maintenance. The structural design of the existing building at the Facility would not support additional equipment on the roof. The straight-grate furnace design at Minorca further complicates the retrofit installation of any reduction technology because the hood and windbox exhaust streams are separated and exhaust through four wet scrubbers. Additionally, each of the technologies evaluated in this section are very complex, which increases installation costs (e.g., ancillary equipment requirements, piping, structural, electrical, demolition, instrumentation, process controls) This is especially true for fixed carbon beds, which have never been demonstrated on a full-scale to be a viable control scheme for a taconite indurating furnace.

Using a retrofit factor is appropriate based on previous project examples. When $SO_2$ controls were being evaluated for the BART cost analyses in 2006, the MPCA agreed the use of a 1.6 retrofit factor was an appropriate way in which to determine economic infeasibility. The technologies evaluated in this section for mercury control are just as complex. Therefore, the retrofit factor is still appropriate. In addition, the EPA response to public comments for the Wyoming Regional Haze State Implementation Plan justified the use of a 1.5 retrofit factor for utility boilers because of congestion near existing equipment that would obstruct access (Reference (64)). The furnace at Minorca is similarly constrained concerning available space and Facility roadways. This installation would significantly impede access for transportation, laydown space, crane access, etc., which justifies a retrofit factor of 1.6. Finally, the CCM notes that retrofit installations are subjective because the plant designers may not have had the foresight to include additional floor space and room between components for new equipment (References (62), (63)). Retrofits can impose additional costs to “shoe-horn” equipment in existing plant space, which is true for this evaluation.

Site-specific estimates of new buildings, site preparation, and ductwork were added to arrive at the total installed cost because those costs were not included in the retrofit factor expenses. Based on the scale and complexity of the proposed equipment installations, it was conservatively assumed that it would take an additional 14 days beyond an annual outage to tie-in the new equipment and resume normal operations, based on Barr’s similar project experience. The cost calculations account for the lost production for this time.

Minorca applied a 30 percent contingency to the purchased equipment costs. As a project progresses through the design process, the estimates for the project costs become progressively more accurate. For the current feasibility/conceptual design phase, where fewer project details have been defined, a 30% contingency is appropriate. In addition, these cost estimates most closely resemble a Class 4 estimate per the American Association of Cost Engineers’ *Cost Estimate Classification System - As Applied in Engineering, Procurement, and Construction for the Process Industries*. The expected accuracy ranges from -30% to +50% to account for unknowns without detailed engineering (Reference (65)). Note, the CCM does not consider contingencies to be the same as uncertainty or retrofit factor costs and are treated separately (References (62), (63)).

For ACI with baghouse and fixed carbon beds, the four existing wet scrubbers would need to be replaced by a new baghouse. Installing a baghouse downstream of a wet scrubber is infeasible because the moisture from the scrubber would plug the bags. Installing a fixed carbon bed downstream of the existing wet scrubbers is not appropriate because a water-saturated waste gas stream would block adsorption sites with moisture and reduce the carbon bed's ability to reduce mercury. In addition, this reduction technology requires enhanced particulate control to avoid plugging the carbon beds. Therefore, a baghouse that replaces the four existing wet scrubbers prior to the fixed carbon beds is used to optimize the filterable particulate control and avoid issues with waste gas that is water-saturated.

Finally, the four existing wet scrubbers provide some level of $SO_2$ control and thus removing them would cause the Facility to be out of compliance with existing permit limits. Therefore, the cost of new $SO_2$ controls (dry sorbent injection) are accounted for to maintain the current level of $SO_2$ removal achieved by the four existing wet scrubbers (this does not apply to ACI with replacement high efficiency scrubber).

**Table 4-10 Cost Effectiveness of Mercury Reduction Technologies**

| Mercury Reduction Technology | Total Capital Investment with Retrofit Factor ($) | Total Annual Cost ($/yr) | Annualized Pollution Control Cost ($/lb) | Cost Effective |
|---|---|---|---|---|
| ACI with Baghouse | $47,890,000 | $7,599,000 | $101,500 | No |
| ACI with Replacement High Efficiency Scrubber | $45,530,000 | $8,331,000 | $111,300 | No |
| Fixed Carbon Bed | $72,370,000 | $10,860,000 | $129,000 | No |

Appendix D contains the detailed cost evaluations. The cost effectiveness of the remaining reduction technologies varies from $101,500 to $129,000 per pound of mercury removed. The costs for all three of the evaluated technologies exceeded the $7,100 per pound of mercury removed cost effectiveness threshold several times over (Section 4.7.1). Therefore, all three of the remaining technologies were eliminated from further consideration.

## 4.8 Step 8 – Determination of BAMRT for Minorca

After evaluating all potentially available mercury reduction technologies against the criteria outlined in Section 4, no technology satisfied all seven steps. Therefore, there is no BAMRT technology that achieves the 72% reduction, while also satisfying the adaptive management and environmental impacts criteria. However, two technologies reduce mercury to a lower percentage while also satisfying the other criteria in Sections 4.2 through 4.5 and are evaluated in the alternative mercury emissions reduction evaluation: mercury capture by existing MACT wet scrubbers with solids removal, and GORE$^{TM}$.

# 5 Alternative Mercury Emissions Reduction Evaluation

In accordance with Minn. R. 7007.0502, subp. 5(A)(2), Minorca determined that the 72% reduction is not technically achievable. Therefore, Minorca evaluated if any mercury reduction technologies could achieve an alternate removal rate. Two reduction technologies, mercury capture by existing MACT wet scrubbers with solids removal and GORE, did not reduce emissions by 72% but still satisfied the other adaptive management and environmental impacts criteria in Sections 4.2 through 4.5 and were therefore subject to the alternative mercury emissions reduction evaluation. The purpose of the alternative mercury emissions reduction evaluation was to determine what percent reduction of mercury air emissions is technically achievable from the indurating furnace at Minorca, again using appropriate evaluative criteria. Figure 4-1 summarizes the alternative mercury emissions reduction evaluation process and its connection to the BAMRT analysis. MPCA's Ferrous Mercury Reduction Plan Form, Item 3(a) provides six steps to evaluate reduction technologies and determine which control strategy to include in the AMERP; details are included in Sections 5.1 through 5.6 below.

## 5.1 Step 1 – Identify and Rank Technologies from BAMRT

Mercury capture by existing wet MACT scrubbers with solids removal and GORE™ were evaluated for potential inclusion in the AMERP. Sections 4.1.3 and 4.1.7 provide additional details on each reduction technology.

**Table 5-1 Rank Remaining Reduction Technologies with Less Than 72% Control Efficiency**

| Rank | Reduction Technology | Total Mercury Control Efficiency(1) | Continue to Next Step? |
|---|---|---|---|
| 1 | GORE™ | 53.8% | Yes |
| 2 | Mercury capture by existing MACT wet scrubbers with solids removal | 22% | Yes |

(1) Refer to Table 4-8.

## 5.2 Step 2 – Eliminate Technically Infeasible Technologies

There is no information to suggest these reduction technologies are not technically feasible. Mercury capture by existing MACT wet scrubbers with solids removal and GORE™ both proceeded to Step 3 of the alternative mercury emissions reduction evaluation.

## 5.3 Step 3 – Rank Remaining Technologies

Mercury capture by existing MACT wet scrubbers with solids removal and GORE™ both proceeded to Step 4 of the alternative mercury emissions reduction evaluation. The technologies are ranked in Table 5-1.

## 5.4 Step 4 – Complete an Environmental Impacts Analysis

The reduction technologies were evaluated to determine if they caused any unacceptable environmental impacts (Table 5-2 and Table 5-3). MPCA's Ferrous Mercury Reduction Plan Form requires the submitter to evaluate environmental impacts other than direct impacts due to emissions of mercury, such as solid or hazardous waste generation, discharges of polluted water from a control device, demand on local water resources, and emissions of other regulated air pollutants.

**Table 5-2 Environmental Impacts Analysis – Mercury Capture by Existing MACT Wet Scrubbers with Solids Removal**

| Description | Explanation |
|---|---|
| Solid/Hazardous Waste Generation | **No impact:** MACT wet scrubber solids are not a solid or hazardous waste. Scrubber solids removed from the process would be sent to the tailings basin. |
| Water Discharge | **No impact:** MACT wet scrubbers do use water; however, the Facility would not discharge scrubber water. The Facility would recover and re-use scrubber water as process water. |
| Demand on Local Water Resources | **No impact:** MACT wet scrubbers do use water; however, the Facility would not expect to increase water usage overall. |
| Other Regulated Air Pollutants | **No impact:** Removing scrubber solids does not impact process emissions of other regulated air pollutants. |

**Table 5-3 Environmental Impacts Analysis - GORE™**

| Description | Explanation |
|---|---|
| Solid/Hazardous Waste Generation | **Minimal impact:** The GORE™ technology generates solid waste, but does not generate hazardous waste. The GORE™ modules would need to be replaced at the end of their product life and the modules would be disposed of properly at that time. |
| Water Discharge | **No impact:** The GORE™ technology does use wash water. The Facility would not discharge wash water. The Facility would treat the wash water and re-use as process water. |
| Demand on Local Water Resources | **No impact:** The GORE™ technology does use wash water; however, the Facility would not expect to increase water usage overall. |
| Other Regulated Air Pollutants | **No impact:** The GORE™ technology does not affect process emissions of other regulated air pollutants. |

Neither mercury capture by existing MACT wet scrubbers with solids removal nor GORE™ cause unacceptable environmental impacts. Both technologies proceeded to Step 5 of the alternative mercury emissions reduction evaluation.

## 5.5 Step 5 – Complete a Cost Effectiveness Evaluation

The cost effectiveness of each reduction technology is evaluated in this section and summarized in Table 5-4. Minorca assumed that mercury capture by existing MACT wet scrubbers with solids removal was cost effective because the process modifications needed to implement mercury capture by existing MACT wet scrubbers with solids removal are minor compared to other reduction technologies and other facilities have already implemented this reduction technology to effectively reduce mercury emissions. In addition, Minorca has the ability to utilize existing equipment to assist with the change. The GORE™ control costs exceeded the $7,100 per pound of mercury removed cost effectiveness threshold several times over (Section 4.7.1), which eliminated GORE™ from further consideration (refer to Appendix E for details). To evaluate control costs for GORE™, Minorca used the same retrofit related assumptions outlined in Section 4.7.2. Note, the installation of GORE™ would be particularly challenging because the exhaust exits through four separate wet scrubbers. Only mercury capture by existing MACT wet scrubbers with solids removal proceeded to Step 6 of the alternative mercury emissions reduction evaluation.

**Table 5-4 Cost Effectiveness of Remaining Reduction Technologies**

| Reduction Technology | Total Capital Investment with Retrofit Factor ($) | Total Annual Cost ($/yr) | Annualized Pollution Control Cost ($/lb) | Cost Effective Threshold ($/lb) | Cost Effective? | Continue to Next Step? |
|---|---|---|---|---|---|---|
| Mercury capture by wet scrubbers with solids removal | NA | NA | NA | NA | Yes(1) | Yes |
| GORE™ | $76,500,000 | $9,884,000 | $216,100 | $7,100 | No | No |

(1) It was assumed that mercury capture by existing wet scrubbers with solids removal was cost effective, for the reasons outlined above.

## 5.6 Step 6 – Select Control Strategy

A 22% reduction in mercury emissions is technically feasible through mercury capture by existing MACT wet scrubbers with solids removal, considering the adaptive management and environmental impacts criteria. The AMERP, presented in Section 6, evaluates this reduction strategy.

# 6 Alternative Mercury Emissions Reduction Plan (AMERP)

The Facility's four MACT wet scrubbers, which are designed for particulate matter control, have shown a co-benefit in reducing mercury with the management of scrubber solids. The Facility currently returns the mercury and iron-containing scrubber solids to the concentrating process for iron recovery. Minorca is proposing to route all of the scrubber solids to the tailings basin, where the mercury will be sequestered rather than recycled within the process and potentially liberated from the greenballs with the furnace gases. By rerouting the scrubber solids to the tailings basin, the mercury air emissions will be reduced by 22%. Additionally, this reduction technology does not increase local deposition of mercury and there is no chemical addition, which may impact water resources or other natural resources. Scrubber solids will be removed from the process by sending the scrubber blowdown stream to the tailings thickener. The tailings thickener recovers water and the thickened solids will be sent to the tailings basin. This process modification is similar to other taconite operating facilities who have had to reduce mercury air emissions under permit conditions (Keetac, Permit No. 13700063-003 and UTAC, Permit No. 13700113-005). Pre-TMDL testing indicates the scrubber solids sequester mercury in the tailings basin; see Section 4.1.3.

The Facility already fires natural gas in the indurating furnace resulting in lower fuel combustion mercury emissions than multi fuel-fired furnaces.

Finally, Minorca will conduct a literature review and/or vendor screening between May 1, 2020 and July 31, 2020 to determine if any new mercury emissions reduction technologies (New Technologies) have been commercially developed and put into use in other industries. The results of the review will be used to fully evaluate only the New Technologies by using the same methodology as employed in the 2018 BAMRT analysis. If no New Technologies are identified, Minorca will submit notification to MPCA that the review has been completed and no New Technologies were identified.

## 6.1 Annual Mercury Emissions and Emissions Reductions under AMERP (MPCA Form items 3b-c)

MPCA's Ferrous Mercury Reduction Plan Form, Items 3b and 3c require an estimate of the annual mass of mercury emitted under the requirements of Minn. R. 7007.0502, subp. 6 and an estimate of the annual mass of mercury emitted and percent reduction achieved under the proposed alternative plan. The methodology for calculating baseline emissions is discussed in Section 3. Table 6-1 contains the emissions before and after employing the proposed alternative control strategy. Calculation details are included in Appendix C.

**Table 6-1 Mercury Emissions and Emissions Reductions under AMERP**

| Emission Unit | Baseline Emissions lb/yr | Percent Reduction | Estimated Emissions lb/yr |
|---|---|---|---|
| EU 026 | 85 | 22% | 66 – 12 month rolling sum |

## 6.2 Description of Mercury Reduction Action (MPCA Form item 4)

*Complete the following table for each emission unit that emits mercury. Use a separate row for each specific control, process, material or work practice that will be employed to achieve the applicable control efficiencies, reductions or allowable emissions. Provide a written summary below as needed for context or background. Minn. R. 7007.0502, subp. 5(A)(1)(a), 5(A)(1)(b), or 5(A)(2)(a).*

Table 6-2 describes the alternative mercury reduction plan.

**Table 6-2 Alternative Mercury Reduction Plan**

| Emission Unit | Reduction Element(1) | Reduction, control efficiency, emission limit, operating limit, or work practice(2) | Describe element in detail(3) |
|---|---|---|---|
| EU 026, SV014-017 | Mercury capture by existing MACT wet scrubbers with solids removal | Work Practice of mercury capture by existing MACT wet scrubbers with solids removal<br>(refer to Table 4-8 for basis of 22% mercury control target) | See Section 4.1.3 for element details. |
| EU 026, SV014-017 | Literature Review and/or vendor screening with BAMRT analysis, as needed | TBD | See Section 6.2.1 |

(1) Control device, work practice, etc.
(2) Indicate units, i.e., lb. hg/ton material, % control; the permit or enforceable document will include the proposed control efficiency, emission limits, or other requirements that achieve the reduction.
(3) Attach manufacturer's information and other resources used to document the reduction.

### 6.2.1 Literature Review and/or Vendor Screening with BAMRT Analysis

Minorca will conduct a literature review and/or vendor screening exercise between May 1, 2020 and July 31, 2020 to determine if any new mercury emission reduction technologies (New Technologies) have been commercially developed and put into use in other industries in the United States. If any New Technologies have been commercially developed and put into use, Minorca will determine if on-site testing is needed to further investigate the suitability and performance of only the New Technologies. The results of the literature review, vendor screening, and on-site testing, if necessary, will be used to fully evaluate only the New Technologies by using the same methodology as employed in the 2018 BAMRT analysis. The New Technologies BAMRT analysis will determine if any New Technology satisfies the adaptive management and environmental impacts criteria and if it is potentially capable of reducing mercury emissions by 72%. If a 72% mercury reduction cannot be met, the same BAMRT evaluation process will be used for any alternative reduction analysis. The New Technologies BAMRT evaluation and updated AMERP, if necessary, will be submitted to MPCA no later than June 1, 2022. Minorca will not re-evaluate technologies or outcomes already considered in the 2018 BAMRT or AMERP.

## 6.3 Schedule (MPCA Form item 5)

*For each reduction element (specific control, process, material or work practice) described in Item 4 that will be employed as part of the mercury reduction plan, complete the following table.*

The proposed schedule in Table 6-3 is dependent on the MPCA's approval this AMERP pursuant to Minn. R. 7007.0502, subp. 4(B). Should the MPCA be delayed in the decision making process, milestone dates below are subject to change.

**Table 6-3 Schedule**

| Emission Unit | Reduction Element | Anticipated Installation date[1] | Anticipated Startup date[2] | Target Reduction Demonstration[3] | Target Reduction Deadline[4] | Anticipated Permit Application Submittal[5] |
|---|---|---|---|---|---|---|
| EU 026, SV014-017 | Mercury capture by existing MACT wet scrubbers with solids removal | 5/15/2023 | 1/1/2024 | 1/1/2025 | 1/1/2025 | 1/1/2023 |
| EU 026, SV014-017 | Literature Review and/or vendor screening with BAMRT analysis, as needed | Minorca will conduct a literature review and/or vendor screening between May 1, 2020 and July 31, 2020. Minorca will revise and resubmit the AMERP if necessary or notify the MPCA that the review has been completed by no later than June 1, 2022. | | | | |

(1) Pending receipt of permit or enforceable document, and assuming no permit appeals.
(2) As soon as practicable, assuming on schedule equipment delivery and no significant issues during commissioning.
(3) Six months after startup or as stipulated in permit or enforceable document.
(4) Deadline per Minn. R. 7007.0502, subp. 3 or as stipulated in permit or enforceable document.
(5) Anticipated submittal schedule pending agency approval of AMERP

## 6.4 Calculation Data (MPCA Form item 6)

*Include all mercury emission calculations for each emissions unit listed in item 4 in an editable electronic spreadsheet. Provide calculations showing the mercury reduction, control efficiency, or emission rate that each emissions unit will achieve once the plan for that emissions unit is fully implemented.*

Emission calculations are included in Appendix F.

### 6.4.1 Emission Factors (MPCA Form item 6a)

*Identify the emission factors and sources of the emission factors used to determine mercury emissions in item 3 in the following table. Please include the rationale behind your decision. Minn. R. 7007.0502, subp. 5(A)(1)(b) or Minn. R. 7007.0502, subp. 5(A)(2)(d).*

Emission factors used to calculate the mercury emission rate are included in Section 3 of this report.

## 6.5 Operation, Monitoring, and Recordkeeping Plan (MPCA Form item 7)

### 6.5.1 Operation and Optimization Plan (MPCA Form item 7a)

*For each control device used to achieve the overall mercury reduction of the plan, describe how you will operate the control system such that mercury reductions are maintained. Explain how an operator might adjust the control system at the facility. Describe system alarms or safeguards to ensure optimal operation of the mercury control system. Optimization also includes training of individuals responsible for operating the control system, and the development and upkeep of operation and maintenance manuals. The MPCA is not requesting that such programs or manuals be included here, rather that they are summarized. Discuss potential variability of mercury emissions and how operations will be monitored to address variability. Minn. R. 7007.0502, subp. 5(A)(1)(c) or Minn. R. 7007.0502, subp. 5(A)(2)(c).*

Minorca proposes to remove scrubber solids from the process by sending the scrubber blowdown stream to the tailings thickener. The thickened solids are then routed to the basin for permanent sequestration and disposal. The scrubber blowdown will be sent to the tailings thickener using redundant pump systems and a flowmeter to monitor flowrate. Therefore, even if a pump failure occurs, a fail-safe is installed to constantly send scrubber solids to the tailings thickener. The equipment will be equipped with alarms so that operations will be notified of malfunctions.

Operators will be trained to operate the pump system and maintenance personnel will be trained to maintain the pump system. In addition, maintenance personnel will perform preventive maintenance consistent with manufacturer specifications.

Minn. R. 7007.0502, subp. 5(A)(2)(c) requires a demonstration that (1) air pollution control equipment, (2) work practices, (3) the use of alternative fuels, or (4) raw materials have been optimized such that the source is using the best controls for mercury that are technically feasible. Each of the four listed processes are already optimized and are further described below:

1. The Facility already operates four existing MACT wet scrubbers, which have been optimized to reduce air emissions and demonstrate compliance with the EPA Taconite Iron Ore Processing NESHAP which includes mercury emissions. The Facility will continue to maintain the current control efficiency and demonstrate continued optimization through compliance with the air emission permit and associated compliance plans.

2. Minorca will continue to operate and maintain control equipment and the indurating furnace in a manner consistent with good air pollution control practices and in accordance with manufacturer and industry best management practices.

3. Under normal operating conditions the Facility’s indurating furnace is natural gas-fired, which is inherently low in mercury emissions. Minorca would only combust ultra-low sulfur diesel during

emergencies. The use of any alternative fuels would only increase mercury emissions from the furnace.

4. Minorca mines taconite near its indurating furnace from controlled and limited mineral deposits. It is not feasible for the Facility to consider an alternative ore feed. Additionally, the fluxstone added to the concentrate prior to the indurating furnace has an immaterial amount of mercury.

### 6.5.2 Proposed Monitoring and Recordkeeping (MPCA Form item 7b)

*For each reduction element (specific control equipment, emission limit, operating limit, material or work practice), describe monitoring to provide a reasonable assurance of continuous control of mercury emissions. If the plan includes control equipment, attach MPCA Air Quality Permit Forms GI-05A and CD-05. Minn. R. 7007.0502, subp. 5(A)(1)(d).*

The Facility proposes to conduct stack testing once every five years using EPA approved test methods (Table 6-4). This is consistent with Minn. R. 7019.3050(E)(5).

**Table 6-4 Monitoring and Recordkeeping**

| Emission Unit | Reduction Element | Reduction, Control Efficiency or Emission Rate | Operating Parameters | Monitoring Method | Monitoring Frequency | Proposed Recordkeeping | Discussion of Why Monitoring is Adequate |
|---|---|---|---|---|---|---|---|
| Furnace Stacks A-D | Mercury capture by existing MACT wet scrubbers with solids removal | 22% Hg reduction target | Work Practice Records of Solids Removal, Mercury stack emissions | Periodic stack testing | Every 5 years | Keep stack test reports for 5 years | Approach is consistent with Minn. R. 7019.3050(E)(5) |

### 6.5.3 Evaluation of CEMS (MPCA Form item 7c)

*Evaluate the use of CEMS for mercury, both the sorbent tube method (U.S. Environmental Protection Agency [EPA] Method 30B) and an extractive "continuous" system. Describe if either method has been used at the mercury emissions source for parametric monitoring or for compliance determination. If CEMS is selected for monitoring of mercury emissions, please include in item 6a above. If it is not selected for monitoring of mercury emissions, please discuss the evaluation of the use of CEMS below.*

Temporary extractive CEMS have been used at Minorca to monitor mercury reduction during Pre-TMDL halide injection testing (Reference (24)) and sorbent tubes and temporary extractive CEMS were used during Phase II or recent ACI evaluations (References (34), (35)). Because the CEMS only measure vapor phase mercury, issues arose with the increase of particulate-bound mercury in the stack gas during the ACI injection and the inability of the CEMS to measure the particulate-bound mercury fraction.

Typically, Method 30B data was used for comparison purposes of one rate or material to the next with ability to turn results around on-site. Method 30B was used during recent ACI testing to establish a baseline mercury emission rate and screen various PAC types at Minorca (Reference (35)).

Method 30B (sorbent tube system) and/or temporary extractive CMMs are appropriate for reduction technology evaluations. However, these methods are not appropriate for a full-scale compliance demonstration for several reasons outlined below and thus are not listed as the proposed monitoring method in Section 6.5.2.

- **Appropriateness of monitoring frequency**
    - Minn. R. 7007.0502 and MPCA's Ferrous Mercury Reduction Plan Form require the Facility to meet a limitation of an annual mass of mercury emitted. Therefore, continuous data collection would be excessive and burdensome. Minute-by-minute data is not appropriate or necessary for an annual emission limit or for a pollutant that does not cause environmental impacts following short-term variations. Similar to other pollutants monitored at the facilities, such as particulate matter (PM), periodic stack testing is a more appropriate method based on the requirement of the rule to reduce emissions on an annual basis.
    - The goal of the statewide mercury reduction effort is to address mercury concentrations in fish tissue in Minnesota's lakes and streams, which is a chronic Hg deposition issue. Continuous monitoring is not appropriate because small short-term variations in Hg emissions would not cause significant adverse environmental impacts.
- **Designed for vapor phase mercury only**
    - Method 30B and CMMs are designed for the measurement of vapor phase mercury only.
- **Susceptible to interference**
    - CMMs are susceptible to interference from gas emission constituents that are common to the industry such as $SO_2$, $NO_X$, and water vapor.
    - Sorbent tube measurements can be adversely impacted by stack gas moisture, which is typically near the saturation point in most taconite facilities' waste gas.
- **Reliability at low concentrations**
    - CMMs are not well suited to measuring trace/low mercury concentrations. Although CMMs are available with low detection limits (i.e. 0.05 μg Hg per cubic meter), emission measurement professionals recommend other measurement approaches, such as periodic performance testing, at the expected mercury concentrations (<1 μg Hg per cubic meter).

- **Reference method and calibration techniques**
  - If EPA Procedure 5 (Reference (66)) is used, it is possible that the quality control criteria could allow the monitor to differ from the actual emissions value by a large margin of error that could impact data accuracy at the expected low-level concentrations.
- **Cost prohibitive**
  - The capital investment costs are high, especially at facilities with more than one stack.
  - CMMs are challenging to install and operate, and require knowledgeable on-site staff for calibrations, maintenance, sample analysis, etc.

The cost for periodic performance testing is much less than the initial investment and operating costs for a sorbent tube system or CMM. An outside contractor would still be required for one mobilization per year to conduct a Relative Accuracy Test Audit (RATA) for continuous extractive CMMs.

## 6.6 AMERP Enforceability (MPCA Form Item 8)

*The elements of the reduction plan will be included in your air emissions permit. If a permit amendment is needed in order to install or implement the control plan, please explain.*

A permit application will be submitted to incorporate the AMERP provisions by January 2023 or within one year of implementation of the reduction technology, whichever is sooner. The proposed schedule (refer to Table 6-3) is dependent on the MPCA's approval of this AMERP pursuant to Minn. R. 7007.0502, subp. 4(B). Should The MPCA be delayed in the decision making process, the permit application submittal date may need to be changed. In addition, Minorca proposes to enter into an enforceable compliance agreement to meet the proposed literature review and/or vendor screening and associated deadlines described in Section 6.3.

## 6.7 Additional Information (MPCA Form Item 9)

*Please provide additional information that will assist in reviewing your Mercury Reduction Plan.*

Minorca is still in the process of evaluating the specifics of this technology and reserves the right to adjust the AMERP when new data suggests that a 22% reduction is not technically achievable. Current operations produce mainly flux pellets. However, should operations shift to different pellet types in the future, it is unknown if this would have any impact on the ability of mercury capture by existing MACT wet scrubbers with solids removal to reduce stack emissions.

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# Appendices

# Appendix A

## MPCA Form: Mercury Reduction Plan Submittal (Ferrous Mining/Processing)

aq-ei2-04a

MINNESOTA POLLUTION CONTROL AGENCY

520 Lafayette Road North
St. Paul, MN 55155-4194

# Mercury Reduction Plan submittal (Ferrous mining/processing)

Air Quality Permit Program
Minn. R. 7007.0502, subp. 3

*Doc Type: Regulated Party Response*

**Instructions:**

- Complete this form to meet the Mercury Reduction Plan requirements for owners and operators of ferrous mining or processing facilities subject to Minn. R. 7007.0502, subp. 3.
- Attach any additional explanatory information, for example, editable spreadsheets with calculations, stack test reports, engineering or design reports, and any other information supporting your reduction plan. Data that is considered to be confidential information must follow the procedures described in item 9 of this form.
- This reduction plan must be approved by the Minnesota Pollution Control Agency (MPCA) prior to submittal of a permit amendment application or development of an enforceable document. It is not a substitution for a permit amendment application.
- **Please submit form to:** Statewide Mercury Total Maximum Daily Load (TMDL) Coordinator, Hassan Bouchareb, Minnesota Pollution Control Agency, 520 Lafayette Road North, St. Paul, Minnesota 55155.

## Mercury Reduction Plan

The goal of the Mercury TMDL is to reduce statewide mercury air emissions to 789 pounds per year. To achieve this goal, the MPCA undertook rulemaking and adopted rules regarding mercury reduction plans in Minn. R. 7007.0502. These rules established a mercury emission reduction, for ferrous mining or processing, of 72% from the amount of mercury emitted in 2008 or 2010. As stated in the Mercury TMDL Implementation Plan and reiterated in the MPCA's Response to Comments for the rulemaking, "*The technology developed to achieve the target must be technically and economically feasible, it must not impair pellet quality, and it must not cause excessive corrosion to pellet furnaces and associated ducting and emission-control equipment. Criteria for determining economic feasibility will be developed through a collaborative effort by the taconite industry and the MPCA.*"

Minn. R. 7007.0502 requires the owners or operators of a ferrous mining or processing facility to prepare a mercury reduction plan that addresses reductions for each indurating furnace or kiln of a taconite processing facility or the rotary hearth furnace of a direct-reduced iron facility. The reduction plan may accomplish reductions at each furnace, across all furnaces at a single stationary source, or across furnaces at multiple stationary sources. The mercury reduction plan submittal and compliance deadlines are shown in the table below.

## Mercury Reduction Plan submittal and compliance deadlines

| Type of source | Mercury Reduction Plan submittal deadline | Compliance deadline |
|---|---|---|
| Ferrous mining or processing | December 30, 2018 | January 1, 2025 |

### 1. Facility information

1.a. Facility name: **ArcelorMittal Minorca Mine Inc.**

1.b. AQ facility ID number: **13700062**

1.c. Facility contact for this reduction plan: **Jaime Johnson**

1.d. Agency Interest ID number: **257**

1.e. Facility contact email address: **Jaime.Johnson@arcelormittal.com**

1.f. Facility contact phone number: **1-218-305-3337**

## 2. Determination of technically achievable

Has the facility determined that the reductions listed in Minn. R. 7007.0502, subp. 6, are technically achievable by the January 1, 2025, compliance date?

☐ Yes Skip item 3. Go to item 4.

☒ No Proceed to item 3.

## 3. Proposal of alternative reduction

If the owner or operator determines that the mercury reductions listed in Minn. R. 7007.0502, subp. 6 are not technically achievable by the identified compliance date; an alternative plan may be submitted under Minn. R. 7007.0502, subp. 5(A)(2). If you are proposing an alternative plan to reduce mercury emissions, please complete the following:

a) Complete Steps 1 through 6 below:

Step 1. Identify all available technologies and rank in descending order of control effectiveness.

**Two reduction technologies, mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal and GORE, do not reduce emissions by 72% but still satisfied the other adaptive management and environmental impacts criteria. The associated control effectiveness ranking is as follows:**

**(1) GORE = 53.8% Total Mercury Control Efficiency**

**(2) Mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal = 22% Total Mercury Control Efficiency**

**These technologies continue onto Step 2.**

**Refer to Section 5.1 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for more information.**

Step 2. Eliminate technically infeasible technologies.

Include references and citations supporting the basis for the determination that the reductions are not technically achievable by the compliance date. If the mercury reductions are not technically achievable based solely or partly on economic factors, include references and citations supporting the basis for the determination that the reductions are not economically feasible.

**There is no information to suggest these reduction technologies are not technically feasible. Mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal and GORE both proceeded to Step 3 of the alternative mercury emissions reduction evaluation**

**Refer to Section 5.2 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for more information.**

Step 3. Rank remaining technologies in descending order of control effectiveness.

**Mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal and GORE both proceeded to Step 4 of the alternative mercury emissions reduction evaluation. The associated control effectiveness ranking is as follows:**

**(1) GORE = 53.8% Total Mercury Control Efficiency**

**(2) Mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal = 22% Total Mercury Control Efficiency**

**Refer to Section 5.3 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for more information.**

Step 4. Complete an environmental impacts analysis.

Provide an analysis of environmental impacts. Focus on impacts other than direct impacts due to emissions of mercury, such as solid or hazardous waste generation, discharges of polluted water from a control device, demand on local water resources, and emissions of other regulated air pollutants.

**Neither mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal nor GORE cause unacceptable environmental impacts. Both technologies proceeded to Step 5 of the alternative mercury emissions reduction evaluation.**

**Refer to Section 5.4 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for more information.**

Step 5. Complete a cost effectiveness evaluation.

Calculate the cost effectiveness of each control technology (in dollars per pound of mercury emissions reduced). This cost effectiveness must address both an average basis for each measure and combination of measures. If multi-pollutant control strategies were considered that have implications on cost, such as the control technology also reducing emissions of other regulated air pollutants, please provide that information as well. The costs associated with direct energy impacts should be calculated and included in the cost analysis. Direct energy consumption impacts include the consumption of fuel and the consumption of electrical or thermal energy. The emphasis of this analysis is on the cost of control relative to the amount of pollutant removed, rather than economic parameters that provide an indication of the general affordability of the control alternative relative to the source.

**Minorca assumed that mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal was cost effective.**

**The GORE control costs exceeded the $7,100 per pound of mercury removed cost effectiveness threshold several times over ($216,100 per pound of mercury removed), which eliminated GORE from further consideration.**

**Only mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal proceeded to Step 6 of the alternative mercury emissions reduction evaluation.**

**Refer to Section 5.5 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for more informaton.**

Step 6. Of the remaining technologies, propose the best-performing control strategy. Describe the selection of the control strategy.

**A 22% reduction in mercury emissions is technically feasible through mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal, considering the adaptive management and environmental impacts criteria**

**Refer to Section 5.6 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for more information.**

b) Provide an estimate of the annual mass of mercury emitted under the requirements of Minn. R. 7007.0502, subp. 6.

**Minorca's Baseline Emissions = 85 lb Hg/yr**

**Refer to Section 6.1 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for more information.**

c) Provide an estimate of the annual mass of mercury emitted and percent reduction achieved under the proposed alternative plan.

**Estimated Emissions = 66.3 lb Hg/yr - 12 month rolling sum**

**Percent Reduction = 22%**

**Refer to Section 6.1 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for more information.**

d) Complete the information in items 4 through 9 for your alternative proposal.

## 4. Description of mercury reduction action

Complete the following table for each emission unit that emits mercury. Use a separate row for each specific control, process, material or work practice that will be employed to achieve the applicable control efficiencies, reductions or allowable emissions. Provide a written summary below as needed for context or background. Minn. R. 7007.0502, subp. 5(A)(1)(a), 5(A)(1)(b), or 5(A)(2)(a).

*This table has an example of information that the MPCA is seeking for industrial boilers. The table is designed to help address each element needed when composing enforceable emission limits, control efficiencies or other conditions to meet mercury reductions. In the below example, the facility is applying control technology and fuel limits between two boilers to meet the total mercury reduction requirement of 70% with no changes proposed for the lime kiln other than tracking suppliers and fuel sampling [examples can be deleted]. To create a new row, place your cursor in the last column of the last row, hit tab.*

| **Emission unit** | **Element to reduce mercury**<br>**(control device, work practice, etc.)** | **Reduction, control efficiency, emission limit, operating limit, or work practice***<br>**(indicate units, i.e., lb. hg/ton material, % control)** | **Describe element in detail**<br>**(include manufacturer's data** as applicable)** |
|---|---|---|---|
| **EU 026, SV014-017** | **Mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal** | **Work Practice of mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal**<br>**(Refer to Table 4-9 for basis of 22% mercury control target)** | **See Section 4.1.3 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for element details.** |
| **EU 026, SV014-017** | **Literature review and/or vendor screening with Best Available Mercury Reduction Technology Analysis, as needed** | **TBD** | **See Section 6.2.1 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for element details.** |
| **Refer to Section 6.2 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan.** | | | |

*The permit or enforceable document will include the proposed control efficiency, emission limits, or other requirements that achieve the reduction.
**Attach manufacturer's information and other resources used to document the reduction

**Written description:**

**Refer to Section 6.2 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan.**

## 5. Schedule

For each reduction element (specific control, process, material or work practice) described in Item 4 that will be employed as part of the mercury reduction plan, complete the following table. *To create a new row, place your cursor in the last column of the last row, hit tab.*

| **Emission unit** | **Reduction element** | **Anticipated element construction/installation date** (mm/dd/yyyy) | **Anticipated startup date** (mm/dd/yyyy) | **Anticipated date for demonstrating reduction target** (mm/dd/yyyy) | **Date reduction needs to be met** (mm/dd/yyyy) | **Anticipated date of permit application submittal (if necessary)** (mm/dd/yyyy) |
|---|---|---|---|---|---|---|

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| **EU 026, SV014-017** | **Mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal** | **5/15/2023** | **1/1/2024** | **1/1/2025** | **1/1/2025** | **1/1/2023** |
| **EU 026, SV014-017** | **Literature review and/or vendor screening with Best Available Mercury Reduction Technology Analysis, as needed** | **Minorca will conduct a literature review and/or vendor screening between May 1, 2020 and July 31, 2020. Minorca will revise and resubmit the alternative mercury emissions reduction plan if necessary or notify the MPCA that the review has been completed by no later than June 1, 2022.** |  |  |  |  |
| **Refer to Section 6.3 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan.** |  |  |  |  |  |  |

## 6. Calculation data

Include all mercury emission calculations for each emissions unit listed in item 4 in an editable electronic spreadsheet. Provide calculations showing the mercury reduction, control efficiency, or emission rate that each emissions unit will achieve once the plan for that emissions unit is fully implemented.

### 6a. Emission factors

Identify the emission factors and sources of the emission factors used to determine mercury emissions in item 3 in the following table. Please include the rationale behind your decision. Minn. R. 7007.0502, subp. 5(A)(1)(b) or Minn. R. 7007.0502, subp. 5(A)(2)(d). *To create a new row, place your cursor in the last column of the last row, hit tab.*

| Emission unit | Emission factors for current mercury emissions rate, if applicable | Source of emission factor | Target emission rate | Source of emission factors for target emission rate |
|---|---|---|---|---|
| **EU 026, SV014-017** | **2.44E-05 lb / long ton of pellets** | **2015 Method 29 Emission Test** | **66.3 lb / yr** | **2015 Method 29 Emission Test and a 22% Reduction Target** |
| **Refer to Section 6.4.1 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan.** |  |  |  |  |

## 7. Operation, monitoring, and recordkeeping plan

### 7a. Operation and optimization plan

For each control device used to achieve the overall mercury reduction of the plan, describe how you will operate the control system such that mercury reductions are maintained. Explain how an operator might adjust the control system at the facility. Describe system alarms or safeguards to ensure optimal operation of the mercury control system. Optimization also includes training of individuals responsible for operating the control system, and the development and upkeep of operation and maintenance manuals. The MPCA is not requesting that such programs or manuals be included here, rather that they are summarized. Discuss potential variability of mercury emissions and how operations will be monitored to address variability. Minn. R. 7007.0502, subp. 5(A)(1)(c) or Minn. R. 7007.0502, subp. 5(A)(2)(c).

**The Facility proposes to remove scrubber solids from the process by sending the scrubber blowdown stream to the tailings thickener. The thickened solids are then routed to the basin for permanent sequestration and disposal. The scrubber blowdown will be sent to the tailings thickener using redundant pump systems and a flowmeter to monitor flowrate. Therefore, even if a pump failure occurs, a fail-safe is installed to constantly send scrubber solids to the tailings thickener. The equipment will be equipped with alarms so that operations will be notified of malfunctions.**

**Operators will be trained to operate the pump system and maintenance personnel will be trained to maintain the pump system. In addition, maintenance personnel will perform preventive maintenance consistent with manufacturer specifications.**

**Refer to Section 6.5.1 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for more information.**

## 7b. Proposed monitoring and recordkeeping

For each reduction element (specific control equipment, emission limit, operating limit, material or work practice), describe monitoring to provide a reasonable assurance of continuous control of mercury emissions. If the plan includes control equipment, attach MPCA Air Quality Permit Forms GI-05A and CD-05. Minn. R. 7007.0502, subp. 5(A)(1)(d).

*This table and following description has example material for a facility with two coal fired boilers [examples can be deleted]. To create a new row, place your cursor in the last column of the last row, hit tab.*

| Emission Unit | Reduction Element | Reduction, Control Efficiency or Emission Rate (include units) | Operating Parameters | Monitoring Method | Parameter Range (include units, if applicable) | Monitoring Frequency | Proposed Recordkeeping | Discussion of Why Monitoring is Adequate |
|---|---|---|---|---|---|---|---|---|
| **EU 026, SV014-017** | **Mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal** | **22% Hg reduction target** | **Work Practice Records of Solids Removal, mercury stack emissions** | **Periodic stack testing** | **N/A** | **Every 5 years** | **Keep stack test reports for 5 years** | **Approach is consistent with Minn. R. 7019.3050(E)(5)** |

**Refer to Section 6.5.2 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan.**

**Additional Discussion:**

**Refer to Section 6.5.2 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan.**

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## 7c. Evaluation of the use of Continuous Emissions Monitoring Systems (CEMS).

Evaluate the use of CEMS for mercury, both the sorbent tube method (U.S. Environmental Protection Agency [EPA] Method 30B) and an extractive “continuous” system. Describe if either method has been used at the mercury emissions source for parametric monitoring or for compliance determination. If CEMS is selected for monitoring of mercury emissions, please include in item 6a above. If it is not selected for monitoring of mercury emissions, please discuss the evaluation of the use of CEMS below:

**Method 30B (sorbent tube system) and/or temporary extractive CMMs are appropriate for reduction technology evaluations. However, these methods are not appropriate for a full-scale continuous compliance demonstration.**

**Refer to Section 6.5.3 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for more information.**

## 8. Mechanism to make reduction plan enforceable.

The elements of the reduction plan will be included in your air emissions permit. If a permit amendment is needed in order to install or implement the control plan, please explain:

**A permit application will be submitted to incorporate the AMERP provisions by January 2023 or within one year of implementation of the reduction technology, whichever is sooner. The proposed schedule (refer to item 5) is dependent on the MPCA’s approval of this AMERP pursuant to Minn. R. 7007.0502, subp. 4(B). Should the MPCA be delayed in the decision making process, the permit application submittal date may need to be changed. In addition, Minorca proposes to enter into an enforceable compliance agreement to meet the proposed literature review and/or vendor screening and associated deadlines (refer to item 5).**

**Refer to Section 6.6 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for more information.**

## 9. Additional information

Please provide additional information that will assist in reviewing your Mercury Reduction Plan.

**The Facility is still in the process of evaluating the specifics of this technology and reserves the right to adjust the AMERP when new data suggests that a 22% reduction is not technically achievable. Current operations produce mainly flux pellets. However, should operations shift to different pellet types in the future, it is unknown if this would have any impact on the ability of mercury capture by existing Maximum Achievable Control Technology (MACT) wet scrubbers with solids removal to reduce stack emissions.**

**Refer to Section 6.7 of the attached Best Available Mercury Reduction Technology Analysis and Proposed Alternative Mercury Emissions Reduction Plan for more information.**

## 10. Confidentiality

If your mercury reduction plan submittal includes confidential information, submit two versions of the mercury reduction plan. One version with the confidential information and one public version with the confidential information redacted.

### 10a. Confidentiality statement

☒ This submittal does not contain material claimed to be confidential under Minn. Stat. §§ 13.37 subd. 1(b) and 116.075. Skip item 10b, go to item 11.

☐ This submittal contains material which is claimed to be confidential under Minn. Stat. §§ 13.37 subd. 1(b) and 116.075. Complete Item 10b. Your submittal must include both Confidential and Public versions of your submittal.

☐ Confidential copy of submittal attached ☐ Public copy of submittal attached

### 10b. Confidentiality certification

To certify data for the confidential use of the MPCA, a responsible official must read the following, certify to its truth by filling in the signature block in this item, and provide the stated attachments.

☐ I certify that the enclosed submittal(s) and all attachments have been reviewed by me and do contain confidential material. I understand that only specific data can be considered confidential and not the entire submittal. I certify that I have enclosed the following to comply with the proper procedure for confidential material:

- ☐ I have enclosed a statement identifying which data contained in my submittal I consider confidential, and I have explained why I believe the information qualifies for confidential (or non-public) treatment under Minnesota Statutes.
- ☐ I have explained why the data for which I am seeking confidential treatment should not be considered "emissions data" which the MPCA is required to make available to the public under federal law.
- ☐ I have enclosed a submittal containing all pertinent information to allow for review and approval of my submittal. This document has been clearly marked "confidential."
- ☐ I have enclosed a second copy of my submittal with the confidential data blacked out (not omitted or deleted entirely). It is evident from this copy that information was there, but that it is not for public review. This document has been clearly marked "public copy."

| **Permittee responsible official** | | **Co-permittee responsible official (if applicable)** | |
|---|---|---|---|
| Print name: | | Print name: | |
| Title: | Date | Title: | Date: |
| Signature: | | Signature: | |
| Phone: | Fax: | Phone: | Fax: |

## 11. Submittal certification

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete.

| **Permittee responsible official** | | **Co-permittee responsible official (if applicable)** | |
|---|---|---|---|
| Print name: **Wet ink signature page included as hard copy** | | Print name: | |
| Title: | Date | Title: | Date: |
| Signature: | | Signature: | |
| Phone: | Fax: | Phone: | Fax: |

# Appendix B

## Historical Mercury Reduction Research Reports See

*Appendix B1-B4_Minorca BAMRT and AMERP FINAL* and

*Appendix B5_Minorca BAMRT and AMERP FINAL* Files

# Appendix C

## Minorca Mercury Baseline Evaluation

# ArcelorMittal Minorca Mine Inc.
# Alternative Mercury Emissions Reduction Plan
## Appendix C
## Baseline Emission Evaluation

### Table 1
### Barr 2015 Mercury Testing - EPA Method 29

| Furnace Stack | HgT [1] | |
|---|---|---|
| | lb/Lton | lb/hr |
| SV 014 | 3.89E-06 | 1.40E-03 |
| SV 015 | 4.93E-06 | 1.74E-03 |
| SV 016 | 7.02E-06 | 2.53E-03 |
| SV 017 | 8.58E-06 | 3.02E-03 |
| **Furnace Total** | **2.44E-05** | **8.70E-03** |

[1] HgT = Hg measured in the front half (HgP) and backhalf (HgG) of the EPA Method 29 stack test performed on 6/23-25/2015.

### Table 2
### Summary of Annual HgT Emissions From Furnace

| Annual Hg Emissions | | |
|---|---|---|
| Year | Annual Pellet Production Capable of Accommodating | Hg Emission Rate Based on Pellet Production Capable of Accomodating [1] |
| | Lt/yr | lb/yr |
| 2001 | 3,368,712 | 82 |
| 2002 | 3,426,408 | 84 |
| 2003 | 3,426,408 | 84 |
| 2004 | 3,569,316 | 87 |
| 2005 | 3,569,316 | 87 |
| 2006 | 3,569,316 | 87 |
| 2007 | 3,467,064 | 85 |
| 2008 | 3,467,064 | 85 |
| 2009 | 3,406,020 | 83 |
| 2010 | 3,397,212 | 83 |
| 2011 | 3,397,212 | 83 |
| 2012 | 3,397,212 | 83 |
| 2013 | 3,411,612 | 83 |
| 2014 | 3,411,612 | 83 |
| 2015 | 3,411,612 | 83 |
| 2016 | 3,332,556 | 81 |
| 2017 | 3,272,040 | 80 |

[1] A mercury emissions factor in lb Hg / Lton pellet is calculated using stack test data and the pellet throughput data collected during the test. The Hg emissions factor is multiplied by the maximum annual furnace throughput capable of accommodating.

**ArcelorMittal Minorca Mine Inc.**
**Alternative Mercury Emissions Reduction Plan**
**Appendix C**
**Pellet Production**

| Date | Total Pellets (LT) | 2 Year Rolling Max By Month | Max COA Annually |
|---|---|---|---|
| Jan-01 | 235,231 | | |
| Feb-01 | 210,607 | | |
| Mar-01 | 238,918 | | |
| Apr-01 | 117,758 | | |
| May-01 | 243,055 | | |
| Jun-01 | 252,158 | | |
| Jul-01 | 277,379 | | |
| Aug-01 | 280,726 | | |
| Sep-01 | 186,857 | | |
| Oct-01 | 262,726 | | |
| Nov-01 | 251,042 | | |
| Dec-01 | 270,477 | | 3,368,712 |
| Jan-02 | 239,216 | | |
| Feb-02 | 229,728 | | |
| Mar-02 | 257,573 | | |
| Apr-02 | 114,202 | | |
| May-02 | 260,051 | | |
| Jun-02 | 282,705 | | |
| Jul-02 | 285,534 | | |
| Aug-02 | 254,558 | | |
| Sep-02 | 199,659 | | |
| Oct-02 | 272,866 | | |
| Nov-02 | 242,422 | | |
| Dec-02 | 231,884 | 3,426,408 | 3,426,408 |
| Jan-03 | 258,063 | 3,426,408 | |
| Feb-03 | 217,154 | 3,426,408 | |
| Mar-03 | 124,987 | 3,426,408 | |
| Apr-03 | 212,076 | 3,426,408 | |
| May-03 | 273,261 | 3,426,408 | |
| Jun-03 | 269,643 | 3,426,408 | |
| Jul-03 | 277,635 | 3,426,408 | |
| Aug-03 | 197,383 | 3,426,408 | |
| Sep-03 | 231,089 | 3,426,408 | |
| Oct-03 | 262,823 | 3,426,408 | |
| Nov-03 | 246,703 | 3,426,408 | |
| Dec-03 | 251,432 | 3,426,408 | 3,426,408 |

**ArcelorMittal Minorca Mine Inc.**

**Alternative Mercury Emissions Reduction Plan**

**Appendix C**

**Pellet Production**

| Date | Total Pellets (LT) | 2 Year Rolling Max By Month | Max COA Annually |
|---|---|---|---|
| Jan-04 | 234,696 | 3,426,408 | |
| Feb-04 | 212,128 | 3,426,408 | |
| Mar-04 | 65,349 | 3,426,408 | |
| Apr-04 | 259,564 | 3,426,408 | |
| May-04 | 269,501 | 3,426,408 | |
| Jun-04 | 286,756 | 3,441,072 | |
| Jul-04 | 297,443 | 3,569,316 | |
| Aug-04 | 167,794 | 3,569,316 | |
| Sep-04 | 296,623 | 3,569,316 | |
| Oct-04 | 285,463 | 3,569,316 | |
| Nov-04 | 273,046 | 3,569,316 | |
| Dec-04 | 259,163 | 3,569,316 | 3,569,316 |
| Jan-05 | 221,589 | 3,569,316 | |
| Feb-05 | 226,468 | 3,569,316 | |
| Mar-05 | 242,565 | 3,569,316 | |
| Apr-05 | 66,924 | 3,569,316 | |
| May-05 | 269,611 | 3,569,316 | |
| Jun-05 | 278,057 | 3,569,316 | |
| Jul-05 | 288,364 | 3,569,316 | |
| Aug-05 | 195,149 | 3,569,316 | |
| Sep-05 | 235,541 | 3,569,316 | |
| Oct-05 | 274,593 | 3,569,316 | |
| Nov-05 | 238,648 | 3,569,316 | |
| Dec-05 | 260,842 | 3,569,316 | 3,569,316 |
| Jan-06 | 262,222 | 3,569,316 | |
| Feb-06 | 200,566 | 3,569,316 | |
| Mar-06 | 236,138 | 3,569,316 | |
| Apr-06 | 103,965 | 3,569,316 | |
| May-06 | 261,104 | 3,569,316 | |
| Jun-06 | 283,137 | 3,569,316 | |
| Jul-06 | 288,922 | 3,559,476 | |
| Aug-06 | 266,754 | 3,559,476 | |
| Sep-06 | 223,449 | 3,467,064 | |
| Oct-06 | 275,612 | 3,467,064 | |
| Nov-06 | 266,055 | 3,467,064 | |
| Dec-06 | 220,149 | 3,467,064 | 3,569,316 |

**ArcelorMittal Minorca Mine Inc.**

**Alternative Mercury Emissions Reduction Plan**

**Appendix C**

**Pellet Production**

| Date | Total Pellets (LT) | 2 Year Rolling Max By Month | Max COA Annually |
|---|---|---|---|
| Jan-07 | 210,210 | 3,467,064 | |
| Feb-07 | 213,296 | 3,467,064 | |
| Mar-07 | 253,692 | 3,467,064 | |
| Apr-07 | 79,174 | 3,467,064 | |
| May-07 | 265,012 | 3,467,064 | |
| Jun-07 | 263,345 | 3,467,064 | |
| Jul-07 | 275,545 | 3,467,064 | |
| Aug-07 | 283,835 | 3,467,064 | |
| Sep-07 | 253,974 | 3,467,064 | |
| Oct-07 | 216,300 | 3,467,064 | |
| Nov-07 | 207,103 | 3,467,064 | |
| Dec-07 | 178,255 | 3,467,064 | 3,467,064 |
| Jan-08 | 215,461 | 3,467,064 | |
| Feb-08 | 232,640 | 3,467,064 | |
| Mar-08 | 233,913 | 3,467,064 | |
| Apr-08 | 89,689 | 3,467,064 | |
| May-08 | 266,103 | 3,467,064 | |
| Jun-08 | 256,729 | 3,467,064 | |
| Jul-08 | 269,249 | 3,406,020 | |
| Aug-08 | 274,947 | 3,406,020 | |
| Sep-08 | 244,822 | 3,406,020 | |
| Oct-08 | 259,363 | 3,406,020 | |
| Nov-08 | 236,908 | 3,406,020 | |
| Dec-08 | 213,732 | 3,406,020 | 3,467,064 |
| Jan-09 | 229,273 | 3,406,020 | |
| Feb-09 | 207,361 | 3,406,020 | |
| Mar-09 | 220,276 | 3,406,020 | |
| Apr-09 | 184,324 | 3,406,020 | |
| May-09 | 0 | 3,406,020 | |
| Jun-09 | 0 | 3,406,020 | |
| Jul-09 | 0 | 3,406,020 | |
| Aug-09 | 0 | 3,299,364 | |
| Sep-09 | 0 | 3,299,364 | |
| Oct-09 | 197,344 | 3,299,364 | |
| Nov-09 | 224,306 | 3,299,364 | |
| Dec-09 | 251,708 | 3,299,364 | 3,406,020 |

## ArcelorMittal Minorca Mine Inc.
## Alternative Mercury Emissions Reduction Plan
## Appendix C
## Pellet Production

| Date | Total Pellets (LT) | 2 Year Rolling Max By Month | Max COA Annually |
|---|---|---|---|
| Jan-10 | 239,485 | 3,299,364 | |
| Feb-10 | 225,464 | 3,299,364 | |
| Mar-10 | 252,742 | 3,299,364 | |
| Apr-10 | 123,571 | 3,299,364 | |
| May-10 | 214,678 | 3,299,364 | |
| Jun-10 | 261,314 | 3,299,364 | |
| Jul-10 | 268,975 | 3,299,364 | |
| Aug-10 | 258,870 | 3,227,700 | |
| Sep-10 | 240,659 | 3,227,700 | |
| Oct-10 | 283,101 | 3,397,212 | |
| Nov-10 | 196,893 | 3,397,212 | |
| Dec-10 | 231,936 | 3,397,212 | 3,397,212 |
| Jan-11 | 221,772 | 3,397,212 | |
| Feb-11 | 212,097 | 3,397,212 | |
| Mar-11 | 209,565 | 3,397,212 | |
| Apr-11 | 115,383 | 3,397,212 | |
| May-11 | 226,810 | 3,397,212 | |
| Jun-11 | 265,973 | 3,397,212 | |
| Jul-11 | 250,619 | 3,397,212 | |
| Aug-11 | 267,974 | 3,397,212 | |
| Sep-11 | 249,039 | 3,397,212 | |
| Oct-11 | 282,315 | 3,397,212 | |
| Nov-11 | 254,965 | 3,397,212 | |
| Dec-11 | 260,946 | 3,397,212 | 3,397,212 |
| Jan-12 | 257,685 | 3,397,212 | |
| Feb-12 | 242,744 | 3,397,212 | |
| Mar-12 | 235,869 | 3,397,212 | |
| Apr-12 | 94,601 | 3,397,212 | |
| May-12 | 259,954 | 3,397,212 | |
| Jun-12 | 258,880 | 3,397,212 | |
| Jul-12 | 264,635 | 3,397,212 | |
| Aug-12 | 266,928 | 3,397,212 | |
| Sep-12 | 257,346 | 3,397,212 | |
| Oct-12 | 251,006 | 3,387,780 | |
| Nov-12 | 245,389 | 3,387,780 | |
| Dec-12 | 236,873 | 3,387,780 | 3,397,212 |

## ArcelorMittal Minorca Mine Inc.
## Alternative Mercury Emissions Reduction Plan
## Appendix C
## Pellet Production

| Date | Total Pellets (LT) | 2 Year Rolling Max By Month | Max COA Annually |
|---|---|---|---|
| Jan-13 | 260,746 | 3,387,780 | |
| Feb-13 | 232,949 | 3,387,780 | |
| Mar-13 | 256,446 | 3,387,780 | |
| Apr-13 | 72,394 | 3,387,780 | |
| May-13 | 269,015 | 3,387,780 | |
| Jun-13 | 253,186 | 3,387,780 | |
| Jul-13 | 278,189 | 3,387,780 | |
| Aug-13 | 284,301 | 3,411,612 | |
| Sep-13 | 264,535 | 3,411,612 | |
| Oct-13 | 223,292 | 3,411,612 | |
| Nov-13 | 253,636 | 3,411,612 | |
| Dec-13 | 226,482 | 3,411,612 | 3,411,612 |
| Jan-14 | 227,907 | 3,411,612 | |
| Feb-14 | 172,113 | 3,411,612 | |
| Mar-14 | 222,011 | 3,411,612 | |
| Apr-14 | 112,510 | 3,411,612 | |
| May-14 | 185,033 | 3,411,612 | |
| Jun-14 | 263,104 | 3,411,612 | |
| Jul-14 | 270,508 | 3,411,612 | |
| Aug-14 | 277,713 | 3,411,612 | |
| Sep-14 | 256,893 | 3,411,612 | |
| Oct-14 | 235,268 | 3,411,612 | |
| Nov-14 | 245,711 | 3,411,612 | |
| Dec-14 | 231,205 | 3,411,612 | 3,411,612 |
| Jan-15 | 259,353 | 3,411,612 | |
| Feb-15 | 214,445 | 3,411,612 | |
| Mar-15 | 256,351 | 3,411,612 | |
| Apr-15 | 114,353 | 3,411,612 | |
| May-15 | 152,518 | 3,411,612 | |
| Jun-15 | 164,444 | 3,411,612 | |
| Jul-15 | 267,194 | 3,411,612 | |
| Aug-15 | 272,670 | 3,332,556 | |
| Sep-15 | 258,469 | 3,332,556 | |
| Oct-15 | 226,375 | 3,332,556 | |
| Nov-15 | 256,641 | 3,332,556 | |
| Dec-15 | 254,704 | 3,332,556 | 3,411,612 |

## ArcelorMittal Minorca Mine Inc.
## Alternative Mercury Emissions Reduction Plan
## Appendix C
## Pellet Production

| Date | Total Pellets (LT) | 2 Year Rolling Max By Month | Max COA Annually |
|---|---|---|---|
| Jan-16 | 239,353 | 3,332,556 | |
| Feb-16 | 234,411 | 3,332,556 | |
| Mar-16 | 244,964 | 3,332,556 | |
| Apr-16 | 97,319 | 3,332,556 | |
| May-16 | 229,123 | 3,332,556 | |
| Jun-16 | 228,857 | 3,332,556 | |
| Jul-16 | 260,429 | 3,332,556 | |
| Aug-16 | 265,368 | 3,272,040 | |
| Sep-16 | 260,613 | 3,272,040 | |
| Oct-16 | 222,507 | 3,272,040 | |
| Nov-16 | 252,179 | 3,272,040 | |
| Dec-16 | 256,018 | 3,272,040 | 3,332,556 |
| Jan-17 | 249,023 | 3,272,040 | |
| Feb-17 | 224,029 | 3,272,040 | |
| Mar-17 | 224,851 | 3,272,040 | |
| Apr-17 | 186,004 | 3,272,040 | |
| May-17 | 150,574 | 3,272,040 | |
| Jun-17 | 247,622 | 3,272,040 | |
| Jul-17 | 265,246 | 3,272,040 | |
| Aug-17 | 260,508 | 3,184,416 | |
| Sep-17 | 263,649 | 3,184,416 | |
| Oct-17 | 231,096 | 3,184,416 | |
| Nov-17 | 234,744 | 3,184,416 | |
| Dec-17 | 234,663 | 3,184,416 | 3,272,040 |

# Appendix D

## BAMRT Mercury Reduction Technology Control Cost Evaluation Workbook

## Appendix D - BAMRT Mercury Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 1 - Cost Evaluation Summary

***Hg Control Technology Description***

| Technology Name | | Fixed Carbon Beds (includes baghouse) | ACI with High Efficiency Scrubber | ACI with Baghouse |
|---|---|---|---|---|
| Expected Equipment Life (years) | [1] | 20 | 20 | 20 |
| Expected Utilization Rate (% of Capacity) | [1] | 100% | 100% | 100% |
| Expected Annual Hours of Operation (hr/year) | [1] | 8,100 | 8,100 | 8,100 |
| Notes on Technology | | | | |

***Control Equipment Costs***

| | | | | |
|---|---|---|---|---|
| *Capital Costs* | | | | |
| Direct Capital Costs (DC) | [2] | $38,326,621 | $23,883,219 | $24,786,124 |
| Indirect Capital Costs (IC) | [2] | $9,974,700 | $6,264,026 | $6,836,116 |
| Total Capital Investment (TCI = DC + IC) | [2] | $48,301,321 | $30,147,246 | $31,622,239 |
| Total Capital Investment (TCI = DC + IC) with Retrofit Factor | [2] | $72,369,506 | $45,526,185 | $47,886,175 |
| *Operating Costs* | | | | |
| Direct Operating Costs ($/year) | [3] | $1,705,002 | $2,685,168 | $1,610,027 |
| Indirect Operating Costs ($/year) | [3] | $9,153,251 | $5,645,507 | $5,988,631 |
| Total Annual Cost ($/year) | [4] | $10,858,252 | $8,330,675 | $7,598,657 |

This cost estimate most closely resembles a Class 4 estimate, based on the classification system outlined in *AACE International Recommended Practice No. 18R-97* [5]

***Hg Emission Controls***

| | | |
|---|---|---|
| Baseline Hg Emission Rate (lb/year) | [6] | 85 |

| | | | | |
|---|---|---|---|---|
| Hg Control Efficiency (mass%) | [7] | 99.00% | 88.10% | 88.10% |
| Controlled Hg Emission Rate (lb Hg/year) | [8] | 0.85 | 10.12 | 10.12 |
| Hg Mass Removed from Exhaust (lb Hg/year) | [9] | 84.15 | 74.89 | 74.89 |
| Hg Control Cost Effectiveness ($/lb Hg removed) | [10] | $129,034 | $111,246 | $101,471 |

## Appendix D - BAMRT Mercury Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 1 - Cost Evaluation Summary

***Footnotes***

[1] Documentation of technology parameters noted

| ***Parameter*** | ***Documentation of Parameter*** | | |
|---|---|---|---|
| Expected Equipment Life | Assumed | Assumed | Assumed |
| Expected Utilization Rate | Assumed | Assumed | Assumed |
| Expected Hours of Operation | Minorca estimate of annual operating hours per furnace | Minorca estimate of annual operating hours per furnace | Minorca estimate of annual operating hours per furnace |

[2] See Table 2 - Capital Costs

[3] See Table 3 - Operating Costs

[4] Total Annual Cost = Direct Operating Costs + Indirect Operating Costs

[5] Class 4 Estimate: Study or Feasibility with -30%/+50% accuracy range according to *AACE International Recommended Practice No. 18R-97, TCM Framework: 7.3 - Cost Estimating and Budgeting, 2005* .

[6] Site-specific baseline emission rate. Refer to Section 3.0 of the Alternative Mercury Emissions Reduction Plan for Details.

[7]

| | | | |
|---|---|---|---|
| Documentation of Hg Control Efficiency for each control technology. | Vendor stated that they typically guarantee >99% control. This is consistent with most sources, which cite 99% control or higher. | *Project 4: Evaluation of a Slipstream Baghouse for the Taconite Industry* indicated that brominated PAC could achieve an 88.1% control at U. S. Steel Keetac. Minorca has not tested this technology, but will assume for this analysis that an 88.1% reduction can be achieved. | *Project 4: Evaluation of a Slipstream Baghouse for the Taconite Industry* indicated that brominated PAC could achieve an 88.1% control at U. S. Steel Keetac. Minorca has not tested this technology, but will assume for this analysis that an 88.1% reduction can be achieved. |

[8] Controlled Hg Emission Rate = (1 - Hg Control Efficiency) * Baseline Hg Emissions

[9] Hg Mass Removed from Exhaust = Baseline Hg Emissions - Controlled Hg Emission Rate

[10] Hg Control Cost Effectiveness = Total Annual Cost / Hg Mass Removed from Exhaust

## Appendix D - BAMRT Mercury Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 2 - Capital Costs

***Hg Control Technology Description***

| **Technology Name** | **Fixed Carbon Beds (includes baghouse)** | **ACI with High Efficiency Scrubber** | **ACI with Baghouse** |
|---|---|---|---|
| Expected Equipment Life (years) | 20 | 20 | 20 |
| Notes on Technology | | | |

| | | | | |
|---|---|---|---|---|
| ***Current Chemical Engineering Plant Cost Index (CEPCI)*** | | 572.9 | 572.9 | 572.9 |
| ***CEPCI of Equipment Cost Estimate Year*** | | N/A | 536.4 | N/A |
| ***Direct Capital Costs (DC)*** | | **$38,326,621** | **$23,883,219** | **$24,786,124** |
| *Purchased Equipment Costs* | | | | |
| Equipment Costs | [1] | $11,367,180 | $8,289,861 | $8,486,798 |
| Instrumentation | [2] | $1,136,718 | $828,986 | $0 |
| Sales Tax | [3] | $781,494 | $569,928 | $583,467 |
| Freight | [4] | $568,359 | $414,493 | $424,340 |
| *Generalized Installation Costs* | | | | |
| Basis for Installation Costs | [5]<br>[6] | Fabric Filter | Venturi Scrubber | Fabric Filter |
| Foundations and Supports | [5] | $554,150 | $606,196 | $379,784 |
| Handling & Erection | [5] | $6,926,875 | $4,041,307 | $4,747,302 |
| Electrical | [5] | $1,108,300 | $101,033 | $759,568 |
| Piping | [5] | $138,538 | $505,163 | $94,946 |
| Insulation | [5] | $969,763 | $303,098 | $664,622 |
| Painting | [5] | $554,150 | $101,033 | $0 |
| *Site-Specific Installation Costs* | | | | |
| Site Preparation (Grade & Level) | [13] | $133,000 | $133,000 | $133,000 |
| Ductwork | [13] | $3,348,616 | $2,818,942 | $2,549,616 |
| Buildings | [13] | $2,551,800 | $654,500 | $1,447,000 |
| Initial Carbon Charge | [13] | $3,672,000 | N/A | N/A |
| Lost Production During Installation | [13] | $4,515,679 | $4,515,679 | $4,515,679 |
| Extended Downtime Days for Tie-in and Restart | [13] | 14 | 14 | 14 |

| | | | | |
|---|---|---|---|---|
| ***Indirect Capital Costs (IC)*** | | **$9,974,700** | **$6,264,026** | **$6,836,116** |
| Basis for Installation Costs | [5]<br>[6] | Fabric Filter | Venturi Scrubber | Fabric Filter |
| Engineering & Supervision | [5] | $1,385,375 | $1,010,327 | $949,460 |
| Construction & Field Expenses | [5] | $2,770,750 | $1,010,327 | $1,898,921 |
| Contractor Fees | [5] | $1,385,375 | $1,010,327 | $949,460 |
| Start-Up Costs | [5] | $138,538 | $101,033 | $94,946 |
| Performance Test | [5] | $138,538 | $101,033 | $94,946 |
| Contingency | [5] | $4,156,125 | $3,030,980 | $2,848,381 |
| Contingency Percentage - Site-Specific | [5] | 30% | 30% | 30% |

| | | | | |
|---|---|---|---|---|
| ***Retrofit Factor*** | [7] | 1.60 | 1.60 | 1.60 |
| ***Total Capital Investment (TCI)*** | [7] | **$48,301,321** | **$30,147,246** | **$31,622,239** |
| ***Total Capital Investment (TCI) with Retrofit Factor*** | [7] | **$72,369,506** | **$45,526,185** | **$47,886,175** |

***Capital Recovery***

| | | | | |
|---|---|---|---|---|
| Interest Rate | [8] | 7.0% | 7.0% | 7.0% |
| Expected Equipment Life | | 20 | 20 | 20 |
| Capital Recovery Factor (CRF) | [9] | 9.44% | 9.44% | 9.44% |
| Cost of Replacement Parts | [10] | $4,775,912 | | $891,259 |
| Adjusted TCI for Capital Recovery | [11] | $67,593,594 | $45,526,185 | $46,994,916 |
| Capital Recovery Cost (CRC) | [12] | $6,380,357 | $4,297,350 | $4,435,988 |

## Appendix D - BAMRT Mercury Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 2 - Capital Costs

***Footnotes***

| | | | | |
|---|---|---|---|---|
| [1] | Documentation of Capital Cost for Hg control technology. | Vendor estimate for fixed bed equipment and baghouse. Fan costs were scaled using *Chemical Engineering Economics* , by Donald E, Garrett, Appendix 1 page 281 from a recent vendor quote. Equipment scaled for injection rate using the 0.6 power law. Includes a vendor quoted cost for a new stack, equipment for dry sorbent injection (DSI) to maintain the current level of SO2 control, and a compressor for additional compressed air needs for the baghouse. | Vendor estimate for new high efficiency scrubber scaled to Minorca flow using 0.6 power law. Fan costs were scaled using Chemical Engineering Economics, by Donald E, Garrett, Appendix 1 page 281 from a recent vendor quote. Included ACI system price, scaled for injection rate using the 0.6 power law. | Vendor quotes for new baghouse, fans, motors, and activated carbon injection system. Included ACI system and dry sorbent injection system price, scaled for injection rate using the 0.6 power law. Includes a vendor quoted cost for a new stack and a compressor for additional compressed air need for the baghouse. |

[2] Per *EPA Air Pollution Control Cost Manual,* 6th edition, 2002. Section 1, Chapter 2, Table 2.4. Instrumentation ranges between 5% and 30% of the quoted Equipment Cost, with a typical value of 10%.

[3] MN sales tax is 6.875% of sale price, applied to the Equipment Costs (MN Department of Revenue, 4/25/2018).

[4] Per *EPA Air Pollution Control Cost Manual,* 6th edition, 2002. Section 1, Chapter 2, Table 2.4. Freight ranges between 1% and 10% of the quoted Equipment Cost, with a typical value of 5%.

[5] Per *EPA Air Pollution Control Cost Manual,* 6th edition, 2002, various chapters for each control technology.

| **Capital Cost Factors for Specific Control Equipment Factor applied to Purchased Equipment Cost** | **Carbon Adsorber System** | **Fabric Filter** | **Venturi Scrubber** | **Electrostatic Precipitator** |
|---|---|---|---|---|
| **Direct Installation Costs** | | | | |
| Foundations & Supports | 0.08 | 0.04 | 0.06 | 0.04 |
| Handling & Erection | 0.14 | 0.50 | 0.40 | 0.50 |
| Electrical | 0.04 | 0.08 | 0.01 | 0.08 |
| Piping | 0.02 | 0.01 | 0.05 | 0.01 |
| Insulation | 0.01 | 0.07 | 0.03 | 0.02 |
| Painting | 0.01 | 0.04 | 0.01 | 0.02 |
| **Indirect Installation Costs** | | | | |
| Engineering | 0.10 | 0.10 | 0.10 | 0.20 |
| Construction & Field Expenses | 0.05 | 0.20 | 0.10 | 0.20 |
| Contractor Fees | 0.10 | 0.10 | 0.10 | 0.10 |
| Start-Up | 0.02 | 0.01 | 0.01 | 0.01 |
| Performance Test | 0.01 | 0.01 | 0.01 | 0.01 |
| Contingency determined by Minorca due to the uncertainty and preliminary design of the proposed installation. | | | | |

| | | | | |
|---|---|---|---|---|
| [6] | Documentation of reason for selecting the control technology's Capital Cost Factors from table in Footnote [5]. | Installed technology is a carbon adsorber with a fabric filter - a baghouse is installed prior to the fixed carbon beds. | Installed technology is a venturi scrubber. | Installed technology is a fabric filter. Instrumentation and painting costs are zeroed because the vendor quote already included these items. |

[7] Total Capital Investment (TCI) = Direct Capital Costs (DC) + Indirect Capital Costs (IC). Minorca included a retrofit factor to account for significant space and installation constraints

[8] Standard interest rate specified by the U.S. Office of Management and Budget (OMB).

[9] Per *EPA Air Pollution Control Cost Manual,* 6th edition, 2002. Section 1, Chapter 2, Equation 2.8a.

$$CRF = \left(\frac{i \times (1+i)^n}{(1+i)^n - 1}\right)$$

Where: $i$ = interest rate
$n$ = number of years

[10] See 'Table 4 - Replacement Parts' for details.

[11] Adjusted TCI for Capital Recovery = TCI - Capital Cost of Replacement Parts

[12] Per *EPA Air Pollution Control Cost Manual,* 6th edition, 2002. Section 1, Chapter 2, Equation 2.8.

$$CRC = NPV \times CRF$$

In this case, the Net Present Value (NPV) factor is replaced with the TCI for the Hg control technology.

[13] Documentation of other items which should be included in the capital cost, but may not be covered by the Purchased Equipment Costs, Generalized Installation Costs, or Indirect Capital Costs.

| ***Parameter*** | ***Documentation of Parameter*** | | |
|---|---|---|---|
| Site Preparation (Grade & Level) | Site-specific engineering estimate | Site-specific engineering estimate | Site-specific engineering estimate |
| Ductwork | Site-specific engineering estimate | Site-specific engineering estimate | Site-specific engineering estimate |
| Buildings | Site-specific engineering estimate | Site-specific engineering estimate | Site-specific engineering estimate |
| Initial Carbon Charge | Initial carbon loading cost provided by vendor | N/A | N/A |
| Lost Production During Installation | Lost for extended downtime to install new retrofit equipment. Based on production rates and ArcelorMittal financial data. | Lost for extended downtime to install new retrofit equipment. Based on production rates and ArcelorMittal financial data. | Lost for extended downtime to install new retrofit equipment. Based on production rates and ArcelorMittal financial data. |
| Extended Downtime Days for Tie-in and Restart | Estimate based on engineering experience. The downtime is the number of days beyond a typical annual outage. | Estimate based on engineering experience. The downtime is the number of days beyond a typical annual outage. | Estimate based on engineering experience. The downtime is the number of days beyond a typical annual outage. |

## Appendix D - BAMRT Mercury Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 3 - Operating Costs

***Hg Control Technology Description***

| **Technology Name** | **Fixed Carbon Beds (includes baghouse)** | **ACI with High Efficiency Scrubber** | **ACI with Baghouse** |
|---|---|---|---|
| Expected Utilization Rate (%) | 100% | 100% | 100% |
| Expected Annual Hours of Operation (hr/year) | 8,100 | 8,100 | 8,100 |
| Notes on Technology | | | |

| ***Direct Annual Costs (DAC, $/year)*** | | | **$1,705,002** | **$2,685,168** | **$1,610,027** |
|---|---|---|---|---|---|
| *Raw Materials* | | | | | |
| Powdered Activated Carbon (HPAC) | Demand (lb/year) | [1] | | 497,178 | 497,178 |
| | Retail Price ($/lb) | [2] | | $1.12 | $1.12 |
| | Cost Per Year ($/year) | [3] | | $556,839 | $556,839 |
| Hydrated Lime | Demand (ton/year) | [1] | 335 | | 335 |
| | Retail Price ($/ton) | [2] | $250.00 | | $250.00 |
| | Cost Per Year ($/year) | [3] | $83,724 | | $83,724 |
| *Utilities* | | | | | |
| Electricity | Demand (kW-hr/year) | [4] | 17,468,209 | 26,214,404 | 7,845,771 |
| | Retail Price ($/kW-hr) | [2] | $0.069 | $0.07 | $0.069 |
| | Cost Per Year ($/year) | [3] | $1,201,813 | $1,803,551 | $539,789 |
| Makeup Water | Demand (Mgal/year) | [4] | | 141,244 | |
| | Retail Price ($/Mgal) | [2] | | $0.32 | |
| | Cost Per Year ($/year) | [3] | | $45,331 | |
| *Operating Labor* | | | | | |
| Operator | Worked Hours Per Year (hr/year) | [5] | 2,025 | 5,063 | 2,025 |
| | Cost Per Hour ($/hr) | [2] | $26.26 | $26.26 | $26.26 |
| | Cost Per Year ($/year) | [3] | $53,177 | $132,941 | $53,177 |
| Supervisor | Cost Per Year ($/year) | [6] | $7,976 | $19,941 | $7,976 |
| *Maintenance* | | | | | |
| Labor | Worked Hours Per Year (hr/year) | [7] | 1,013 | 1,519 | 1,013 |
| | Cost Per Hour ($/hr) | [2] | $27.73 | $27.73 | $27.73 |
| | Cost Per Year ($/year) | [3] | $28,077 | $42,115 | $28,077 |
| Materials | Cost Per Year ($/year) | [8] | $28,077 | $42,115 | $28,077 |
| *Waste Management* | | | | | |
| Non-Haz Solid Waste Offsite Disposal | Waste Production Rate (ton/year) | [9] | 5,897.95 | | 6,146.54 |
| | Transport Demand (ton-mile/year) | [10] | 9,591.40 | | 9,591.40 |
| | Disposal Fee ($/ton) | [2] | $41.07 | | $41.07 |
| | Transport Fee ($/ton-mile) | [2] | $1.83 | | $1.83 |
| | Cost Per Year ($/year) | [11] | $259,824 | | $270,033 |
| *Product Loss* | | | | | |
| Taconite Pellets | Product Lost (ton/year) | [12] | 1,411.20 | 1,411.20 | 1,411.20 |
| | Retail Price ($/ton) | [2] | $30.00 | $30.00 | $30.00 |
| | Cost Per Year ($/year) | [3] | $42,334 | $42,334.49 | $42,334 |

| ***Indirect Annual Costs (IAC, $/year)*** | | **$9,153,251** | **$5,645,507** | **$5,988,631** |
|---|---|---|---|---|
| Overhead | [13] | $70,384 | $142,267 | $70,384 |
| Administration | [14] | $966,026 | $602,945 | $632,445 |
| Property Tax | [15] | $483,013 | $301,472 | $316,222 |
| Insurance | [16] | $483,013 | $301,472 | $316,222 |
| Capital Recovery for Replacement Parts | [17] | $770,457 | | $217,370 |
| Capital Recovery | [18] | $6,380,357 | $4,297,350 | $4,435,988 |

| | | | |
|---|---|---|---|
| ***Total Annual Costs (TAC = DAC + IAC, $/year)*** | **$10,858,252** | **$8,330,675** | **$7,598,657** |

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***Footnotes***

[1] Source of information for the demand of each raw material for each Hg control technology.

| ***Raw Material Demand*** | ***Documentation of Demand Calculation*** | | |
|---|---|---|---|
| Powdered Activated Carbon (HPAC) | | *Project 4: Evaluation of a Slipstream Baghouse for the Taconite Industry* indicated that brominated PAC could achieve an 88.1% control at U. S. Steel Keetac with a 1.1 lb/mmacf injection rate. Minorca will assume the same injection rate. | *Project 4: Evaluation of a Slipstream Baghouse for the Taconite Industry* indicated that brominated PAC could achieve an 88.1% control at U. S. Steel Keetac with a 1.1 lb/mmacf injection rate. Minorca will assume the same injection rate. |
| Hydrated Lime | Lime injection rates maintain the current level of SO2 control achieved by the existing scrubbers (assumed 30%). Vendor data from previous project experience determined the normalized stoichiometric ratios. | | Lime injection rates maintain the current level of SO2 control achieved by the existing scrubbers (assumed 30%). Vendor data from previous project experience determined the normalized stoichiometric ratios. |

[2] See 'Table 5 - Raw Material, Utility, and Waste Disposal Costs ' for details.

[3] Cost per year = Demand/year * Retail Price

[4] Source of information for the demand of each utility for each Hg control technology.

## Appendix D - BAMRT Mercury Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 3 - Operating Costs

| ***Utility Demand*** | ***Documentation of Demand Calculation*** | | |
|---|---|---|---|
| Electricity | 6" pressure drop from baghouse and 6" pressure drop through carbon beds, per vendors. EPA Air Pollution Control Cost Manual 6th Ed 2002, Chapter 1 equation 1.14. Also included pressure drop due to ducting. To calculate the incremental electricity demand, the pressure drop across the current scrubbers was subtracted from the total. The electricity demand due to the compressor is also included. | 23" pressure drop per scrubber vendor. Also included pressure drop due to ducting. EPA Air Pollution Control Cost Manual 6th Ed 2002, Chapter 1 equation 1.14. Electricity demand is only the incremental amount above baseline conditions. | 6" pressure drop through baghouse per vendor information. EPA Air Pollution Control Cost Manual 6th Ed 2002, Chapter 1 equation 1.14. Also included pressure drop due to ducting. To calculate the incremental electricity demand, the pressure drop across the current scrubbers was subtracted from the total. The electricity demand due to the compressor is also included. |
| Makeup Water | | Makeup water cost for high efficiency scrubber assumed to be $0.32 / 1000 gal per EPA Air Pollution Control Cost Manual 6th Ed 2002. | |

## Appendix D - BAMRT Mercury Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 3 - Operating Costs

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[5]
Assumed 5.0 and 2.0 hrs of operator attention per 8 hr shift of unit operation for units with a venturi scrubber and fabric filter, respectively.

[6] 15% of operator costs per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.

[7]
Assumed 1.5 and 1.0 hrs of operator attention per 8 hr shift of unit operation for units with a venturi scrubber and fabric filter, respectively.

[8] 100% of maintenance labor per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.

[9] Source of information for the waste production rate for each Hg control technology.

| ***Waste Disposal Demand*** | ***Documentation of Demand Calculation*** | | |
|---|---|---|---|
| Non-Haz Solid Waste Offsite Disposal | Assumes that all of the solids captured by the baghouse would be disposed of as solid waste. Sampling of waste for Hg concentration will be done before sending to the landfill to determine whether or not it should be considered hazardous. | | Assumes that all of the solids captured by the baghouse would be disposed of as solid waste. Sampling of waste for Hg concentration will be done before sending to the landfill to determine whether or not it should be considered hazardous. |

[10] Source of information for the waste disposal transport needs for each control technology.

| *Waste Transport Demand* | | *Documentation of Demand Calculation* | | |
|---|---|---|---|---|
| Non-Haz Waste Transport | Waste Generation (loads/year) | 69.00 | | 69.00 |
| | Truck Capacity (ton/load) [19] | 3.14 | | 3.14 |
| | Distance to Disposal Facility (one way, mile) | 44.20 | | 44.20 |
| | Transport Distance (ton-mile/year) | 9,591.40 | | 9,591.40 |

[11] Cost per year = Demand/year * Retail Price + Transport Demand * Transport Fee

[12] Source of information for the product loss for each control technology.

| ***Product Loss From Control Technology*** | ***Documentation of Product Loss Calculation*** | | |
|---|---|---|---|
| Taconite Pellets | All of the scrubber solids are recovered for pellet production under normal operations. Captured dust would be disposed of as solid waste due to the addition of SO2 control reagents. | All of the scrubber solids are recovered for pellet production under normal operations. Scrubber solids would need to be removed to avoid recycling captured PAC and mercury. | All of the scrubber solids are recovered for pellet production under normal operations. Captured dust would be disposed of as solid waste due to the addition of SO2 control reagents and to avoid recycling PAC and mercury. |

[13] Overhead estimated as 60% of total labor and maintenance materials per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.

[14] Administration estimated as 2% of Total Capital Investment (TCI) per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.

[15] Property tax estimated as 1% of Total Capital Investment (TCI) per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.

[16] Insurance estimated as 1% of Total Capital Investment (TCI) per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.

[17] See 'Table 4 - Replacement Parts' for details.

[18] See 'Table 2 - Capital Costs ' for details.

[19] Site specific estimate - average tonnage of 2017 waste loads.

[20] Distance from Minorca mine to the landfill is 44.2 miles.

## Appendix D - BAMRT Mercury Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 4 - Replacement Parts

***Hg Control Technology Description***

| **Technology Name** | **Fixed Carbon Beds (includes baghouse)** | **ACI with High Efficiency Scrubber** | **ACI with Baghouse** |
|---|---|---|---|
| Notes on Technology | | | |

| | | **Fixed Carbon Beds (includes baghouse)** | **ACI with High Efficiency Scrubber** | **ACI with Baghouse** |
|---|---|---|---|---|
| ***Cost of Replacement Parts ($)*** | | **$4,775,912** | | **$891,259** |
| ***Capital Recovery for Replacement Parts($/year)*** | | **$770,457** | | **$217,370** |
| Replacement Part Name | | Filter Bags | | Filter Bags |
| Interest Rate | [1] | 7.0% | | 7.0% |
| Expected Life of Replacement Part (years) | [2] | 5 | | 5 |
| Cost of Replacement Part ($/replacement) | [2] | $859,031 | | $859,031 |
| Cost of Labor for Replacement ($/replacement) | [2] | $32,228 | | $32,228 |
| $CRF_P$ | [3] | 24.39% | | 24.39% |
| $CRC_P$ ($/year) | [4] | $217,370 | | $217,370 |
| Replacement Part Name | | Carbon Change | | |
| Interest Rate | [1] | 7.0% | | |
| Expected Life of Replacement Part (years) | [2] | 10 | | |
| Cost of Replacement Part ($/replacement) | [2] | $3,690,702 | | |
| Cost of Labor for Replacement ($/replacement) | [2] | $193,952 | | |
| $CRF_P$ | [3] | 14.24% | | |
| $CRC_P$ ($/year) | [4] | $553,087 | | |

## Appendix D - BAMRT Mercury Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 4 - Replacement Parts

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***Footnotes***

[1] Standard interest rate specified by the U.S. Office of Management and Budget (OMB).

[2] Documentation of parameters noted for replacement parts above.

| ***Name*** | ***Filter Bags*** | | ***Filter Bags*** |
|---|---|---|---|
| Documentation of Life Expectancy | Provided by baghouse manufacturer. | | Provided by baghouse manufacturer. |
| Documentation of Replacement Part Cost, including sales tax and freight. | Provided by baghouse manufacturer. Equipment life of 5 years at $110/bag. | | Provided by baghouse manufacturer. Equipment life of 5 years at $110/bag. |
| Documentation of Labor Costs for Replacement Part | EPA Air Pollution Control Cost Manual 6th Ed 2002 Chapter 1.5.1.4. Assumes 10 minutes per bag and US Bureau of Labor rates. | | EPA Air Pollution Control Cost Manual 6th Ed 2002 Chapter 1.5.1.4. Assumes 10 minutes per bag and US Bureau of Labor rates. |
| ***Name*** | ***Carbon Change*** | | |
| Documentation of Life Expectancy | 10 years per vendor, due to contamination from flue gas | | |
| Documentation of Replacement Part Cost, including sales tax and freight. | Cost includes new carbon and non-hazardous waste disposal of spent carbon. | | |
| Documentation of Labor Costs for Replacement Part | Assumes 16 person days per 50,000 lb per EPA Control Cost Manual Section 3, Chapter 1, Section 1.4.1.4 | | |

[3] Capital Recovery Factor for Replacement Parts. Per *EPA Air Pollution Control Cost Manual* , 6th edition, 2002. Section 1, Chapter 2, Equation 2.8a.

$$CRF = \left(\frac{i \times (1+i)^n}{(1+i)^n - 1}\right)$$

Where: $i$ = interest rate
$n$ = number of years

[4] Capital Recovery Cost of Replacement Parts. Per *EPA Air Pollution Control Cost Manual,* 6th edition, 2002. Section 1, Chapter 2, Equation 2.11.

$$CRC_p = \left(C_p + C_{pl}\right) \times CRF_p$$

Where: $C_p$ = initial cost of replacement parts including sales and freight
$C_{pl}$ = cost of labor for parts-replacement
$CRF_p$ = capital recovery factor for replacement parts

## Appendix D - BAMRT Mercury Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 5 - Raw Material, Utility, and Waste Disposal Costs

***Raw Material Costs***

| *Raw Material* | *Cost Per Unit* | *Unit* | *Year Basis* | *Footnote* | *Cost Index* | *Cost Index for Base Year* | *Cost Index for 2018* | *Adjusted Cost ($/Unit)* |
|---|---|---|---|---|---|---|---|---|
| Powdered Activated Carbon (HPAC) | $1.12 | lb | 2018 | [1] | Assume 3% Inflation | 100 | 100 | $ 1.12 |
| Baghouse Filter Bags | $110.00 | ea | 2018 | [9] | Assume 3% Inflation | 100 | 100 | $ 110 |
| Hydrated Lime | $250.00 | ton | 2018 | [10] | Assume 3% Inflation | 100 | 100 | $ 250 |

***Utility Costs***

| *Utility* | *Cost Per Unit* | *Unit* | *Year Basis* | *Footnote* | *Cost Index* | *Cost Index for Base Year* | *Cost Index for 2018* | *Adjusted Cost ($/Unit)* |
|---|---|---|---|---|---|---|---|---|
| Electricity | $0.07 | kW-hr | 2018 | [3] | Assume 3% Inflation | 100 | 100 | $0.07 |
| Natural Gas | $3.13 | MMBtu | 2018 | [4] | Assume 3% Inflation | 100 | 100 | $3.13 |
| Compressed Air | $0.25 | mscf | 1998 | [5] | Assume 3% Inflation | 100 | 181 | $0.45 |
| Makeup Water | $0.20 | Mgal | 2002 | [13] | Assume 3% Inflation | 100 | 160 | $0.32 |

***Labor Costs***

| *Occupation* | *Cost Per Unit* | *Unit* | *Year Basis* | *Footnote* | *Cost Index* | *Cost Index for Base Year* | *Cost Index for 2018* | *Adjusted Cost ($/Unit)* |
|---|---|---|---|---|---|---|---|---|
| Operator | $26.26 | hour | 2018 | [2] | Assume 3% Inflation | 100 | 100 | $26.26 |
| Maintenance | $27.73 | hour | 2018 | [11] | Assume 3% Inflation | 100 | 100 | $27.73 |
| Supervisor | $28.31 | hour | 2018 | [12] | Assume 3% Inflation | 100 | 100 | $28.31 |

***Waste Disposal Costs***

| *Disposal Type* | *Cost Per Unit* | *Unit* | *Year Basis* | *Footnote* | *Cost Index* | *Cost Index for Base Year* | *Cost Index for 2018* | *Adjusted Cost ($/Unit)* |
|---|---|---|---|---|---|---|---|---|
| Solid Waste Disposal | $41.07 | ton | 2018 | [6] | NA | 100 | 100 | $41.07 |
| Solid Waste Disposal Transportation Cost | $1.83 | ton-mile | 2018 | [6] | NA | 100 | 100 | $1.83 |
| Hazardous Waste Disposal | $250.00 | ton | 2002 | [7] | Assume 3% Inflation | 100 | 160 | $401.18 |

***Finished Products***

| *Product* | *Cost Per Unit* | *Unit* | *Year Basis* | *Footnote* | *Cost Index* | *Cost Index for Base Year* | *Cost Index for 2018* | *Adjusted Cost ($/Unit)* |
|---|---|---|---|---|---|---|---|---|
| Finished Pellets | $30.00 | ton | 2018 | [8] | NA | 100 | 100 | $30.00 |

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***Footnotes***

[1] Delivered price from vendor for HPAC.

[2] Median hourly wage for "Continuous Mining Machine Operators" in Metal Ore Mining industry as of May 2017, per US Bureau of Labor Statistics.
http://www.bls.gov/oes/current/oes475041.htm

[3] Minorca site-specific electricity cost

[4] Minorca site-specific natural gas cost

[5] *EPA Air Pollution Control Cost Manual* , 6th Ed, 2002, Section 6, Chapter 1, Paragraph 1.5.1.8.
http://www.epa.gov/ttncatc1/dir1/c_allchs.pdf

[6] Minorca site-specific solid waste disposal cost - $41.07 for industrial mine waste and average transportation fee ($255/load) converted to ton-mile.

[7] *EPA Air Pollution Control Cost Manual,* 6th Ed 2002, Section 2, Chapter 2.5.5.5.
Section 2 lists $200 - $300/ton. Assumed median value of $250/ton.

[8] Mining sales margin of $30/ton based on ArcelorMittal's 3rd Quarter 2018 earnings report.

[9] Filter bag cost provided by vendor.

[10] Vendor-provided delivered hydrated lime cost

[11] Median hourly wage for "Industrial Machinery Installation, Maintenance, and Repair Occupations" in Metal Ore Mining industry as of May 2017, per US Bureau of Labor Statistics.
https://www.bls.gov/oes/current/naics4_212200.htm#49-0000

[12] Median hourly wage for "First-Line Supervisors of Production and Operating Workers" in Metal Ore Mining industry as of May 2014, per US Bureau of Labor Statistics.
http://www.bls.gov/oes/current/oes511011.htm

[13] *EPA Air Pollution Control Cost Manual* , 6th Ed 2002, Section 3.1.

# Appendix E

## AMERP Mercury Reduction Technology Control Cost Evaluation Workbook

# Appendix E - AMERP Control Cost Effectiveness
# ArcelorMittal Minorca Mine Inc.
# Table 1 - Cost Evaluation Summary

***Hg Control Technology Description***

| **Technology Name** | | **GORE** |
|---|---|---|
| Expected Equipment Life (years) | [1] | 20 |
| Expected Utilization Rate (% of Capacity) | [1] | 100% |
| Expected Annual Hours of Operation (hr/year) | [1] | 8,100 |
| Notes on Technology | | |

***Control Equipment Costs***

| *Capital Costs* | | |
|---|---|---|
| Direct Capital Costs (DC) | [2] | $38,985,344 |
| Indirect Capital Costs (IC) | [2] | $10,522,596 |
| Total Capital Investment (TCI = DC + IC) | [2] | $49,507,940 |
| Total Capital Investment (TCI = DC + IC) with Retrofit Factor | [2] | $76,503,296 |
| *Operating Costs* | | |
| Direct Operating Costs ($/year) | [3] | $656,358 |
| Indirect Operating Costs ($/year) | [3] | $9,227,706 |
| Total Annual Cost ($/year) | [4] | $9,884,064 |

This cost estimate most closely resembles a Class 4 estimate, based on the classification system outlined in *AACE International Recommended Practice No. 18R-97* [5]

***Hg Emission Controls***

| | | |
|---|---|---|
| Baseline Hg Emission Rate (lb/year) | [6] | 85 |

| | | |
|---|---|---|
| Hg Control Efficiency (mass%) | [7] | 53.80% |
| Controlled Hg Emission Rate (lb Hg/year) | [8] | 39.27 |
| Hg Mass Removed from Exhaust (lb Hg/year) | [9] | 45.73 |
| Hg Control Cost Effectiveness ($/lb Hg removed) | [10] | $216,140 |

## Table 1 - Cost Evaluation Summary

***Footnotes***

[1] Documentation of technology parameters noted

| ***Parameter*** | ***Documentation of Parameter*** |
|---|---|
| Expected Equipment Life | Assumed |
| Expected Utilization Rate | Assumed |
| Expected Hours of Operation | Minorca estimate of annual operating hours per furnace |

[2] See Table 2 - Capital Costs

[3] See Table 3 - Operating Costs

[4] Total Annual Cost = Direct Operating Costs + Indirect Operating Costs

[5] Class 4 Estimate: Study or Feasibility with -30%/+50% accuracy range according to *AACE International Recommended Practice No. 18R-97, TCM Framework: 7.3 - Cost Estimating and Budgeting, 2005* .

[6] Refer to Section 3.0 of the Alternative Mercury Emissions Reduction Plan (AMERP) for details.

[7]

| | |
|---|---|
| Documentation of Hg Control Efficiency for each control technology. | Control efficiency based on GORE pilot testing at Minorca. |

[8] Controlled Hg Emission Rate = (1 - Hg Control Efficiency) * Baseline Hg Emissions

[9] Hg Mass Removed from Exhaust = Baseline Hg Emissions - Controlled Hg Emission Rate

[10] Hg Control Cost Effectiveness = Total Annual Cost / Hg Mass Removed from Exhaust

# Appendix E - AMERP Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 2 - Capital Costs

***Hg Control Technology Description***

| **Technology Name** | **GORE** |
|---|---|
| Expected Equipment Life (years) | 20 |
| Notes on Technology | |

| | |
|---|---|
| ***Current Chemical Engineering Plant Cost Index (CEPCI)*** | 572.9 |
| ***CEPCI of Equipment Cost Estimate Year*** | N/A |
| ***Direct Capital Costs (DC)*** | **$38,985,344** |

| | | |
|---|---|---|
| *Purchased Equipment Costs* | | |
| Equipment Costs | [1] | $14,886,078 |
| Instrumentation | [2] | $1,488,608 |
| Sales Tax | [3] | $1,023,418 |
| Freight | [4] | $744,304 |
| *Generalized Installation Costs* | | |
| Basis for Installation Costs | [5]<br>[6] | Carbon Adsorber System |
| Foundations and Supports | [5] | $1,451,393 |
| Handling & Erection | [5] | $2,539,937 |
| Electrical | [5] | $725,696 |
| Piping | [5] | $362,848 |
| Insulation | [5] | $181,424 |
| Painting | [5] | $181,424 |
| *Site-Specific Installation Costs* | | |
| Site Preparation (Grade & Level) | [13] | $133,000 |
| Ductwork | [13] | $2,661,835 |
| Buildings | [13] | $589,700 |
| GORE Wastewater Treatment | [13] | $7,500,000 |
| Lost Production During Installation | [13] | $4,515,679 |
| Extended Downtime Days for Tie-in and Restart | [13] | 14 |

| | |
|---|---|
| ***Indirect Capital Costs (IC)*** | **$10,522,596** |

| | | |
|---|---|---|
| Basis for Installation Costs | [5]<br>[6] | Carbon Adsorber System |
| Engineering & Supervision | [5] | $1,814,241 |
| Construction & Field Expenses | [5] | $907,120 |
| Contractor Fees | [5] | $1,814,241 |
| Start-Up Costs | [5] | $362,848 |
| Performance Test | [5] | $181,424 |
| Contingency | [5] | $5,442,722 |
| Contingency Percentage - Site-Specific | [5] | 30% |

| | | |
|---|---|---|
| ***Retrofit Factor*** | [7] | 1.60 |
| ***Total Capital Investment (TCI)*** | [7] | **$49,507,940** |
| ***Total Capital Investment (TCI) with Retrofit Factor*** | [7] | **$76,503,296** |

## Appendix E - AMERP Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 2 - Capital Costs

***Capital Recovery***

| | | |
|---|---|---|
| Interest Rate | [8] | 7.0% |
| Expected Equipment Life | | 20 |
| Capital Recovery Factor (CRF) | [9] | 9.44% |
| Cost of Replacement Parts | [10] | $8,452,600 |
| Adjusted TCI for Capital Recovery | [11] | $68,050,696 |
| Capital Recovery Cost (CRC) | [12] | $6,423,504 |

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***Footnotes***

| | | |
|---|---|---|
| [1] | Documentation of Capital Cost for Hg control technology. | Vendor estimate for GORE modules/equipment. Fan costs were scaled using *Chemical Engineering Economics* , by Donald E, Garrett, Appendix 1 page 281 from a recent vendor quote. Includes a vendor quoted cost for a new stack and fans. |

[2] Per *EPA Air Pollution Control Cost Manual,* 6th edition, 2002. Section 1, Chapter 2, Table 2.4. Instrumentation ranges between 5% and 30% of the quoted Equipment Cost, with a typical value of 10%.

[3] MN sales tax is 6.875% of sale price, applied to the Equipment Costs (MN Department of Revenue, 4/25/2018).

[4] Per *EPA Air Pollution Control Cost Manual,* 6th edition, 2002. Section 1, Chapter 2, Table 2.4. Freight ranges between 1% and 10% of the quoted Equipment Cost, with a typical value of 5%.

[5] Per *EPA Air Pollution Control Cost Manual,* 6th edition, 2002, various chapters for each control technology.

| **Capital Cost Factors for Specific Control Equipment Factor applied to Purchased Equipment Cost** | **Carbon Adsorber System** | **Fabric Filter** | **Venturi Scrubber** | **Electrostatic Precipitator** |
|---|---|---|---|---|
| **Direct Installation Costs** | | | | |
| Foundations & Supports | 0.08 | 0.04 | 0.06 | 0.04 |
| Handling & Erection | 0.14 | 0.50 | 0.40 | 0.50 |
| Electrical | 0.04 | 0.08 | 0.01 | 0.08 |
| Piping | 0.02 | 0.01 | 0.05 | 0.01 |
| Insulation | 0.01 | 0.07 | 0.03 | 0.02 |
| Painting | 0.01 | 0.04 | 0.01 | 0.02 |
| **Indirect Installation Costs** | | | | |
| Engineering | 0.10 | 0.10 | 0.10 | 0.20 |
| Construction & Field Expenses | 0.05 | 0.20 | 0.10 | 0.20 |
| Contractor Fees | 0.10 | 0.10 | 0.10 | 0.10 |
| Start-Up | 0.02 | 0.01 | 0.01 | 0.01 |
| Performance Test | 0.01 | 0.01 | 0.01 | 0.01 |
| Contingency determined by Minorca due to the uncertainty and preliminary design of the proposed installation. | | | | |

| | | |
|---|---|---|
| [6] | Documentation of reason for selecting the control technology's Capital Cost Factors from table in Footnote [5]. | GORE functions similar to a carbon adsorber system, so it was assumed that these factors would provide the most appropriate installation cost factor basis. |

[7] Total Capital Investment (TCI) = Direct Capital Costs (DC) + Indirect Capital Costs (IC). Minorca included a retrofit factor to account for significant space and installation constraints

[8] Standard interest rate specified by the U.S. Office of Management and Budget (OMB).

[9] Per *EPA Air Pollution Control Cost Manual,* 6th edition, 2002. Section 1, Chapter 2, Equation 2.8a.

$$CRF = \left(\frac{i \times (1+i)^n}{(1+i)^n - 1}\right)$$

Where: $i$ = interest rate
$n$ = number of years

[10] See 'Table 4 - Replacement Parts' for details.

[11] Adjusted TCI for Capital Recovery = TCI - Capital Cost of Replacement Parts

[12] Per *EPA Air Pollution Control Cost Manual,* 6th edition, 2002. Section 1, Chapter 2, Equation 2.8.

$$CRC = NPV \times CRF$$

In this case, the Net Present Value (NPV) factor is replaced with the TCI for the Hg control technology.

[13] Documentation of other items which should be included in the capital cost, but may not be covered by the Purchased Equipment Costs, Generalized Installation Costs, or Indirect Capital Costs.

| ***Parameter*** | ***Documentation of Parameter*** |
|---|---|
| Site Preparation (Grade & Level) | Site-specific engineering estimate |
| Ductwork | Site-specific engineering estimate |
| Buildings | Site-specific engineering estimate |
| GORE Wastewater Treatment | Design and cost estimate for treatment of the GORE effluent is an engineering estimate based on previous project experience. Value is installed capital cost. |
| Lost Production During Installation | Lost revenue for extended downtime to install new retrofit equipment. Based on production rates and ArcelorMittal financial data. |
| Extended Downtime Days for Tie-in and Restart | Estimate based on engineering experience. The downtime is the number of days beyond a typical annual outage. |

# Appendix E - AMERP Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 3 - Operating Costs

***Hg Control Technology Description***

| **Technology Name** | **GORE** |
|---|---|
| Expected Utilization Rate (%) | 100% |
| Expected Annual Hours of Operation (hr/year) | 8,100 |
| Notes on Technology | |

***Direct Annual Costs (DAC, $/year)*** **$656,358**

| | | | |
|---|---|---|---|
| *Utilities* | | | |
| Electricity | Demand (kW-hr/year) | [4] | 1,642,340 |
| | Retail Price ($/kW-hr) | [2] | $0.069 |
| | Cost Per Year ($/year) | [3] | $112,993 |
| *Operating Labor* | | | |
| Operator | Worked Hours Per Year (hr/year) | [5] | 506 |
| | Cost Per Hour ($/hr) | [2] | $26.26 |
| | Cost Per Year ($/year) | [3] | $13,294 |
| Supervisor | Cost Per Year ($/year) | [6] | $1,994 |
| *Maintenance* | | | |
| Labor | Worked Hours Per Year (hr/year) | [7] | 506 |
| | Cost Per Hour ($/hr) | [2] | $27.73 |
| | Cost Per Year ($/year) | [3] | $14,038 |
| Materials | Cost Per Year ($/year) | [8] | $14,038 |
| *Waste Management* | | | |
| GORE Wastewater Treatment | Waste Production Rate (mgal/year) | [9] | |
| | Disposal Fee ($/mgal) | [2] | |
| | Cost Per Year ($/year) | [3] | $500,000 |
| *Product Loss* | | | |
| Taconite Pellets | Product Lost (ton/year) | [12] | 0.00 |
| | Retail Price ($/ton) | [2] | |
| | Cost Per Year ($/year) | [3] | |

***Indirect Annual Costs (IAC, $/year)*** **$9,227,706**

| | | |
|---|---|---|
| Overhead | [13] | $26,019 |
| Administration | [14] | $990,159 |
| Property Tax | [15] | $495,079 |
| Insurance | [16] | $495,079 |
| Capital Recovery for Replacement Parts | [17] | $797,866 |
| Capital Recovery | [18] | $6,423,504 |

***Total Annual Costs (TAC = DAC + IAC, $/year)*** **$9,884,064**

# Appendix E - AMERP Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 3 - Operating Costs

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***Footnotes***

[1] Source of information for the demand of each raw material for each Hg control technology.

[2] See 'Table 5 - Raw Material, Utility, and Waste Disposal Costs ' for details.

[3] Cost per year = Demand/year * Retail Price

[4] Source of information for the demand of each utility for each Hg control technology.

| ***Utility Demand*** | ***Documentation of Demand Calculation*** |
|---|---|
| Electricity | Vendor quoted 0.97" pressure drop through modules, plus the pressure drop due to ducting. |

[5] Assumed 0.5 hrs of operator attention per 8 hr shift of unit operation for units with a carbon adsorber system.

[6] 15% of operator costs per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.

[7] Assumed 0.5 hrs of maintenance per 8 hr shift of unit operation for units with a carbon adsorber system.

[8] 100% of maintenance labor per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.

[9] Source of information for the waste production rate for each Hg control technology.

| ***Waste Disposal Demand*** | ***Documentation of Demand Calculation*** |
|---|---|
| GORE Wastewater Treatment | Annual operating costs of WWTP required to treat and reuse GORE wash water effluent to vendor recommended water quality standards. Water contaminant concentrations based on pilot testing data. |

[10] Transport fees are included in the disposal fee, so transport demand equals 0.

[11] Cost per year = Demand/year * Retail Price + Transport Demand * Transport Fee

[12] Source of information for the product loss for each control technology.

| ***Product Loss From Control Technology*** | ***Documentation of Product Loss Calculation*** |
|---|---|
| Taconite Pellets | |

[13] Overhead estimated as 60% of total labor and maintenance materials per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.

[14] Administration estimated as 2% of Total Capital Investment (TCI) per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.

[15] Property tax estimated as 1% of Total Capital Investment (TCI) per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.

[16] Insurance estimated as 1% of Total Capital Investment (TCI) per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.

[17] See 'Table 4 - Replacement Parts' for details.

[18] See 'Table 2 - Capital Costs ' for details.

# Appendix E - AMERP Control Cost Effectiveness
# ArcelorMittal Minorca Mine Inc.
## Table 4 - Replacement Parts

***Hg Control Technology Description***

| **Technology Name** | **GORE** |
|---|---|
| Notes on Technology | |

***Cost of Replacement Parts ($)*** **$8,452,600**

***Capital Recovery for Replacement Parts($/year)*** **$797,866**

| Replacement Part Name | | GORE Module |
|---|---|---|
| Interest Rate | [1] | 7.0% |
| Expected Life of Replacement Part (years) | [2] | 20 |
| Cost of Replacement Part ($/replacement) | [2] | $8,377,600 |
| Cost of Labor for Replacement ($/replacement) | [2] | $75,000 |
| $CRF_P$ | [3] | 9.44% |
| $CRC_P$ ($/year) | [4] | $797,866 |

# Appendix E - AMERP Control Cost Effectiveness
# ArcelorMittal Minorca Mine Inc.
# Table 4 - Replacement Parts

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***Footnotes***

[1] Standard interest rate specified by the U.S. Office of Management and Budget (OMB).

[2] Documentation of parameters noted for replacement parts above.

| *Name* | *GORE Module* |
|---|---|
| Documentation of Life Expectancy | Assumed 20 year equipment life. |
| Documentation of Replacement Part Cost, including sales tax and freight. | Vendor quote provided. Includes vendor estimated disposal cost of $45/module. |
| Documentation of Labor Costs for Replacement Part | Vendor estimate |

[3] Capital Recovery Factor for Replacement Parts. Per *EPA Air Pollution Control Cost Manual* , 6th edition, 2002. Section 1, Chapter 2, Equation 2.8a.

$$CRF = \left(\frac{i \times (1+i)^n}{(1+i)^n - 1}\right)$$

Where: $i$ = interest rate
$n$ = number of years

[4] Capital Recovery Cost of Replacement Parts. Per *EPA Air Pollution Control Cost Manual,* 6th edition, 2002. Section 1, Chapter 2, Equation 2.11.

$$CRC_p = \left(C_p + C_{pl}\right) \times CRF_p$$

Where: $C_p$ = initial cost of replacement parts including sales and freight
$C_{pl}$ = cost of labor for parts-replacement
$CRF_p$ = capital recovery factor for replacement parts

## Appendix E - AMERP Control Cost Effectiveness
## ArcelorMittal Minorca Mine Inc.
## Table 5 - Raw Material, Utility, and Waste Disposal Costs

***Raw Material Costs***

| *Raw Material* | *Cost Per Unit* | *Unit* | *Year Basis* | *Footnote* | *Cost Index* | *Cost Index for Base Year* | *Cost Index for 2018* | *Adjusted Cost ($/Unit)* |
|---|---|---|---|---|---|---|---|---|
| Powdered Activated Carbon (HPAC) | $1.12 | lb | 2018 | [1] | Assume 3% Inflation | 100 | 100 | $ 1.12 |
| Baghouse Filter Bags | $110.00 | ea | 2018 | [9] | Assume 3% Inflation | 100 | 100 | $ 110 |
| Hydrated Lime | $250.00 | ton | 2018 | [10] | Assume 3% Inflation | 100 | 100 | $ 250 |

***Utility Costs***

| *Utility* | *Cost Per Unit* | *Unit* | *Year Basis* | *Footnote* | *Cost Index* | *Cost Index for Base Year* | *Cost Index for 2018* | *Adjusted Cost ($/Unit)* |
|---|---|---|---|---|---|---|---|---|
| Electricity | $0.07 | kW-hr | 2018 | [3] | Assume 3% Inflation | 100 | 100 | $0.07 |
| Natural Gas | $3.13 | MMBtu | 2018 | [4] | Assume 3% Inflation | 100 | 100 | $3.13 |
| Compressed Air | $0.25 | mscf | 1998 | [5] | Assume 3% Inflation | 100 | 181 | $0.45 |
| Makeup Water | $0.20 | Mgal | 2002 | [13] | Assume 3% Inflation | 100 | 160 | $0.32 |

***Labor Costs***

| *Occupation* | *Cost Per Unit* | *Unit* | *Year Basis* | *Footnote* | *Cost Index* | *Cost Index for Base Year* | *Cost Index for 2018* | *Adjusted Cost ($/Unit)* |
|---|---|---|---|---|---|---|---|---|
| Operator | $26.26 | hour | 2018 | [2] | Assume 3% Inflation | 100 | 100 | $26.26 |
| Maintenance | $27.73 | hour | 2018 | [11] | Assume 3% Inflation | 100 | 100 | $27.73 |
| Supervisor | $28.31 | hour | 2018 | [12] | Assume 3% Inflation | 100 | 100 | $28.31 |

***Waste Disposal Costs***

| *Disposal Type* | *Cost Per Unit* | *Unit* | *Year Basis* | *Footnote* | *Cost Index* | *Cost Index for Base Year* | *Cost Index for 2018* | *Adjusted Cost ($/Unit)* |
|---|---|---|---|---|---|---|---|---|
| Solid Waste Disposal | $41.07 | ton | 2018 | [6] | NA | 100 | 100 | $41.07 |
| Hazardous Waste Disposal | $250.00 | ton | 2002 | [7] | Assume 3% Inflation | 100 | 160 | $401.18 |

***Finished Products***

| *Product* | *Cost Per Unit* | *Unit* | *Year Basis* | *Footnote* | *Cost Index* | *Cost Index for Base Year* | *Cost Index for 2018* | *Adjusted Cost ($/Unit)* |
|---|---|---|---|---|---|---|---|---|
| Finished Pellets | $30.00 | ton | 2018 | [8] | NA | 100 | 100 | $30.00 |

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***Footnotes***

[1] Delivered price from vendor for HPAC.

[2] Median hourly wage for "Continuous Mining Machine Operators" in Metal Ore Mining industry as of May 2017, per US Bureau of Labor Statistics.
http://www.bls.gov/oes/current/oes475041.htm

[3] Minorca site-specific electricity cost

[4] Minorca site-specific natural gas cost

[5] *EPA Air Pollution Control Cost Manual* , 6th Ed, 2002, Section 6, Chapter 1, Paragraph 1.5.1.8.
http://www.epa.gov/ttncatc1/dir1/c_allchs.pdf

[6] Minorca site-specific solid waste disposal cost - $41.07 for industrial mine waste.

[7] *EPA Air Pollution Control Cost Manual,* 6th Ed 2002, Section 2, Chapter 2.5.5.5.
Section 2 lists $200 - $300/ton. Assumed median value of $250/ton.

[8] Mining sales margin of $30/ton based on ArcelorMittal's 3rd Quarter 2018 earnings report.

[9] Filter bag cost provided by vendor.

[10] Vendor-provided delivered hydrated lime cost.

[11] Median hourly wage for "Industrial Machinery Installation, Maintenance, and Repair Occupations" in Metal Ore Mining industry as of May 2017, per US Bureau of Labor Statistics.
https://www.bls.gov/oes/current/naics4_212200.htm#49-0000

[12] Median hourly wage for "First-Line Supervisors of Production and Operating Workers" in Metal Ore Mining industry as of May 2014, per US Bureau of Labor Statistics.
http://www.bls.gov/oes/current/oes511011.htm

[13] *EPA Air Pollution Control Cost Manual* , 6th Ed 2002, Section 3.1.

# Appendix F

## Mercury Emissions Reduction Calculations

# ArcelorMittal Minorca Mine Inc.
# Alternative Mercury Emissions Reduction Plan
# Appendix F
# Mercury Emission Reductions

**Mercury Emissions Reductions under AMERP**

| Line | Baseline Emissions (lb/yr) | Percent Reduction [1] | Estimated Emissions (lb/yr) |
|---|---|---|---|
| EU 026 | 85 | 22% | 66 |

[1] Percent reduction from scrubber solids mass balance memo.

**Example Calculation:**

Baseline Emissions * (1 - Percent Reduction) = Estimated Emissions

85 lb/yr * (1 - .22) = 66 lb/yr