Best Available Mercury Reduction Technology Evaluation and Mercury Emissions Reduction Plan

Prepared for
Hibbing Taconite Company

December 2018

aq-ei2-12a

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Acronyms and Abbreviations

Acronym	**Description**
ACI	Activated Carbon Injection
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
HEDT	High Energy Dissociation Technology
HPAC	High Temperature Brominated Powdered Activated Carbon
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
MERP	Mercury Emissions Reduction Plan
Minn. R.	Minnesota Rules
Minntac	U. S. Steel – Minntac
Minorca	ArcelorMittal Minorca Mine
MPCA	Minnesota Pollution Control Agency
MTMCAC	Minnesota Taconite Mercury Control Advisory Committee
NaBr	Sodium Bromide
NaCl	Sodium Chloride
$NaClO_2$	Sodium Chlorite
NESHAP	National Emission Standards for Hazardous Air Pollutants
OHM	Ontario Hydro Method

PAC	Powdered Activated Carbon
PM	Particulate Matter
RATA	Relative Accuracy Test Audit
SAM	Sulfuric Acid Mist
SO_2	Sulfur Dioxide
TMDL	Total Maximum Daily Load
UTAC	United Taconite

Best Available Mercury Reduction Technology Analysis

Prepared for
Hibbing Taconite Company

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1 Executive Summary

In accordance with Minnesota Rules 7007.0502 (Minn. R. 7007.0502), Hibbing Taconite Company (HTC) evaluated reduction technologies for mercury air emissions from the facility's indurating furnaces to determine if 72% reduction from the 2008 or 2010 mercury emissions baseline, whichever is greater, is technically achievable. The rule requires HTC to propose an alternative plan to reduce mercury emissions if the evaluation determines that the 72% reduction threshold is not technically achievable. This report describes the background and methods used in the Best Available Mercury Reduction Technology (BAMRT) analysis for HTC's taconite processing plant located in Hibbing, Minnesota.

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 in Figure 4-1. 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 wet scrubbers with scrubber solids removal
- Mercury oxidation for 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
- Fixed bed carbon adsorption
- GORE^{TM} (previously known as Monolithic Polymer Resin Adsorption (Reference (1)))
- Monolithic Honeycomb Adsorption

The BAMRT analysis evaluated if the 72% mercury emissions reduction threshold was technically achievable with the potentially available mercury emissions reduction technologies. The analysis used the four technical achievability standards established by the Minnesota Pollution Control Agency (MPCA) (must be technically and economically feasible; must not impair pellet quality; and must not cause excessive corrosion to pellet furnaces or associated ducting or emission-control equipment) and the criterion of acceptable environmental impacts. The BAMRT analysis determined that achieving a 72% mercury emissions reduction threshold at the indurating furnaces was not technically achievable or did not have acceptable environmental impacts for the available mercury emissions reduction technologies as summarized in Table ES-1 below.

A full alternatives analysis (Section 5) was not required because all technologies evaluated in the BAMRT analysis were eliminated from further consideration.

Section MERP-1 presents HTC's Mercury Emissions Reduction Plan (MERP), submitted pursuant to Minn. R. 7007.0502, subp. 5(A)(2), HTC proposes to conduct a technology review in 2020 to determine if any new mercury emissions reduction technologies are available and complete a subsequent BAMRT analysis by June 30, 2022 if applicable.

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 scrubber solids removal – Not considered a potential reduction technology, little to no mercury reduction can be achieved for HTC	NA – See Step 1	NA – See Step 1	NA – See Step 1	NA – See Step 1	NA – See Step 1	NA – See Step 1
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
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 wet scrubbers	Yes	Yes	No	Yes - Increased likelihood of local mercury deposition, eliminated from further consideration	NA - see Step 5	NA - see Step 5
ACI with baghouse	Yes	Yes	No	No	Yes	No, eliminated from further consideration

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	Yes	Yes	No	Yes - Increased likelihood of local mercury deposition, eliminated from further consideration	NA - see Step 5	NA - see Step 5
Fixed carbon bed	Yes	Yes	No	No	Yes	No, eliminated from further consideration
GORE™	Yes	Yes	No	No	Yes	No, eliminated from further consideration
Monolithic Honeycomb Adsorption	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

2 Introduction

This section discusses the purpose and background information associated with the BAMRT analysis and MERP. In addition, a description of HTC's process is included for context in the reduction technology evaluations.

2.1 Purpose

This section outlines the history of the Minnesota Total Maximum Daily Load (TMDL), mercury reduction research, and rulemaking for the taconite processing industry. The background information explains why HTC is completing this BAMRT analysis and MERP.

2.1.1 Mercury Reduction Research from Minnesota Taconite Processing

The taconite processing industry in northeastern Minnesota has actively researched methods to reduce mercury emissions from processing taconite ore to produce taconite pellets for use in blast furnaces. Facilities that have participated in the ongoing efforts to reduce mercury emissions from operations include HTC, ArcelorMittal Minorca Mine (Minorca), 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 (however, these fuels are not used at HTC).

During the development of the Minnesota statewide mercury emissions reduction goals, a cooperative effort between 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 from taconite processing, 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 first-of-its kind 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 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 the TMDL, mercury is primarily introduced to surface waters through atmospheric deposition, the majority of which (90%) originates from sources outside of Minnesota. See Figure 2-1 below for details.

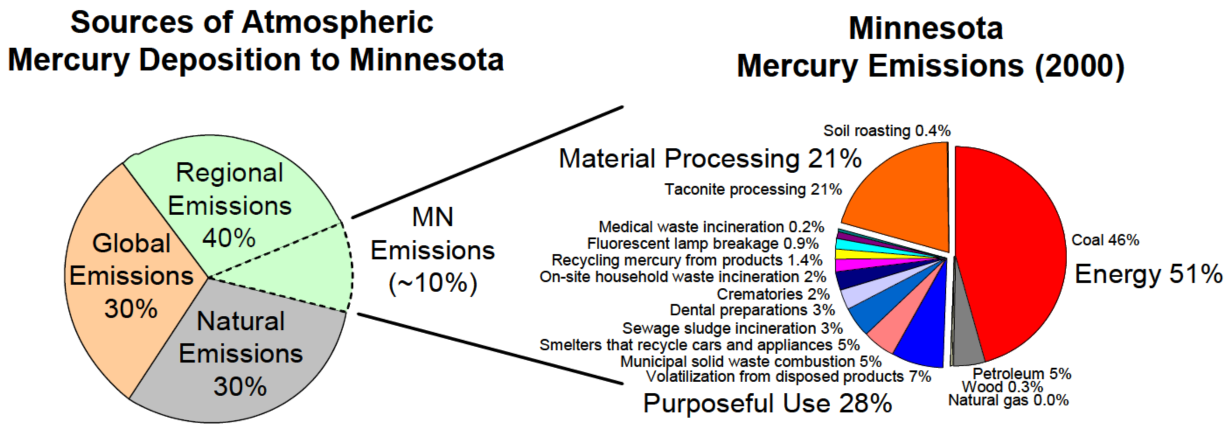


Figure 2-1 **Sources of Mercury Deposition and Estimated Mercury Emission Sources in Minnesota (Reference (2))**

The TMDL proposed a set of outcome-based, tiered reduction targets and milestones that were dependent on achieving certain national mercury emissions reduction milestones. When national emission reductions reached 65%, 80%, or 93% of 1990 levels, Minnesota’s emission target would be 1,700 pounds, 1,100 pounds, or 780 pounds, respectively. Table 2 in MPCA’s 2009 TMDL Implementation Plan described 2005 mercury emission rates for different Source Categories (Reference (3)). The Source Category related to stationary sources with MPCA Air Permits (including coal-fired electric generation, industrial/commercial/institutional (ICI) boilers, ferrous mining/processing, etc.) emitted 2,741 pounds per year of mercury in 2005. In MPCA’s September 2017 ‘Statewide Mercury TMDL Emission Inventory for Minnesota’ report, 2016 estimated emissions for the permitted stationary sources was 882 pounds per year of mercury. This represents a 68% reduction for these sources and additional reductions are expected as coal-fired electrical generating units and ICI boilers continue to utilize increasing amounts of natural gas in place of coal (Reference (4)).

The MPCA, with assistance from the Minnesota Environmental Initiative and the involvement of stakeholders, released a “Strategy Framework” to implement the Mercury TMDL the following year (Reference (5)). The Strategy Framework document was developed with the objective of achieving the ultimate statewide mercury emission target of 789 lb/yr, including the taconite sector mercury emission target of 210 lb/year.

The Strategy Framework document acknowledged that reductions to the taconite target of 210 lb/year would be a challenge because “mercury reduction technology does not currently exist for use on taconite pellet furnaces” (Reference (5)). It was acknowledged that the concept of “adaptive management” would be necessary to achieve the reduction target by “focusing on research to develop the technology in the near term and installation of mercury emission control equipment thereafter” (Reference (5)). The Strategy Framework further acknowledged “[t]he 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" (hereafter, "the adaptive management criteria") (*emphasis added,* Reference (5)).

The MPCA incorporated the Strategy Framework in its entirety into Appendix 1 of the plan it released in 2009 to implement the Mercury TMDL (Reference (3)). The Implementation Plan discussed steps necessary to achieve the TMDL's ultimate statewide emission goal of 789 lb/year.

The MPCA estimated mercury air emissions from the taconite industry as 734.8 pounds per year for 2005, 648.5 pounds per year for 2008, and 745.4 pounds per year for 2011 (Reference (4)). 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, both of which are due to the direct deposition of gas phase species, and through 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)).

MPCA, in their 2007 Minnesota Statewide Mercury TMDL, stated that the report "sets a target for fish tissue concentration of mercury that is generally safe for human consumption, and translates the target to reduction goals for mercury sources" (Reference (2)). However, achievement of all TMDL targets, complete implementation of the 2014 Mercury Rules, or even total elimination of all mercury sources in Minnesota, will not achieve the TMDL's overarching objective.

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 (2)). Total international global mercury emissions are estimated between 12,100,000 and 13,200,000 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)).

This information illustrates that reducing mercury emissions is a pervasive issue that must be addressed on a global scale. Implementation of Minnesota's TMDL and Mercury Rule should balance meaningful environmental outcomes against imposing significant costs to Minnesota's industries, many of which are competitive, internationally trade exposed industries that cannot pass along those costs to consumers in the same manner as utility ratepayers.

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

The MPCA proceeded to develop draft rules to require mercury emissions reporting and reduction requirements for certain mercury emission sources that were identified in the TMDL. The draft mercury rules did not address all of the sources addressed in the TMDL; therefore, they do not support achieving the overall TMDL reduction goal. The Proposed Mercury Rules were placed on public notice on December 2, 2013 (Reference (15)).

On September 29, 2014, the State of Minnesota finalized its air quality rules to include mercury air emissions reporting and reduction requirements. Most significantly, for taconite sources, the rules require submission of a Mercury Emissions Reduction Plan by December 30, 2018 that identifies a technology to achieve a mercury reduction target of 72% from 2008 or 2010 emission levels or allows a taconite facility to submit an alternative control plan if 72% reductions are not achievable. As part of the BAMRT analysis for HTC, all adaptive management criteria discussed above, as well as the criterion of acceptable environmental impacts, were evaluated to determine if a suitable technology could be implemented.

The BAMRT analysis evaluated reduction technologies for mercury air emissions from the facility's indurating furnaces to determine if 72% reduction from the 2008 or 2010 mercury emissions baseline, whichever is greater, is technically achievable, using the adaptive management and acceptable environmental impacts criteria. The rule requires HTC to propose an alternative plan, MERP, to reduce mercury emissions if the evaluation determines that the 72% reduction threshold is not technically achievable. As none of the evaluated reduction technologies met those requirements, HTC prepared its MERP, pursuant to Minn. R. 7007.0502, subp. 5(A)(2).

2.1.4 Hibbing Taconite Company Efforts towards Mercury Air Emission Reduction

Since before inception of the mercury TMDL, HTC has been investing resources to better understand the facility's mercury balance, mercury emissions, and potential reduction methods for those emissions. Since the draft rule was published in the state register, HTC has spent approximately $1 million on research and testing to identify potentially available mercury emissions reduction technologies. This value does not incorporate the time expended by the facility's employees as part of the data gathering and analysis, project planning and execution, and general research. Additional detail of this research and testing is provided in Section 4.

2.2 Facility Description

HTC mines iron ore (magnetite) and produces taconite pellets that are shipped to steel producers for processing in blast furnaces. The iron ore is crushed and routed through several concentration stages including grinding, magnetic separation, and thickening.

A concentrated iron ore slurry is dewatered by vacuum disk filters, mixed with bentonite, and conveyed to balling drums. Greenballs produced on the balling drums 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.

HTC operates three pellet indurating furnace lines (EU 020 – EU 022). Each Line is a straight-grate induration furnace design. The first two zones 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 conversion of magnetite to hematite is completed in the firing zone. The last two zones are cooling zones that allow the pellets to be safely discharged.

Heated air discharged from the two cooling zones is recirculated to the drying, preheat and firing zones. Flue gas from the furnaces are vented primarily through two ducts, the hood exhaust that handles the drying and recirculated cooling gases, and the windbox exhaust, which handles the preheat and firing gases. The windbox flue gas flows through the multiclones, and then enters a common header shared with the hood flue gas stream. The flue gases are subsequently divided into four streams which lead to four venturi rod scrubbers (CE 022 – CE 025, CE 027 – CE 030, CE 032 – CE 035) and exit from four individual stacks (SV 021 – SV 024, SV 025 – SV 028, SV 029 – SV 032). An overview of the furnace design is provided on Figure 2-2.

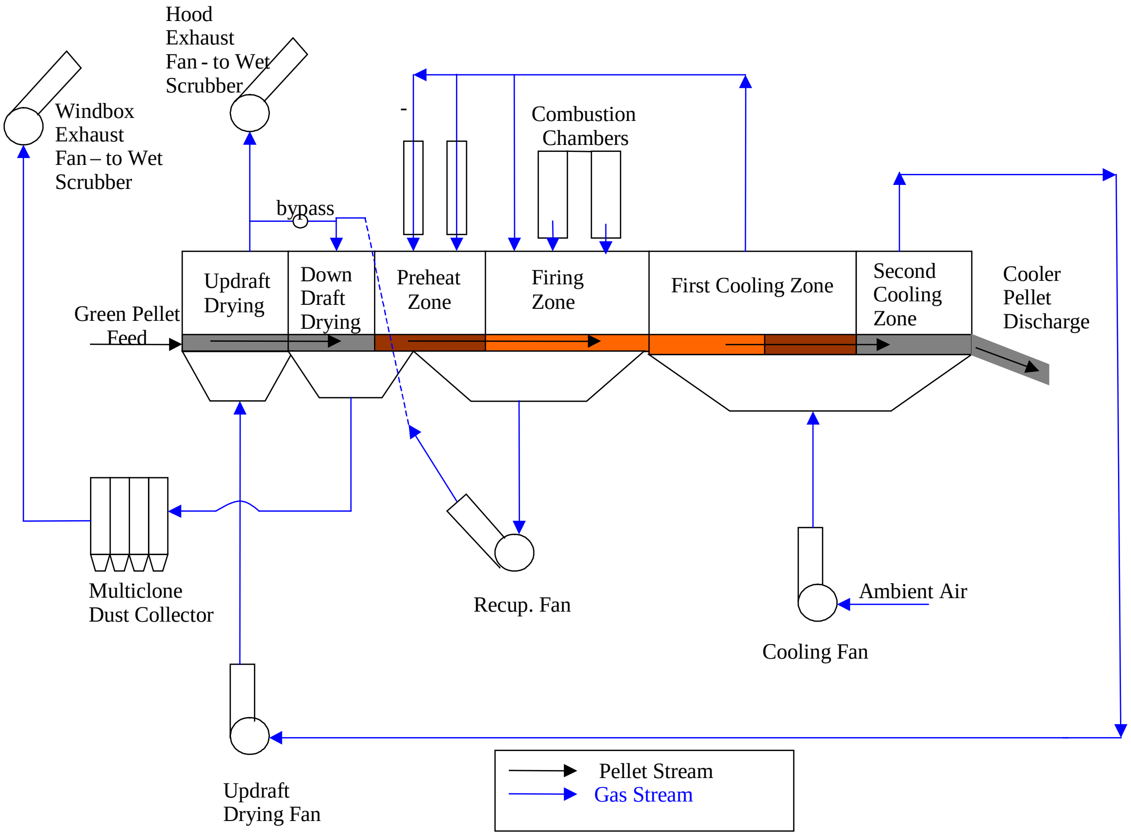


Figure 2-2 **Straight Grate Furnace Diagram**

3 Analysis of Baseline Mercury Emissions

This section describes how HTC calculated the annual mass of mercury emitted (i.e. baseline emissions) per the requirements of Minn. R. 7007.0502, subp. 6 (question 3b on the MPCA's Ferrous Mercury Reduction Plan Form (MPCA Form aq-ei2-04a)). Mercury emission rates are primarily influenced by ore mercury concentrations and pellet production rates.

3.1 HTC's Historical Annual Mercury Emissions Representation

The TMDL Implementation Plan originally estimated HTC's mercury emissions to be 227.1 pounds per year for 2005, 2010, and 2018 (Reference (3)). These estimates were based on mercury volatilization emission factors from a report titled *Mercury Emissions from Induration of Taconite Concentrate Pellets – Stack Testing Results from Facilities in Minnesota* (Reference (16)). However, HTC has since conducted additional emission testing, which shows that the TMDL emission factor was not representative of HTC's emission rate. HTC has more appropriately characterized the annual facility-wide mercury emissions representation as discussed in the following section.

3.2 Mercury Emissions Baseline Period Analysis

Pursuant to Minn. R. 7007.0502, subp. 6(A)(1), the BAMRT analysis and MERP must evaluate the mercury emissions reductions from the 2008 or 2010 baseline mercury emissions, whichever is greater. Unfavorable economic conditions in 2010 attributed to an abnormally low production year, resulting in lower annual mercury emissions compared to a typical operating year. Therefore, HTC's baseline mercury emission rate is based on the 2008 production rates (long ton of pellets per year).

HTC conducted mercury emission testing in 2016 and 2017 in accordance with EPA approved test methods (References (17), (18)). The emission testing shows that the TMDL emission factor was not representative of HTC's emission rate. Therefore, an average between the 2016 and 2017 emission test rate is more accurate than the TMDL emission rate estimate.

HTC applied the average emission test rate (lb mercury per long ton of pellets) to the 2008 production rate (long tons of pellets) to produce a production-normalized mercury emission rate (lb mercury per year) as presented in Table 3-1.

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

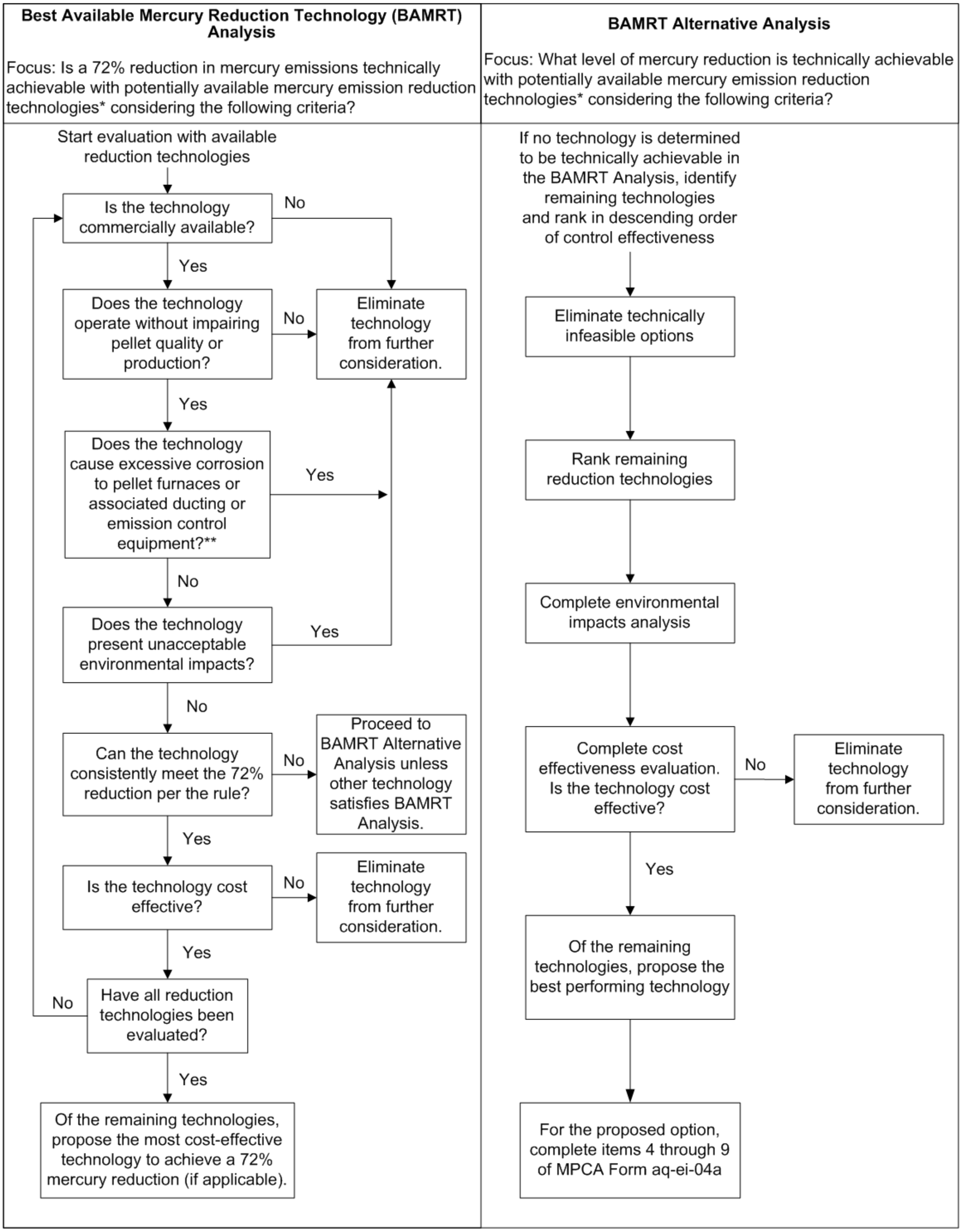
2008 Production (dry long ton of pellets)	2010 Production (dry long ton of pellets)	Average Stack Test Emission Factor (lb mercury per long ton of pellets)	2008 Baseline Emissions (lb/yr)	2010 Baseline Emissions (lb/yr)
8,083,000	5,716,000	2.632 x 10-5	213	150

Based on the approach to the baseline calculations described above, the proposed annual mass of mercury emitted is 213 pounds per year. HTC reserves the right to revisit its baseline calculations in the future to potentially account for values reflective of full production.

4 Best Available Mercury Reduction Technology Analysis

The BAMRT analysis evaluated whether potentially available mercury emissions reduction technologies identified at HTC were technically achievable, without unacceptable environmental impacts, and capable of achieving the 72% mercury emissions reduction threshold described in Minnesota Rules, using the adaptive management and acceptable environmental impacts criteria. Any technologies that cannot meet the mercury reduction percentage required by Minn. R. 7007.0502, subp. 6, are evaluated as an alternative reduction technology (refer to Section 5) if they satisfy the adaptive management and acceptable environmental impacts criteria.

Figure 4-1 below summarizes the step-wise BAMRT process for evaluating potentially available mercury emissions reduction technologies against the reduction threshold and technically achievable and acceptable environmental impacts criteria as well as evaluating certain technologies' suitability as an alternative reduction technology.



*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

The taconite processing industry completed an evaluation of potentially available mercury emissions reduction technologies by adapting an approach similar to the EPA-approved BART analysis and top-down BACT analysis. The BAMRT analysis sought to determine if mercury reduction technologies were technically achievable, using the adaptive management and acceptable environmental impacts criteria. The steps of the analysis 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 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 technical and cost 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 criteria. Adjusting the sequence would increase the level of effort and cost of this analysis while having no impact on the conclusions.

Step 1 – Identification of potentially available mercury emissions reduction technologies

The first step in the BAMRT analysis was to identify all potentially available mercury emissions reduction technologies for the taconite processing industry. Unlike BART, where only technologies that have been permitted and installed need to be evaluated, the industry included any known technology at the time of the analysis that may have been subject to bench or pilot scale testing. Any mercury reduction technologies employed in other industries were evaluated because mercury emissions reduction technologies do not currently exist in the taconite processing sector. Reduction technologies include specific control equipment, processes, materials or work practice standards that may be considered to achieve the required mercury reduction. Details on each potentially available mercury emissions reduction technology identified are described in Section 4.1.

Step 2 – Determine if the technology is commercially available

As part of determining if the controls were technically feasible, the second step in the BAMRT analysis was to assess if the technologies identified in Step 1 were commercially available. Details on how commercial availability for each technology was determined can be found in Section 4.2. Any technologies that were not commercially available were 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 in order to produce marketable pellets, and must not be adversely impacted by the mercury emissions reduction technology. Details can be found in Section 4.3. 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. 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 kind of environmental impact (i.e., waste generation/disposal, water, or air implications). Impacts that can be mitigated through treatment or management methods do not eliminate a technology from further consideration. However, any technology that produces un-mitigatable environmental harm or contradicts the goals of the TMDL was removed from further consideration. For example, a potential reduction technology that is found to increase particulate-bound or oxidized mercury emissions would be unacceptable because those forms of mercury increase rates of local mercury deposition, which is contrary to the goals of the TMDL (Reference (19)). 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 evaluated under 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 (Minn. R. 7007.0502, subp. 6(A)(1)) was evaluated in HTC's MERP evaluation (Minn. R. 7007.0502, subp. 5(A)(2)) if needed as determined in Step 8.

Step 7 – Determine if the technology is cost effective

The seventh step of the BAMRT analysis determined the cost effectiveness of each mercury emissions reduction technology not eliminated in Steps 1 through 6. This step compared the annualized cost per pound of mercury removed ($/lb) for the remaining technologies. Details on the cost effectiveness evaluation can be found in Section 4.7.

If the BAMRT analysis determined that a potential reduction technology exceeds reasonable cost effectiveness thresholds based on MPCA and EPA precedents, 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 determined the best technology selected for HTC by using the results from Steps 1 through 7. If after completing Steps 1 through 7 a technology could not achieve the 72% reduction but was technically achievable (any technologies eliminated in Step 6), the BAMRT process would be repeated to evaluate potential alternative reduction levels for those technologies, according to Minn. R. 7007.0502, subp. 5(A)(2). The BAMRT evaluates potential alternative reduction levels from technologies that cannot achieve a 72% reduction and have not been eliminated from further consideration in Steps 1-5.

4.1 Step 1 – Identification of Potentially Available Mercury Emissions 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 emissions reduction technologies. The list of potentially available mercury emissions reduction technologies was compiled based on a full review of historical research and testing that has been completed at both the industry and site-specific levels. The historical review covered each of the following "stages" of mercury reduction studies that have been completed:

- Pre-TMDL Implementation Plan DNR Research (Pre-TMDL research), 1997 - 2009
- Phase I – Minnesota Taconite Mercury Control Advisory Committee (MTMCAC) (Phase I), 2010 - 2012
- Phase II – Extended Testing of ACI (Phase II), 2013
- Gore Technology Demonstrations (GORE^{TM}), 2014 - 2015
- Site-specific Evaluations, 2016 - 2018

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

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 potentially available mercury emissions reduction technologies utilized in other industries. It concluded that the chemical oxidation and sorbent injection methods used or considered for the power industry may be able to be adapted by the taconite processing industry (Reference (20)).

Based on pre-TMDL evaluations, the taconite processing industry focused on chemical oxidation and sorbent injection technologies in the next phase (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 HTC.

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 UTAC, Minorca, and Minntac. GORE^{TM} demonstrated that it had the potential to reduce mercury emissions by 72% under specific conditions.

The above testing left several unanswered questions and data gaps. In order to address these issues, HTC conducted additional chemical oxidation and sorbent injection site-specific evaluations.

4.1.2 Potentially Available Mercury Emissions Reduction Technologies

Table 4-1 lists the potentially available mercury emissions reduction technologies that were evaluated as part of the BAMRT analysis along with a short summary on the theory behind the technology's mercury reductions. This summary also includes background information and considerations from the testing stages outlined 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 scrubber solids removal		Oxidized and particulate-bound mercury can be captured in existing wet scrubbers' solids. These scrubber solids are typically recycled back into the process to produce greenballs. The captured mercury can then be released during pellet induration. The scrubber solids could instead be sent to the tailings basin sequestering the mercury and preventing it from being emitted to the atmosphere.	4.1.3
Mercury oxidation for capture by existing 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
	HEDT	Generation of reactive halogens at high temperatures outside of the process prior to injection downstream of the furnace, which aid 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 existing wet scrubbers or a new baghouse.	4.1.5.1
	With baghouse		4.1.5.2
	At lower injection rate with existing wet scrubbers		4.1.5.3
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 does not 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 Scrubber Solids Removal

Mercury contained in the greenballs is liberated during the indurating process and becomes entrained in the furnace flue gas. Flue gas mercury is comprised primarily of elemental mercury and a smaller portion of oxidized mercury, which may combine with dust particles, thereby becoming particulate-bound mercury. Wet scrubbers are capable of removing oxidized and particulate-bound mercury and are not effective at removing elemental mercury (Reference (21)). Mercury adsorbed to particles in the flue gas has a better chance of being captured by the existing wet scrubbers due to the scrubbers' ability to reduce particulate emissions. Mercury that is captured by the existing wet scrubbers remains either in the scrubber water discharge or with the collected solids. Over time, the mercury in the water typically absorbs to the non-magnetic solids. Pre-TMDL research and testing evaluated scrubber solids removal as a method of mercury reduction (Reference (21)).

At HTC, the mercury captured by the existing wet scrubbers proceeds to the scrubber solids sump. This sump contains water from the scrubber sprays and scrubber solids (particulate captured by the scrubbers). The scrubber slurry (scrubber solids and water) is recycled back to the concentrator where it is used in the grinding mills. After grinding, the material is processed through the concentrator circuit including the magnetic separators with a portion returning to the pellet plant to form greenballs via the concentrate and the other portion being sent to the tailings basin. Since most of the mercury in the scrubber slurry is bound to non-magnetic particles, the vast majority of the captured mercury is already being removed to the tailings basin where it is permanently sequestered.

Routing scrubber solids to the concentrator is uncommon in the taconite industry. Most taconite processing facilities recycle scrubber solids back to a concentrate thickener and therefore, do not pass the scrubber slurry through magnetic separation. At HTC, scrubber solids are recycled back to the concentrator to reclaim iron units within the scrubber solids while rejecting the non-magnetic scrubber solids to the tailings basin.

The Pre-TMDL research testing for HTC indicated that 90 – 95% of the captured mercury is eliminated from their process lines (Reference (22)).

HTC conducted a two-phase ACI test in 2016. The first phase returned the scrubber solids to the concentrator as normal. The second phase routed the scrubber solids to the tailings basin. The total mercury reduction did not change when all scrubber solids were sent to the tailings basin as compared to normal plant operations as described above (Reference (17)).

HTC conducted process sampling in 2018 to estimate how much of a reduction in mercury emissions is achievable by redirecting the scrubber slurry from all three indurating furnace lines directly to the tailings basin (Reference (23)). The samples demonstrate that under existing conditions, the scrubber slurry only contains approximately 17.4 pounds of mercury per year from the existing wet scrubbers. Each furnace line’s scrubbers use a total of 1500 gallons per minute (gpm) or more of water, which reports to the scrubber sump. Only 0.04% of the scrubber slurry is solids and only 26% of the solids are magnetic. The samples show that mercury binds more with the nonmagnetic material than the magnetic material. Considering all these factors, only 2% of the mercury from the scrubber slurry would return to the pellet plant to form greenballs and be emitted through the indurating furnace stacks. HTC would reduce total mercury emissions by less than one pound per year by sending the scrubber slurry directly to the tailings basin from all three indurating furnaces. In addition, this study confirmed earlier Pre-TMDL research which showed that HTC already significantly reduces mercury emissions by routing the scrubber slurry back to the concentrator and wasting non-magnetic particles to the tailings basin.

The pre-TMDL research, 2016 ACI testing, and 2018 sampling indicate that routing the scrubber slurry directly to the tailings basin would provide little to no reduction in mercury emissions from the indurating furnaces. HTC does not consider mercury capture by existing wet scrubbers with scrubber solids removal to provide any additional mercury reduction potential. Therefore, this technology was not evaluated throughout the remainder of the BAMRT analysis.

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 (21)). Therefore, in principle, increased mercury oxidation of the flue gas should result in an increased proportion of mercury that is captured by the existing wet scrubbers.

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 flue gas oxidation via introduction of halides and in-scrubber oxidation. HTC conducted additional halide injection testing in 2017 (Reference (18)).

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 HTC and other taconite processing facilities include:

- Sodium chloride (NaCl) addition to greenballs - This potential mercury reduction method was tested at HTC Line 3 and at UTAC Line 2 (Reference (24)). Both continuous mercury monitors (CMMs) and flue-gas absorbent-trap mercury speciation (FAMS) traps were placed on the stacks to measure the mercury concentration. It was assumed that the decrease in mercury concentration recorded by the monitor at the stack corresponded to the total mercury reduction. Injection rates were 0.5 and 1 lb/long ton of greenballs.

- NaCl injection to preheat zone - This potential mercury reduction method was tested at HTC Line 3 (Reference (24)). A CMM was used to monitor mercury stack emissions. It was assumed that the decrease in mercury concentration recorded by the monitor at the stack corresponded to the total mercury reduction. The NaCl injection rate tested was 50 lb/hr.

- Sodium bromide (NaBr) injection to greenballs - This potential mercury reduction method was tested at Minntac Line 3 (Reference (25)). 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 (24)). A CMM was used to monitor mercury stack emissions. It was assumed that the decrease in mercury concentration recorded by the monitor at the stack corresponded to the total mercury reduction. The NaBr injection rate tested was 50 lb/hr.

- Calcium chloride ($CaCl_2$) injection to preheat zone - This potential mercury reduction method was tested at HTC Line 3 (Reference (24)). A CMM was used to monitor mercury stack emissions. It was assumed that the decrease in mercury concentration recorded by the monitor at the stack corresponded to the total mercury reduction. The $CaCl_2$ injection rate tested was 50 lb/hr.

- Hydrogen bromide (HBr) injection to preheat zone - This potential mercury reduction method was tested at HTC during the recent halide injection testing in late 2017 (Reference (18)). The reduction in mercury emissions was determined using EPA Method 30B during screening trials. The injection rate was 2 gal/hr of HBr solution.

- HBr injection to the windbox exhaust - This potential mercury reduction method was tested at HTC during the recent halide injection testing in late 2017 (Reference (18)). The reduction in mercury emissions was determined using EPA Method 30B during screening trials. The injection rate was 2 gal/hr of HBr solution.

- Calcium bromide ($CaBr_2$) injection to preheat zone - This potential mercury reduction method was tested at HTC Line 3 and Minorca during the pre-TMDL research (References (24), (26)). A CMM was used to monitor mercury stack emissions. It was assumed that the decrease in mercury concentration recorded by the monitor at the stack corresponded to the total mercury reduction. The $CaBr_2$ injection rates tested were 50 lb/hr at HTC and 0.09 gpm at 48 wt% solution of $CaBr_2$ at Minorca. In addition, $CaBr_2$ was tested on Line 2 at HTC during the recent halide injection testing in late 2017 (Reference (18)). The reduction in mercury emissions was determined using EPA Method 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 long-term trial of 52 days. Mercury reductions were determined by comparing the baseline (no halide injection) and long-term injection Ontario Hydro stack tests (provides total and speciated mercury emission rates).

- $CaBr_2$ injection to the windbox exhaust - This potential mercury reduction method was tested at HTC during the recent halide injection testing in late 2017 (Reference (18)). The reduction in mercury emissions was determined using EPA Method 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 HTC) (Reference (26)). Of the evaluated chemicals, NaCl and $CaCl_2$ consistently resulted in less mercury reductions compared to brominated salts ($CaBr_2$, NaBr, and HBr). Of the brominated salts, $CaBr_2$ compared to NaBr achieved a higher reduction. $CaBr_2$ and HBr to the preheat zone achieved the highest mercury reductions for HTC (References (18), (24), (26)). Both $CaBr_2$ and HBr demonstrated about the same mercury reduction. However, HBr is a highly toxic chemical and 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.

HTC evaluated halide injection as a potential reduction technology under Step 2 (Section 4.2).

4.1.4.2 In-scrubber Oxidation

In-scrubber oxidation consists of adding oxidizing chemicals directly to the scrubber water (rather than to the furnace 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. 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 (24)). H_2O_2 was not further developed or tested again for the taconite processing industry. Therefore, HTC does not consider the addition of H_2O_2 to scrubber water 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 (27)). Therefore, HTC does not consider the addition of DEDTC to scrubber water 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 (24)).

- $NaClO_2$ Testing at Minntac: Minntac added $NaClO_2$ to their wet scrubber on Line 3. Minntac used CMMs to determine a reduction efficiency. Details for the Minntac test are not available, but the test only saw a minimal reduction in mercury emissions in the stack gas. It was postulated in the Pre-TMDL research report "On the Measurement of Stack Emissions at Taconite Processing Plants" (Reference (25)) that the oxidant addition appeared to interfere with the particulate's ability to adsorb mercury.

- $NaClO_2$ Testing at Minorca: Minorca added $NaClO_2$ to their wet scrubber water. Minorca used CMMs to determine a reduction efficiency. Mercury emissions actually increased during this test and decreased back to baseline after injection ceased (Reference (28)).

As demonstrated by the testing 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 reduction technology for HTC. Therefore, in-scrubber oxidation was not evaluated throughout the remainder of the BAMRT analysis.

4.1.4.3 HEDT

HEDT is an Energy & Environmental Research Center (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 (29)). This technology was tested during the Pre-TMDL research.

This technology was further evaluated as a potential reduction technology for HTC under Step 2 (Section 4.2).

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 (see above discussions).

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 (30)). 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 scrubbers, if this method were applied at the full scale. Additional evaluations of this injection method were ceased because adding carbon to the greenballs impaired pellet quality by decreasing the compression strength of the fired pellet (Reference (31)).

- Preheat zone - Minntac's Line 3 was used to test PAC and brominated PAC injection into the furnace preheat zone (Reference (27)). 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. Note, results from injection PAC to the preheat zone at Minntac are not directly applicable to HTC because Minntac operates a grate-kiln furnace as opposed to HTC's straight-grate design. One key difference is that straight-grates lack preheat fans.

- Flue gas - This potential mercury reduction method was tested during Phases I and II (References (32), (33)). Note, straight-grate type furnaces (e.g. HTC and Minorca) only injected PAC into the windbox exhaust because it contains most of the mercury leaving the furnace. 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 - 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 existing wet scrubbers. HTC conducted an additional long-term test of this injection location in late 2016.

Brominated PACs achieved a greater reduction in mercury (Reference (32)). Therefore, all subsequent testing was with brominated PACs.

ACI increases the particulate loading at the wet scrubbers. HTC was not out of compliance with permit limits during ACI testing. However, higher filterable particulate concentrations were observed in the furnace stacks. This technology was further evaluated as a potential reduction technology for HTC under Step 2 (Section 4.2).

4.1.5.2 ACI with Baghouse (Replaces Existing Wet Scrubbers)

As discussed above, ACI can adsorb elemental and oxidized mercury from the flue gas to form mercury bound to particulates. However, smaller and less dense (i.e., PAC as opposed to iron particles) particles are less likely to be captured by the existing wet scrubbers. Therefore, smaller PAC particles with mercury adsorbed to it can be emitted as particulate-bound mercury. To address this issue, a baghouse can replace the existing wet scrubbers to provide increased particulate control. The baghouse cannot be installed downstream of the existing wet scrubbers because the moisture content of the flue gas would wet the bags and quickly plug the system. The net effect of installing a baghouse is to increase the capture efficiency of filterable particulates (i.e. PAC and process dust) and thereby increase the overall mercury reduction of ACI.

A study from Phase I, *Project 4: Evaluation of a Slipstream Baghouse for the Taconite Industry* (Reference (34)) evaluated the possibility of using a fabric filter to capture the PAC. CMMs and sorbent traps were used to measure mercury reduction efficiency. PAC injection rates tested were 1.1, 2, and 2.2 lb/MMacf. Brominated PAC injection rates tested were 0.6 and 1.1 lb/MMacf.

There is a significant pressure drop when using a baghouse, which may require the installation of extra fans. The furnace exhaust flow rate is considerably large, further complicating the issue. This technology was further evaluated as a potential reduction technology for HTC under Step 2 (Section 4.2).

4.1.5.3 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 to a rate that would decrease the amount of particulate emitted out of the stacks and minimize the adverse environmental impacts associated with increased particulate-bound mercury emissions. HTC's 2016 long-term test of this technology (Reference (17)) injected PAC at a lower rate compared to the Phase II research. This technology was further evaluated as a potential reduction technology for HTC under Step 2 (Section 4.2).

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 production. Considerable facility-specific mechanical upgrades would be needed in order to design and install the required equipment to be able to overcome the resistance through the adsorption beds. In addition to the resistance of the beds, the space constraints at HTC present significant installation challenges due to the large footprint required. 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, HTC would need to utilize a baghouse that replaces the existing wet scrubbers prior to the fixed carbon beds to optimize the filterable particulate control and avoid issues with waste gas that is water-saturated.

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 (35)), 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 1 work, additional testing was completed at HTC, Minorca, and UTAC; see "*Developing Cost-Effective Solutions to Reduce Mercury Emissions from Minnesota Taconite Plants*" (Reference (36)) to further review the potential of a fixed bed carbon adsorption system. 2012 results indicated a high level (>75%) of control was achievable based on small scale slip stream testing. This technology was further evaluated as a potential reduction technology for HTC under Step 2 (Section 4.2).

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™ 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™ 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: Minntac – Line 7, Minorca, 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. Water was used in the system to spray the GORE™ modules to remove particulate and any other build-up.

The taconite processing facilities produce either standard or flux pellets (limestone added to the greenballs). The additional limestone for flux pellet production absorbs SO_2 and results in lower SO_2 emissions from the furnace. The GORE™ 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 (37)). Minorca burns inherently low sulfur natural gas in its indurating furnace and was producing flux pellets (SO_2 scrubbing) during the GORE™ pilot testing. In contrast, UTAC and Minntac both burn other higher-sulfur fuels, such as coal, and were producing standard pellets during the GORE™ pilot testing. HTC operates similar to Minorca because the furnaces combust low sulfur natural gas fuel.

The long-term effects of increased build-up could cause unacceptable differential pressure increases across the GORE™ unit, thereby reducing indurating airflow and jeopardizing pellet quality and production. The wash water influent mercury concentrations ranged from non-detect to approximately 10 ng/L, and the results of mercury concentration in the GORE™ membrane wash water effluent ranged from 2,460 ng/L – 30,300 ng/L. 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™ 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.

Industry pilot testing used GORE™ GEN2 modules. GORE™ recently released GEN3 modules, which have a higher control efficiency per module, thus reducing the overall footprint and capital cost. The taconite industry has been in discussions with GORE™ since pilot testing in 2015 to discuss follow up questions and observed concerns and if concerns observed during pilot testing (wash water contamination, plugging, pressure drop, etc.) would be addressed with the latest developments. In September 2018, the taconite industry met with GORE™ 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.

In addition, GORE™ representatives were only aware of one full-scale commercial installation of the GEN3 modules at the time of the meeting. This application was for a utility boiler and is not representative of HTC's waste gas conditions. Therefore, GORE™ is not a widely accepted technology across other industries. In addition, there is no proof that a full-scale installation would be appropriate for HTC because of the uncertainty surrounding the allowable particulate loading to the GORE™ modules. Particulate plugging was a concern when the industry conducted pilot testing and GORE™ could not provide a maximum allowable particulate concentration.

Even with the concerns listed above, and in order to evaluate as many technologies as possible, HTC conservatively considered GORE™ to be a potential reduction technology, which was further evaluated under Step 2 (Section 4.2).

4.1.8 Monolithic Honeycomb Adsorption

Monolithic honeycomb adsorption was never tested at a taconite facility, but was previously reviewed 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.

HTC evaluated monolithic honeycomb adsorption as a potential reduction technology, Step 2 (Section 4.2).

4.2 Step 2 – Determine if the Technologies are Commercially Available

Commercial availability, a component of the "technically feasible" adaptive management criterion, was determined by contacting vendors to determine whether the materials needed to implement each technology were available for purchase at the time this analysis 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?	Continue to Next Step?
Mercury oxidation for capture by existing wet scrubbers	Halide injection	Yes	Yes
	HEDT	No	No
Activated carbon injection	With existing wet scrubbers	Yes	Yes
	With baghouse	Yes	Yes
	At lower injection rate with existing wet scrubbers	Yes	Yes
Fixed carbon bed		Yes	Yes
GORE^{TM}		Yes	Yes
Monolithic Honeycomb Adsorption		No	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 HEDT

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 as of June 2018. In addition, testing showed that no total mercury reduction was achieved, indicating that this technology may not even be an effective means to reduce mercury emissions (Reference (29)). 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

HTC operates according to an ISO 9001 quality management system to ensure that pellets meet quality standards that are within a defined acceptable range according to the customer's pellet specifications. Based on information available to date, none of the remaining reduction technologies are anticipated to materially affect pellet quality (according to HTC's ISO 9001 quality management system) or HTC's production. Therefore, for the purpose of the BAMRT 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. Only halide injection was thought to have the potential to create acceleration of corrosion in the processing equipment. 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.

During the Pre-TMDL research, the EERC 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 was titled *Assessment of Potential Corrosion Induced by Bromine Species used for Mercury Reduction in a Taconite Facility* (Reference (38)). The short term small scale testing showed that 40 ppm HBr in a simulated taconite process flue gas environment caused slight surface corrosion. However, bromine deposition and losses of Fe, Ni, and Cr were mainly confined to the surface. Further, 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 effects 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.

Potential corrosion effects of halide injection were further studied during recent HTC testing in 2017. The results from the corrosion testing show significantly increased corrosion of the grate bars and furnace ducting coupons (Reference (18)). While the tests showed a higher rate of corrosion compared to baseline conditions, no corrosion could be seen with the naked eye. The higher rates of corrosion are an operational concern with long-term halide injection; however, increased maintenance could mitigate the effects. In addition, the furnace, ducting, and pollution-control equipment were visually inspected for signs of additional buildup, wear, and corrosion and these potential effects of halide injection use were not apparent.

Long-term analysis on potential corrosion effects could not be conducted. For the purpose of this evaluation, halide injection was not eliminated based on excessive corrosion potential beyond an acceptable threshold, so as to maximize the number of technologies evaluated. This threshold is pursuant to existing preventative maintenance practices (i.e. does the technology significantly increase the required preventative maintenance to plant equipment). HTC reserves the right to revisit this evaluation and subsequent resulting conclusion if new information becomes available in the future. 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

Reduction technologies may have limited environmental impacts (i.e., additional wastewater treatment, solid waste disposal, etc.). These impacts are not considered unacceptable because they could be reasonably mitigated with well-established management techniques. However, the TMDL sought to reduce mercury concentrations in fish tissue (Reference (2)). Therefore, any technology that results in environmental impacts contrary to this goal is considered unacceptable. A summary of the results of Step 5 are summarized in Table 4-3.

Table 4-3 Environmental Impacts of Remaining Mercury Emissions Reduction Technologies

Reduction Technology		Unacceptable Environmental Impacts?	Continue to Next Step?
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
	At lower injection rate with existing wet scrubbers	Yes	No – See Section 4.5.2
Fixed carbon bed		No	Yes
GORE^{TM}		No	Yes

Halide injection, ACI with existing wet scrubbers, and ACI at a lower injection rate with existing wet scrubbers was determined to pose unacceptable environmental impacts for the reasons discussed in detail below.

4.5.1 Halide Injection

HTC was able to achieve a reduction in total mercury emissions during its most recent halide injection testing at a reduced injection rate compared to the Pre-TMDL research. Stack testing during halide injection demonstrated that both oxidized and particulate-bound mercury emissions increased over baseline conditions as shown in Table 4-4. This is because halide injection significantly altered the speciation of particulate, elemental, and oxidized mercury, which results in unacceptable environmental impacts contrary to the goals of the TMDL.

Table 4-4 Mercury Speciated Emission Rates During HTC Halide Injection Testing (Reference (18))

Test	Total Mercury	Particulate	Elemental	Oxidized
Baseline, lb/year (% of total)(1)	213.0	1.0 (0.5%)	185.9 (87.3%)	25.1 (11.8%)
Long-term halide test, lb/year (% of total) (1)	142.0	10.0 (7.1%)	29.2 (20.6%)	102.3 (72.1%)
Increase or decrease, lb/year **(% of baseline)** (1)	-71.0 **(-33.3%)**	9.0 **(860.0%)**	-156.6 **(-84.3%)**	77.3 **(308.3%)**

(1) Calculations apply the mercury speciation profiles from HTC's halide injection testing report to the baseline emission rate from Section 3 for all three furnaces (Reference (18)). Speciation percentages during baseline and long-term halide injection testing may not add up to 100% exactly due to rounding.

Third party technical experts reviewed the impact of halide injection on local mercury deposition (Local Deposition Evaluation, Reference (19)). 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 with the technology's decreased total mercury emissions (Reference (19)). 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 (19)). 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 (-156.6 lb/yr) was greater than the increase in oxidized mercury emissions (+77.3 lb/yr). Table 2 of the Local Deposition Evaluation (Reference (19)) demonstrates that even a small increase in oxidized mercury with a corresponding decrease in elemental 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 (19)).

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 (39)) and in New England (References (40), (41)). In the evaluation by the Florida Department of Environmental Protection (Reference (39)), 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 (41)). Associated with increased local deposition of mercury, fish tissue mercury concentrations were elevated in nearby water bodies (References (39), (41)). 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 (19)) demonstrates that even a small increase in oxidized mercury emissions can increase local deposition of mercury and loading to the environment.

Since the lower halide injection rate caused unacceptable environmental impacts (increased local deposition), HTC expects higher halide injection rates (similar to those used during the pre-TMDL testing) would yield similar or more severe environmental impacts.

In addition, the increase in particulate-bound mercury during 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 (19)). Table 2 of the Local Deposition Evaluation demonstrates that a small increase in particulate mercury speciation may increase local deposition, which has the potential to increase mercury concentrations in fish tissue (Reference (19)).

The decrease in elemental mercury from this technology would not benefit Minnesota's environment considering the great distances that the elemental mercury can travel and its atmospheric lifetime of several months to a year (Reference (19)). Halide injection increases oxidized and particulate mercury emissions, which increases local mercury deposition. This directly contradicts the purpose of the TMDL to reduce mercury concentrations in fish tissue in Minnesota. Halide injection causes unacceptable environmental impacts and was therefore eliminated from further consideration.

4.5.2 ACI with Existing Wet Scrubbers and ACI at a Lower Injection Rate with Existing Wet Scrubbers

HTC observed a reduction in total mercury emissions during their most recent ACI testing at a reduced High Temperature Brominated Powdered Activated Carbon (HPAC) injection rate compared to Phase II testing. However, particulate-bound mercury emissions increased significantly at the stack during the test compared to baseline conditions as shown in Table 4-5.

Table 4-5 Mercury Emission Rates During HTC ACI Testing (Reference (17))

Test	Total Hg	Particulate	Elemental	Oxidized
Baseline, lb/year (% of total)(1)	213.0	0.4 (0.2%)	190.9 (89.6%)	21.7 (10.2%)
Long-term ACI test, lb/year (% of total)(1, 2)	127.6	39.8 (31.2%)	81.3 (63.7%)	6.5 (5.1%)
Increase or decrease, lb/year **(% of baseline)**(1)	-85.4 **(-40.1%)**	39.4 **(9075.0%)**	-109.5 **(-57.4%)**	-15.2 **(-70.0%)**

(1) Calculations apply the mercury speciation profiles from HTC's ACI testing report to the baseline emission rate from Section 3 for all three furnaces (Reference (17)).

(2) Average of long-term stack tests A and B (Reference (17)).

As described in Section 4.5.1, particulate-bound mercury has a higher likelihood of being deposited locally compared to elemental mercury (Reference (19)). Particulate-bound mercury is generally thought to be deposited in a range of 30-50 miles from the point of emission to the atmosphere, compared to elemental mercury "that can readily travel for hundreds to thousands of miles, depending upon wind patterns, prior to deposition" (Reference (7)). Increased local deposition of particulate mercury has the potential to increase mercury concentrations in fish tissue (Reference (19)). The increase in particulate-bound mercury emissions is an unacceptable environmental impact.

Since the environmental impacts at a reduced PAC injection rate are considered to be unacceptable, then the increased PAC injection rates used during the Phase II testing would yield similar or more severe environmental impacts. HTC does not have particulate mercury speciation data from Phase II testing. However, HTC found that the filterable particulate concentration exiting the stack increased significantly during Phase II ACI testing (Reference (33)).

The increase in particulate-bound mercury with ACI is due to a portion of the PAC passing through the existing wet scrubbers. The PAC that is not captured by the existing wet scrubbers contains adsorbed mercury from the furnace waste gas. As noted by the DNR's review of the Phase II report (Reference (42)), ACI increases the particulate loading to the existing wet scrubbers and mercury bound to PAC particles was slipping past the existing 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." As noted above, this an unacceptable environmental impact because particulate-bound mercury emissions are more likely to be deposited locally compared to elemental mercury, similar to oxidized mercury (Reference (19)).

The potential for increased local mercury deposition is an unacceptable environmental impact. This is because it directly contradicts the purpose of the TMDL. Therefore, ACI and lower injection rate ACI with the existing wet scrubbers were eliminated from further consideration.

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

Table 4-6 summarizes the control effectiveness of the remaining mercury emissions reduction technologies.

Table 4-6 Control Effectiveness of Remaining Mercury Emissions Reduction Technologies

Reduction Technology		Total Mercury Control Efficiency	Continue to Next Step?
Activated carbon injection	With baghouse	88.1%(1)	Yes
Fixed carbon bed		99%(2)	Yes
GORE™		72%(3)	Yes

(1) Slip stream baghouse testing at Keetac (Reference (34)) indicated that brominated PAC could reduce mercury emissions by 88.1%. HTC has not tested this technology, but will assume for the BAMRT analysis that an 88.1% reduction can be achieved.

(2) Vendor estimated control efficiency and most literature for fixed bed control efficiency values reference a control efficiency greater than 99%. HTC has not tested this technology, but will assume for the BAMRT analysis that a 99% reduction can be achieved.

(3) GORE was not tested at HTC. Testing at Minntac, UTAC, and Minorca indicated that a 72% reduction per the rule may be achievable (Reference (37)). HTC will assume that this technology can reduce mercury emissions by 72%.

HTC assumed all remaining mercury emissions reduction technologies listed in Table 4-6 can meet a consistent 72% reduction in mercury emissions and proceeded to the next step.

4.7 Step 7 – Determine if the Technology is Cost Effective

ACI with a baghouse, fixed carbon beds, and GORE^{TM} 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" Maximum Achievable Control Technology (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 4-7. 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 emission reductions.

Other industries were researched in order to determine an acceptable cost effectiveness threshold. 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 (43)). 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 (44)).

Table 4-7 Cost Effectiveness Considerations

Cost Effectiveness ($ per lb Hg)	Accepted by EPA	Regulation	Standard Considered
$1,300 (Reference (45))	Proposed	Gold Mining MACT 40 CFR 63 Subpart 7E	Beyond the floor, refrigeration unit (or condenser) and a carbon adsorber on autoclaves
$2,000 (Reference (46))	Yes	Portland Cement MACT 40 CFR 63 Subpart LLL	Recalculated floor from 58 to 55 lb Hg/MMtons clinker
$7,100 (Reference (44))	Yes	Ferroalloys Production MACT 40 CFR 63 Subpart XXX	Beyond the floor, brominated ACI and polishing baghouse; FeMn furnace operating 100% of year
$13,600 (Reference (44))	Yes	Ferroalloys Production MACT 40 CFR 63 Subpart XXX	Beyond the floor, brominated ACI and polishing baghouse; FeMn furnace operating 50% of year
$20,000 (Reference (47))	Proposed	Mercury Cell Chlor-Alkali Plant MACT 40 CFR 63 Subpart IIIII	Non-mercury technology option
$27,016 (Reference (48))	Yes	Mercury and Air Toxics Standards (MATS) (existing Electrical Generating Units [EGUs]) 40 CFR 63 Subpart UUUUU	Beyond the floor standard of 4 lb Hg/ TBtu using brominated ACI
$44,000 (Reference (45))	No	Gold Mining MACT 40 CFR 63 Subpart 7E	Beyond the floor, non-carbon concentrate process with second carbon adsorber in series on melt furnaces
$74,000 (Reference (49))	No	Brick and Structural Clay MACT 40 CFR 63 Subpart JJJJJ	Beyond the floor, make existing units meet limits for new units
$14,000 - $127,000 (Reference (50))	No	Taconite MACT 40 CFR 63 Subpart RRRRR	Beyond the floor, wet scrubber wasting
$61,000 - $183,500 (Reference (51))	No	MATS (new EGUs) 40 CFR 63 Subpart UUUUU	Beyond the floor, hypothetical new plant with ACI and fabric filter
$80,000 - $100,000 (Reference (52))	No	Sewage Sludge Incinerator MACT	Beyond the floor, afterburners, ACI, and fabric filters
$100,000 (Reference (45))	No	Gold Mining MACT 40 CFR 63 Subpart 7E	Beyond the floor, carbon process with second carbon adsorber in series on autoclaves
$420,000-540,000 (Reference (53))	No	Portland Cement MACT 40 CFR 63 Subpart LLL	Beyond the floor, additional ACI system

Following EPA's approach for evaluating the economic acceptability of mercury control options, the taconite processing industry reviewed the cost effectiveness of control options found to be acceptable in other regulations; see the table above with cost effectiveness values from federal MACT regulations. The taconite processing industry considers $7,100 per pound of mercury reduced to be an acceptable cost effectiveness threshold for mercury control, 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 small 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 control options for 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 control option (ACI retrofit).

From the review of MACT standards (Table 4-7), 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 control 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 Emissions Reduction Technologies

The annualized cost includes both capital and operating costs. Economic effects were analyzed using the procedures found in the EPA Air Pollution Control Cost Manual (CCM, References (54), (55)). 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 4-8 details the expected costs associated with the installation of the above mercury emissions reduction technologies for installations on all three furnaces. Equipment design was based on mercury control efficiencies outlined in Table 4-6, baseline values determined in Section 3, vendor estimates, and the CCM (References (54), (55)). 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, unless provided by a vendor. Operating costs were based on 100% utilization and annual operating hours of 7,690 hours. Operating costs of consumable materials, such as electricity, water, and chemicals, were established based on the CCM and engineering experience. The detailed cost analysis and design assumptions are provided in Appendix B.

Due to space considerations, a 60% markup of the total capital investment (i.e. 1.6 retrofit factor) is 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 furnaces are congested, or the areas surrounding the building support frequent vehicle traffic or crane access for maintenance. The structural design of the existing building would not support additional equipment on the roof. Additionally, the technologies evaluated in this section are complex and increase the associated installation costs (e.g. ancillary equipment requirements, piping, structural, electrical, demolition, etc.). Using a 1.6 retrofit factor is appropriate based on previous project examples. When Cleveland Cliffs was evaluating SO_2 controls for the BART cost analyses in 2006, a 1.6 retrofit factor was used (Reference (56)). The evaluated technologies for mercury control have a similar level of complexity. Therefore, the retrofit factor is still appropriate. 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 (54), (55)). Retrofits can impose additional costs to "shoe-horn" equipment in existing plant space, which is true for HTC.

A site-specific estimate of site preparation and ductwork was added to arrive at the total installed cost. Finally, based on the scale of the proposed equipment installations, it was assumed that it would take 14 more days than a typical outage to tie-in the new equipment and resume normal operations. The cost calculations account for the lost production for this time. The conservative estimate is based on Barr's experience on other projects.

A 30% contingency was applied 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, with expected accuracy ranging from -30% to +50% to account for unknowns without detailed engineering (Reference (57)). Note, the CCM does not consider contingencies to be the same as uncertainty or retrofit factor costs and are treated separately (References (54), (55)).

For ACI with baghouse and Fixed Carbon Beds, the existing wet scrubbers would 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, HTC would need to utilize a baghouse that replaces the existing wet scrubbers prior to the fixed carbon beds to optimize the filterable particulate control and avoid issues with waste gas that is water-saturated. In addition, the baghouses and fixed carbon beds could not be located in the current wet scrubber location due to space constraints.

The existing wet scrubbers provide some level of SO_2 control and thus removing them would cause HTC to be out of compliance with their existing regulatory limits. Therefore, HTC accounted for the cost of new

SO_2 controls (dry sorbent injection) to maintain the current level of SO_2 removal achieved by the existing wet scrubbers (does not apply to GORE^{TM}).

Finally, GORE^{TM} cannot be retrofitted in or near the existing stacks so it would require separate buildings. GORE^{TM} also requires the installation of a wastewater treatment plant to remove sulfates and mercury from the module wash water (Refer to Section 4.1.7). This wash water must be treated to manufacturer specifications to recycle and reuse the module wash water.

Table 4-8 Cost Effectiveness of Mercury Emissions Reduction Technologies

Mercury Emissions Reduction Technology	Total Capital Investment with Retrofit Factor ($)	Total Annual Cost ($/yr)	Annualized Pollution Control Cost ($/lb)	Continue to Next Step?
ACI with Baghouse	$154,900,000	$24,240,000	$129,200	No
Fixed Carbon Bed	$233,200,000	$35,020,000	$166,100	No
GORE^{TM}	$210,100,000	$26,650,000	$173,800	No

The cost effectiveness of the remaining reduction technologies varies from $129,200 to $173,800 per pound of mercury removed. The anticipated costs listed above greatly exceed the $7,100 per pound of mercury removed threshold discussed in Section 4.7.1. Therefore, the remaining technologies were eliminated from further consideration.

4.8 Step 8 – Determination of BAMRT for HTC

After evaluating all potentially available mercury emissions reduction technologies against the criteria outlined in Section 4, no technology satisfied all of the first seven steps in the BAMRT process to evaluate technologies capable of achieving a 72% reduction. ACI with a baghouse, fixed carbon beds, and GORE^{TM} were all eliminated from consideration at Step 7 because they exceeded reasonable cost effectiveness thresholds. All other identified technologies were eliminated from further consideration based on the other adaptive management criteria or the unacceptable environmental impacts criterion. HTC further evaluated other mercury reduction opportunities in Section 5, below.

5 BAMRT Alternative Analysis

A suitable technology was not identified that meets the BAMRT criteria while also reducing emissions by 72% of the baseline as required by Minn. R. 7007.0502, subp. 5(A)(1). Therefore, HTC proceeded to evaluate if any mercury reduction technologies could achieve an alternate removal rate, according to Minn. R. 7007.0502, subp. 5(A)(2).

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.*

No technology was determined to satisfy BAMRT criteria, and no technologies met the criteria for further consideration as a BAMRT Alternative consistent with the MPCA’s Ferrous Mercury Reduction Plan Form, Item 3(a). See Figure 4-1 in Section 4 for details on the BAMRT process flow.

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: Hibbing Taconite Company

1.b. AQ facility ID number: 13700061

1.c. Facility contact for this reduction plan: Julie Lucas

1.d. Agency Interest ID number: 1146

1.e. Facility contact email address: Julie.Lucas@clevelandcliffs.com

1.f. Facility contact phone number: (218) 262-6856

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.

No technology was determined to satisfy the criteria outlined in Minn. R. 7007.0502, subp. 5(A)(2). Therefore, no technologies met the criteria for further consideration as a BAMRT Alternative.

Refer to Section 5 of the attached Best Available Mercury Reduction Technology Analysis.

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.

N/A - no technologies met the criteria for further consideration as a BAMRT Alternative.

Refer to Section 5 of the attached Best Available Mercury Reduction Technology Analysis.

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

N/A - no technologies met the criteria for further consideration as a BAMRT Alternative.

Refer to Section 5 of the attached Best Available Mercury Reduction Technology Analysis.

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.

N/A - no technologies met the criteria for further consideration as a BAMRT Alternative.

Refer to Section 5 of the attached Best Available Mercury Reduction Technology Analysis.

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.

N/A - no technologies met the criteria for further consideration as a BAMRT Alternative.

Refer to Section 5 of the attached Best Available Mercury Reduction Technology Analysis.

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

N/A - no technologies met the criteria for further consideration as a BAMRT Alternative.

Refer to Section 5 of the attached Best Available Mercury Reduction Technology Analysis.

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

HTC's Baseline Emissions = 213 lb Hg/yr

Refer to Section MERP-1.1 of the attached Mercury Emissions Reduction Plan.

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

Estimated Emissions = 213 lb Hg/yr

Percent Reduction = N/A

No reduction technology was determined to be technically achievable to reduce mercury emissions.

Refer to Section MERP-1.1 of the attached Mercury Emissions Reduction Plan.

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 (control device, work practice, etc.)**	**Reduction, control efficiency, emission limit, operating limit, or work practice* (indicate units, i.e., lb. hg/ton material, % control)**	**Describe element in detail (include manufacturer's data** as applicable)**
Facility-wide	Technology review and BAMRT analysis, as needed	TBD	See Section MERP-1.2.1 of the attached 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 MERP-1.2 of the attached 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)
Facility-wide	Literature review and/or vendor screening with BAMRT analysis	N/A - HTC will conduct a literature review and/or vendor screening between May 1, 2020 and July 31, 2020. HTC will revise and resubmit the MERP by June 30, 2022 if a new, viable technology is identified through the BAMRT analysis. Refer to Section MERP-1.3 of the attached 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**
Facility-wide	2.632 x 10-5 lb Hg / long ton of pellet	Average emission rate from mercury emission testing conducted in 2016 and 2017 in accordance with EPA approved test methods.	213 lb Hg / yr	Mercury emission testing conducted in 2016 and 2017 in accordance with EPA approved test methods
Refer to Section MERP-1.4.1 of the attached 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).

This is not applicable with the current proposed alternative action. HTC would revise this section if any reduction technologies are found to be technically achievable in the future.

HTC addressed the requirements of Minn. R. 7007.0502, subp. 5(A)(2)(c) in Section MERP-1.5.1 of the attached Mercury Emissions Reduction Plan.

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 020, 021, or 022	NA	NA	Mercury stack emissions	Periodic stack testing	N/A	One furnace line every 5 years	Keep stack test reports onsite for 5 years	Approach is consistent with Minn. R. 7019.3050(E)(5)
Refer to Section MERP-1.5.2 of the attached Mercury Emissions Reduction Plan.								

Additional Discussion:

Refer to Section MERP-1.5.2 of the attached Mercury Emissions Reduction Plan.

.

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:

HTC determined that it is not appropriate to use CMMs for continuous compliance determination (neither the sorbent tube system nor a CMM). For periodic testing, Method 30B remains an appropriate test method.

Refer to Section MERP-1.5.3 of the attached Mercury Emissions Reduction Plan.

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:

None of the potentially available mercury emissions reduction technologies are technically achievable and thus, are not required to be included in the facility's air permit. However, HTC proposes to enter into an enforceable compliance agreement to meet the proposed action and associated deadlines described in Sections MERP-1.2.1 and MERP-1.3. Should other identified new technologies become technically achievable in the future, HTC will submit a regulatory permit application as deemed appropriate.

Refer to Section MERP-1.6 of the attached Mercury Emissions Reduction Plan.

9. Additional information

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

Refer to the BAMRT analysis for additional information. The BAMRT analysis was used as the basis for development of HTC's MERP.

Refer to Section MERP-1.7 of the attached Mercury Emissions Reduction Plan.

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

Print name: ______________________

Title: ______________ Date ______________

Signature: ______________________

Phone: ______________ Fax: ______________

Co-permittee responsible official (if applicable)

Print name: ______________________

Title: ______________ Date: ______________

Signature: ______________________

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

Print name: Edward LaTendresse

Title: General Manager Date 12/19/18

Signature: Edward LaTend

Phone: (218) 262-5977 Fax: N/A

Co-permittee responsible official (if applicable)

Print name: N/A

Title: ______________ Date: ______________

Signature: ______________________

Phone: ______________ Fax: ______________

MERP-1 Mercury Emissions Reduction Plan (MERP)

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 was used as the basis for the development of HTC's MERP. HTC determined that none of the proposed reduction technologies were technically achievable or without unacceptable environmental impacts in the BAMRT analysis. HTC proposes the following alternative action in the MERP:

> HTC 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 Technology) 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 Technology by using the same methodology as employed

in the 2018 BAMRT analysis. If no New Technology is identified, HTC will submit notification to the MPCA that the review has been completed and no new technologies were identified.

MERP-1.1 Annual Mercury Emissions and Emission Reductions under BAMRT Alternative Analysis (MPCA Form items 3b-c)

The MPCA's Ferrous Mercury Reduction Plan Form, items 3b and 3c requests 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. Table MERP-1 contains HTC's emissions before and after employing the proposed alternative control strategy.

Table MERP-1 Mercury Emissions and Emission Reductions under BAMRT Alternative Analysis

Emission Unit	Baseline Emissions lb/yr(1)	Percent Reduction(2)	Estimated Emissions lb/yr
EU 020	71	NA	71
EU 021	71	NA	71
EU 022	71	NA	71
TOTAL	**213**	NA	**213**

(1) It was assumed that the entire baseline emission rate is spread evenly across all three furnaces.
(2) No reduction technology was determined to be technically achievable to reduce mercury emissions.

MERP-1.2 Description of Mercury Reduction Action (MPCA Form item 4)

The MPCA's Ferrous Mercury Reduction Plan Form, item 4 states the following and HTC's associated responses are presented in Table MERP-2:

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 MERP-2 Mercury Reduction Plan

Emission Unit	Reduction Element(1)	Reduction, control efficiency, emission limit, operating limit, or work practice(2)	Describe element in detail(3)
Facility-wide	Technology review and BAMRT analysis as needed	TBD	See Section MERP-1.2.1

(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

MERP-1.2.1 Literature Review and/or Vendor Screening with BAMRT Analysis

HTC 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 Technology) have been commercially developed and put into use in other industries in the United States. If any New Technology has been commercially developed and put into use, HTC will determine if on-site testing is needed to further investigate the suitability and performance of only the New Technology. The results of the literature review, vendor screening, and/or on-site testing, if necessary, will be used to fully evaluate only the New Technology by using the same methodology as employed in the 2018 BAMRT analysis.

The New Technology BAMRT analysis will determine if the 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 analysis process will be used for any alternative reduction analysis.

MERP-1.3 Schedule (MPCA Form item 5)

The MPCA's Ferrous Mercury Reduction Plan Form, item 5 states the following and HTC's associated responses are presented in Table MERP-3:

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.

Table MERP-3 Schedule

Emission Unit	Reduction Element	Anticipated Installation date	Anticipated Startup date	Target Reduction Demonstration	Target Reduction Deadline	Anticipated Permit Application Submittal
Facility-wide	Literature review and/or vendor screening with BAMRT analysis	N/A - HTC will conduct a literature review and/or vendor screening between May 1, 2020 and July 31, 2020. HTC will revise and resubmit the MERP by June 30, 2022 if a new, viable technology is identified through the BAMRT analysis.				

MERP-1.4 Calculation Data (MPCA Form item 6)

The MPCA's Ferrous Mercury Reduction Plan Form, item 6 states the following:

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.

Refer to Appendix C for details.

MERP-1.4.1 Emission Factors (MPCA Form item 6a)

The MPCA's Ferrous Mercury Reduction Plan Form, item 6a states the following:

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).

The emission factor used to calculate the baseline mercury emission rate is 2.632 x 10-5 lb mercury per long ton of pellets (see Section 3 of the BAMRT analysis for details). The emission factor is the average emission rate from mercury emission testing conducted in 2016 and 2017 in accordance with EPA approved test methods.

MERP-1.5 Operation, Monitoring, and Recordkeeping Plan (MPCA Form item 7)

MERP-1.5.1 Operation and Optimization Plan (MPCA Form item 7a)

The MPCA's Ferrous Mercury Reduction Plan Form, item 7a states the following:

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)

This is not applicable with the current proposed alternative action. HTC would revise this section if any reduction technologies are found to be technically achievable in the future.

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. HTC already operates 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. HTC will continue to maintain the current control efficiency and demonstrate continued optimization through compliance with the air emission permit and associated compliance plans.

2. HTC 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, HTC's furnaces are natural gas-fired, which is inherently low in mercury emissions. The use of any alternative fuels would only increase mercury emissions from the furnace.
4. HTC mines taconite near its indurating furnace from controlled and limited mineral deposits. It is not feasible for HTC to consider an alternative ore feed. Additionally, the additives incorporated into the concentrate prior to the indurating furnace have an immaterial amount of mercury.

MERP-1.5.2 Proposed Monitoring and Recordkeeping (MPCA Form item 7b)

The MPCA's Ferrous Mercury Reduction Plan Form, item 7b states the following:

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).

HTC proposes to conduct stack testing once every five years using EPA approved test methods, consistent with Minn. R. 7019.3050(E)(5).

Table MERP-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
EU 020, 021, or 022	NA	NA	Mercury stack emissions	Periodic stack testing	One furnace line every 5 years	Keep stack test reports onsite for 5 years	Approach is consistent with Minn. R. 7019.3050(E)(5)

MERP-1.5.3 Evaluation of CEMS

The MPCA's Ferrous Mercury Reduction Plan Form, item 7c states the following:

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.

HTC used temporary extractive CMMs to monitor mercury reduction during the screening tests for various activated carbon types and injection rates during Phase II of the mercury reductions study in 2013 and during the pre-TMDL halide injection testing (References (26), (33)). Since the CMMs 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 CMMs to measure the particulate-bound mercury fraction. HTC used modified EPA Method 30B to compare and confirm results of the temporary extractive CMMs during Phase II testing (Reference (33)).

HTC has also used EPA Method 30B for mercury reduction screening during recent halide injection and low level ACI trials (References (17), (18)). HTC used Method 30B data to compare emissions while varying injection rates because of the ability to determine results on-site.

HTC determined that it is not appropriate to use CMMs (neither the sorbent tube system nor continuous extractive system) for the reasons listed below:

- **Appropriateness of monitoring frequency**
  - Minn. R. 7007.0502 and the 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 spikes. 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 spikes 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 affected 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 (58)) 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 affect 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).

MERP-1.6 MERP Enforceability (MPCA Form item 8)

The MPCA's Ferrous Mercury Reduction Plan Form, item 8 states the following:

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.

None of the potentially available mercury emissions reduction technologies are technically achievable and thus, are not required to be included in the facility's air permit. However, HTC proposes to enter into an enforceable compliance agreement to meet the proposed action and associated deadlines described in Sections MERP-1.2.1 and MERP-1.3. Should other identified new technologies become technically achievable in the future, HTC will submit a regulatory permit application as deemed appropriate.

MERP-1.7 Additional Information

The MPCA's Ferrous Mercury Reduction Plan Form, item 9 states the following:

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

Refer to the BAMRT analysis for additional information. The BAMRT analysis was used as the basis for development of HTC's MERP.

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Appendix A

Historical Mercury Reduction Research Reports

See Appendix A_HTC BAMRT_MERP FINAL File

Appendix B

Mercury Reduction Technology Control Cost Evaluation Workbook

Mercury Control Cost Effectiveness
Hibbing Taconite Company (HTC)
Table 1 - Cost Evaluation Summary for All Furnaces

Hg Control Technology Description

Technology Name		**Fixed Carbon Beds (includes baghouse)**	**GORE**	**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]	7,690	7,690	7,690
Notes on Technology				

Control Equipment Costs

Capital Costs				
Direct Capital Costs (DC)	[2]	$122,421,374	$106,933,085	$79,969,108
Indirect Capital Costs (IC)	[2]	$32,858,461	$30,077,059	$22,518,918
Total Capital Investment (TCI = DC + IC)	[2]	$155,279,835	$137,010,144	$102,488,025
Total Capital Investment (TCI = DC + IC) with Retrofit Factor	[2]	$233,225,828	$210,090,706	$154,855,315
Operating Costs				
Direct Operating Costs ($/year)	[3]	$5,575,992	$1,275,879	$4,853,544
Indirect Operating Costs ($/year)	[3]	$29,442,732	$25,370,772	$19,382,666
Total Annual Cost ($/year)	[4]	$35,018,724	$26,646,651	$24,236,210

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]	213	**FOR ALL FURNACES COMBINED**

Hg Control Efficiency (mass%)	[7]	99.00%	72.00%	88.10%
Controlled Hg Emission Rate (lb Hg/year)	[8]	2.13	59.64	25.35
Hg Mass Removed from Exhaust (lb Hg/year)	[9]	210.87	153.36	187.65
Hg Control Cost Effectiveness ($/lb Hg removed)	[10]	$166,068	$173,752	$129,154

Mercury Control Cost Effectiveness
Hibbing Taconite Company (HTC)
Table 1 - Cost Evaluation Summary for All Furnaces

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	HTC estimate of annual operating hours per furnace	HTC estimate of annual operating hours per furnace	HTC 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
Class 4 Estimate: Study or Feasibility with -30%/+50% accuracy range according to *AACE International Recommended Practice No.*

[5] *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 cite 99% control or higher.	GORE was not tested at HTC. Testing at U.S. Steel Minntac, Cleveland Cliffs United Taconite, and Arcelor Mittal Minorca indicated that a 72% reduction per the rule may be achievable. HTC will assume that this technology can reduce mercury emissions by 72% based on a new vendor quote	*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. HTC 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

Mercury Control Cost Effectiveness
Hibbing Taconite Company (HTC)
Table 2 - Capital Costs for Installations for All Furnaces

Hg Control Technology Description

Technology Name	**Fixed Carbon Beds (includes baghouse)**	**GORE**	**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	N/A	N/A
Direct Capital Costs (DC)		**$122,421,374**	**$106,933,085**	**$79,969,108**
Purchased Equipment Costs				
Equipment Costs	[1]	$37,445,540	$42,549,332	$27,956,446
Instrumentation	[2]	$3,744,554	$4,254,933	$0
Sales Tax	[3]	$2,574,381	$2,925,267	$1,922,006
Freight	[4]	$1,872,277	$2,127,467	$1,397,822
Generalized Installation Costs				
Basis for Installation Costs	[5] [6]	Fabric Filter	Carbon Adsorber System	Fabric Filter
Foundations and Supports	[5]	$1,825,470	$4,148,560	$1,251,051
Handling & Erection	[5]	$22,818,376	$7,259,980	$15,638,137
Electrical	[5]	$3,650,940	$2,074,280	$2,502,102
Piping	[5]	$456,368	$1,037,140	$312,763
Insulation	[5]	$3,194,573	$518,570	$2,189,339
Painting	[5]	$1,825,470	$518,570	$0
Site-Specific Installation Costs				
Site Preparation (Grade & Level)	[13]	$162,000	$89,000	$107,000
Ductwork	[13]	$8,846,337	$7,405,940	$6,296,193
Buildings	[13]	$8,315,700	$3,995,300	$4,867,500
CEMS Relocation	[13]	$319,540	$319,540	$319,540
Initial Carbon Charge	[13]	$10,160,640	N/A	N/A
GORE Wastewater Treatment	[13]	N/A	$12,500,000	N/A
Lost Production During Installation	[13]	$15,209,208	$15,209,208	$15,209,208
Extended Downtime Days for Tie-in and Restart	[13]	14	14	14

Indirect Capital Costs (IC)		**$32,858,461**	**$30,077,059**	**$22,518,918**
Basis for Installation Costs	[5] [6]	Fabric Filter	Carbon Adsorber System	Fabric Filter
Engineering & Supervision	[5]	$4,563,675	$5,185,700	$3,127,627
Construction & Field Expenses	[5]	$9,127,350	$2,592,850	$6,255,255
Contractor Fees	[5]	$4,563,675	$5,185,700	$3,127,627
Start-Up Costs	[5]	$456,368	$1,037,140	$312,763
Performance Test	[5]	$456,368	$518,570	$312,763
Contingency	[5]	$13,691,026	$15,557,099	$9,382,882
Contingency Percentage - Site-Specific	[5]	30%	30%	30%

Retrofit Factor	[7]	1.60	1.60	1.60
Total Capital Investment (TCI)	[7]	**$155,279,835**	**$137,010,144**	**$102,488,025**
Total Capital Investment (TCI) with Retrofit Factor	[7]	**$233,225,828**	**$210,090,706**	**$154,855,315**

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]	$14,849,568	$22,844,520	$3,371,468
Adjusted TCI for Capital Recovery	[11]	$218,376,260	$187,246,186	$151,483,847
Capital Recovery Cost (CRC)	[12]	$20,613,174	$17,674,715	$14,299,004

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. Included ACI system price, scaled for injection rate using the 0.6 power law, for dry sorbent injection system. Includes a vendor quoted cost for a new stack, ductburner for warmup, and air compressor for pulse-jet baghouse air	Vendor quote provided for GORE technology. 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.	Vendor quotes for new baghouse, fans, motors, and activated carbon injection system. Included ACI system price, scaled for injection rate using the 0.6 power law, for dry sorbent injection system. Includes a vendor quoted cost for a new stack, duct burner for warm up, and air compressor for pulse-jet baghouse air

[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 Hibbing Taconite Company 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].	A baghouse is installed prior to the fixed carbon beds.	GORE functions similar to a carbon adsorber system, so it was assumed that these factors would provide the most appropriate installation cost factor basis.	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). HTC included a retrofit factor to account for significant space and installation constraints. Note, the retrofit factor is not multiplied by lost production costs or the initial carbon charge for fixed carbon beds.

[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 All Furnaces' 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
CEMS Relocation	Site-specific engineering estimate; cost for umbilicals and CEMS shelter associated with installation of a new stack for each line	Site-specific engineering estimate; cost for umbilicals and CEMS shelter associated with installation of a new stack for each line	Site-specific engineering estimate; cost for umbilicals and CEMS shelter associated with installation of a new stack for each line
Initial Carbon Charge	Initial carbon loading cost provided by vendor	N/A	N/A
GORE Wastewater Treatment	N/A	Design and cost estimate for treatment of the GORE effluent is an engineering estimate based on Barr's experience on other minng projects. Value is installed capital cost.	N/A
Lost Production During Installation	Lost production for extended downtime to install new retrofit equipment. Based on production rates and Cleveland Cliffs publically available financial data.	Lost production for extended downtime to install new retrofit equipment. Based on production rates and Cleveland Cliffs publically available financial data.	Lost production for extended downtime to install new retrofit equipment. Based on production rates and Cleveland Cliffs publically available 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 outage.	Estimate based on engineering experience. The downtime is the number of days beyond a typical outage.	Estimate based on engineering experience. The downtime is the number of days beyond a typical outage.

Mercury Control Cost Effectiveness
Hibbing Taconite Company (HTC)
Table 3 - Operating Costs for All Furnaces

Hg Control Technology Description

Technology Name	**Fixed Carbon Beds (includes baghouse)**	**GORE**	**ACI with Baghouse**
Expected Utilization Rate (%)	100%	100%	100%
Expected Annual Hours of Operation (hr/year)	7,690	7,690	7,690
Notes on Technology			

Direct Annual Costs (DAC, $/year)			**$5,575,992**	**$1,275,879**	**$4,853,544**
Raw Materials					
Powdered Activated Carbon (HPAC)	Demand (lb/year)	[1]			1,574,389
	Retail Price ($/lb)	[2]			$1.12
	Cost Per Year ($/year)	[3]			$1,763,316
Hydrated Lime	Demand (ton/year)	[1]	1,818		1,818
	Retail Price ($/ton)	[2]	$250.00		$250.00
	Cost Per Year ($/year)	[3]	$454,406		$454,406
Utilities					
Electricity	Demand (kW-hr/year)	[4]	56,034,883	6,979,699	19,501,434
	Retail Price ($/kW-hr)	[2]	$0.068	$0.068	$0.068
	Cost Per Year ($/year)	[3]	$3,829,984	$477,062	$1,332,923
Natural Gas	Demand (MMBtu/year)	[4]	108		108
	Retail Price ($/MMBtu)	[2]	$3.52		$3.52
	Cost Per Year ($/year)	[3]	$380		$380
Operating Labor					
Operator	Worked Hours Per Year (hr/year)	[5]	1,923	481	1,923
	Cost Per Hour ($/hr)	[2]	$65.27	$65.27	$65.27
	Cost Per Year ($/year)	[3]	$125,482	$31,370	$125,482
Supervisor	Cost Per Year ($/year)	[6]	$18,822	$4,706	$18,822
Maintenance					
Labor	Worked Hours Per Year (hr/year)	[7]	961	481	961
	Cost Per Hour ($/hr)	[2]	$65.27	$65.27	$65.27
	Cost Per Year ($/year)	[3]	$62,741	$31,370	$62,741
Materials	Cost Per Year ($/year)	[8]	$62,741	$31,370	$62,741
Waste Management					
Non-Haz Solid Waste Offsite Disposal	Waste Production Rate (ton/year)	[9]	19,702.23		19,964.63
	Transport Demand (ton-mile/year)	[10]	0.00		0.00
	Disposal Fee ($/ton)	[2]	$43.06		$43.06
	Transport Fee ($/ton-mile)	[2]			
	Cost Per Year ($/year)	[11]	$848,289		$859,587
GORE Wastewater Treatment	Waste Production Rate (mgal/year)	[9]			
	Disposal Fee ($/mgal)	[2]			
	Cost Per Year ($/year)	[3]		$700,000	
Product Loss					
Taconite Pellets	Product Lost (ton/year)	[12]	4,498.37		4,498.37
	Retail Price ($/ton)	[2]	$38.49		$38.49
	Cost Per Year ($/year)	[3]	$173,147		$173,147

Mercury Control Cost Effectiveness
Hibbing Taconite Company (HTC)
Table 3 - Operating Costs for All Furnaces

Indirect Annual Costs (IAC, $/year)		**$29,442,732**	**$25,370,772**	**$19,382,666**
Overhead	[13]	$161,871	$59,290	$161,871
Administration	[14]	$3,105,597	$2,740,203	$2,049,761
Property Tax	[15]	$1,552,798	$1,370,101	$1,024,880
Insurance	[16]	$1,552,798	$1,370,101	$1,024,880
Capital Recovery for Replacement Parts	[17]	$2,456,493	$2,156,361	$822,270
Capital Recovery	[18]	$20,613,174	$17,674,715	$14,299,004

Total Annual Costs (TAC = DAC + IAC, $/year)		**$35,018,724**	**$26,646,651**	**$24,236,210**

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. HTC will assume the same injection rate.
Hydrated Lime	Lime injection rates maintain the current level of SO2 control achieved by the existing scrubbers (Assumed 25%). 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 25%). Vendor data from previous project experience determined the normalized stoichiometric ratios.

[2] See 'Table 5 - Raw Material, Utility, and Waste Disposal Costs for All Furnaces' 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	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. Includes electricity demand due to the 1200 hp compressor.	Assumed 0.66" pressure drop through modules based on vendor quote for vertical arrangement. EPA Air Pollution Control Cost Manual 6th Ed 2002, Chapter 1 equation 1.14. Also included pressure drop due to ducting.	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. Includes electricity demand due to the 1200 hp compressor.
Natural Gas	Assumes two, 9 hour natural gas startups (for each furnace) to preheat filter bags to avoid condensation on filter media. Assumes a 15 degree temperature dfferential.		Assumes two, 9 hour natural gas startups (for each furnace) to preheat filter bags to avoid condensation on filter media. Assumes a 15 degree temperature dfferential.

Mercury Control Cost Effectiveness
Hibbing Taconite Company (HTC)
Table 3 - Operating Costs for All Furnaces

[5] Assumed 0.5 and 2.0 hrs of operator attention per 8 hr shift of unit operation for units with a carbon adsorber and baghouse basis respectively.
[6] 15% of operator costs per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.
[7] Assumed 0.5 and 1.0 hrs of operator attention per 8 hr shift of unit operation for units with a carbon adsorber and baghouse basis 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.		Assumes that all of the solids captured by the baghouse would be disposed of as solid waste.
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	27% of the captured process dust in the baghouse stream could have been be recovered for pellet production if the wet scrubbers were not replaced. See Table 6.1 of *Mercury Transport in Taconite Processing Facilities: (II) Fate of Mercury Captured by Wet Scrubbers*		27% of the captured process dust in the baghouse stream could have been be recovered for pellet production if the wet scrubbers were not replaced. *See Table 6.1 of Mercury Transport in Taconite Processing Facilities: (II) Fate of Mercury Captured by Wet Scrubbers*

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

Mercury Control Cost Effectiveness
Hibbing Taconite Company (HTC)
Table 4 - Replacement Parts for All Furnaces

Hg Control Technology Description

Technology Name		**Fixed Carbon Beds (includes baghouse)**	**GORE**	**ACI with Baghouse**
Notes on Technology				

Cost of Replacement Parts ($)		**$14,849,568**	**$22,844,520**	**$3,371,468**
Capital Recovery for Replacement Parts($/year)		**$2,456,493**	**$2,156,361**	**$822,270**
Replacement Part Name		Filter Bags	Gore Module	Filter Bags
Interest Rate	[1]	7.0%	7.0%	7.0%
Expected Life of Replacement Part (years)	[2]	5	20	5
Cost of Replacement Part ($/replacement)	[2]	$2,865,428	$22,619,520	$2,865,428
Cost of Labor for Replacement ($/replacement)	[2]	$506,041	$225,000	$506,041
CRF_P	[3]	24.39%	9.44%	24.39%
CRC_P ($/year)	[4]	$822,270	$2,156,361	$822,270
Replacement Part Name		Carbon Change		
Interest Rate	[1]	7.0%		
Expected Life of Replacement Part (years)	[2]	10		
Cost of Replacement Part ($/replacement)	[2]	$10,214,890		
Cost of Labor for Replacement ($/replacement)	[2]	$1,263,209		
CRF_P	[3]	14.24%		
CRC_P ($/year)	[4]	$1,634,223		

Mercury Control Cost Effectiveness
Hibbing Taconite Company (HTC)
Table 4 - Replacement Parts for All Furnaces

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***	***Gore Module***	***Filter Bags***
Documentation of Life Expectancy	Provided by baghouse manufacturer	Assumed 20 year equipment life.	Provided by baghouse manufacturer
Documentation of Replacement Part Cost, including sales tax and freight.	Provided by baghouse manufacturer. Requires 7,750 bags with an equipment life of 5 years at $110/bag.	Vendor quote provided for GORE module cost. Includes vendor estimated disposal cost of $45/module.	Provided by baghouse manufacturer. Requires 7,750 bags with an equipment life of 5 years at $110/bag. Cost includes solid waste disposal of bags.
Documentation of Labor Costs for Replacement Part	EPA Air Pollution Control Cost Manual 6th Ed 2002 Chapter 1.5.1.4. Assumes 20 minutes per bag and HTC specific labor rates.	Vendor quote provided for another taconite indurating furnace.	EPA Air Pollution Control Cost Manual 6th Ed 2002 Chapter 1.5.1.4. Assumes 20 minutes per bag and HTC specific 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

Mercury Control Cost Effectiveness
Hibbing Taconite Company (HTC)
Table 5 - Raw Material, Utility, and Waste Disposal Costs for All Furnaces

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	$ 110.00
Hydrated Lime	$250.00	ton	2018	[10]	Assume 3% Inflation	100	100	$ 250.00

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	$3.52	MMBtu	2018	[4]	Assume 3% Inflation	100	100	$3.52
Compressed Air	$0.25	mscf	1998	[5]	Assume 3% Inflation	100	181	$0.45

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	$65.27	hour	2018	[2]	Assume 3% Inflation	100	100	$65.27
Maintenance	$65.27	hour	2018	[2]	Assume 3% Inflation	100	100	$65.27
Supervisor	$65.27	hour	2018	[2]	Assume 3% Inflation	100	100	$65.27

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	$41.80	ton	2017	[6]	NA	100	103	$43.06
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	$38.49	ton	2018	[8]	NA	100	100	$38.49

Footnotes

[1] Delivered price from vendor for HPAC

[2] HTC site-specific labor cost (includes benefits)

[3] HTC site-specific electricity cost

[4] HTC 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] HTC site-specific solid waste disposal cost. Assumes $20.46/ton and $175/load with 8.2 ton/load (average of 2017) loads

[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] Cost per ton based on Cleveland Cliffs Reports, Third Quarter 2018 Results

[9] Filter bag cost provided by vendor.

[10] Vendor-provided hydrated lime cost from previous project experience

Appendix C

Mercury Emission Reduction Calculations

Hibbing Taconite Company
Mercury Emissions Reduction Plan
Appendix C
Mercury Emissions Reductions - MPCA Form Item 6

Mercury Emissions Reductions Under HTC's MERP

Emission Unit	Baseline Emissions lb/yr	Percent Reduction	Estimated Emissions lb/yr
EU 020	71	0%	71
EU 021	71	0%	71
EU 022	71	0%	71
TOTAL	**213**	**0%**	**213**

(1) HTC's MERP does not propose emissions reductions. This spreadsheet is included for completeness per MPCA Form item 6.