Best Available Mercury Reduction Technology Analysis and Mercury Emissions Reduction Plan

Prepared for
United Taconite LLC

December 2018

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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 Units
EPA	U.S. Environmental Protection Agency
FAMS	Flue-gas Absorbent-trap Mercury Speciation
fps	feet per second
gph	gallons per hour
gpm	gallons per minute
H_2O_2	Hydrogen Peroxide
HBr	Hydrogen Bromide
HCl	Hydrogen Chloride
HEDT	High Energy Dissociation Technology
HTC	Hibbing Taconite Company (HibTac)
ICI	Industrial, Commercial, and Institutional
Keetac	U. S. Steel – Keetac
MACT	Maximum Achievable Control Technology
MATS	Mercury and Air Toxics Standards
ME2C	Midwest Energy Emissions Corporation
MERP	Mercury Emissions Reduction Plan
Minn. R.	Minnesota Rules
Minntac	U. S. Steel – Minntac
Minorca	ArcelorMittal Minorca Mine
MPCA	Minnesota Pollution Control Agency
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
SAM	Sulfuric Acid Mist
SO_2	Sulfur Dioxide
TVOP	Title V Operating Permit
TMDL	Total Maximum Daily Load
UTAC	United Taconite LLC

Best Available Mercury Reduction Technology Analysis

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1 Executive Summary

In accordance with Minnesota Rules 7007.0502 (Minn. R. 7007.0502), United Taconite LLC (UTAC) evaluated reduction technologies for mercury air emissions from the facility's indurating furnaces to determine if 72% reduction threshold from the 2008 or 2010 mercury emissions baseline, whichever is greater, is technically achievable. The rule requires the owner or operator of an existing mercury emissions source 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) evaluation for UTAC's taconite processing plant located in Forbes, 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 below. The details of each step, including the methods used to analyze acceptability of each step, are discussed further in Sections 4.1 through 4.8.

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

- Mercury capture by existing wet scrubbers with solids removal
- Mercury oxidation for capture by wet scrubbers
    - Halide injection
    - In-scrubber oxidation
    - High energy dissociation technology (HEDT)
- Activated carbon injection (ACI)
    - ACI with existing scrubber
    - ACI with baghouse
    - ACI with high efficiency scrubber
- 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, pursuant to Minn. R. 7007.0502, subp. 6, was technically achievable with the proposed reduction technologies, using the four technical achievability standards established by the Minnesota Pollution Control Agency (MPCA) and the criterion of acceptable environmental impacts. Figure 4-1 illustrates the sequential steps for considering the reduction technologies and Section 4 presents the detailed BAMRT analysis. 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 reduction technologies as summarized in Table ES-1 below.

The BAMRT analysis then proceeded to evaluate which alternative mercury control strategies are technically achievable and would achieve the highest mercury emissions reductions, independent of the 72% mercury emissions reduction threshold, as presented in Section 5. The BAMRT determined that mercury capture by existing wet scrubbers with solids removal—the only technology identified through the BAMRT analysis as warranting evaluation as an alternative–is not technically achievable.

Section MERP-1 presents UTAC's Mercury Emissions Reduction Plan (MERP). Pursuant to Minn. R. 7007.0502, subp. 5(A)(2), UTAC proposes to:

1. Evaluate engineering solutions to improve iron recovery and cost effectiveness for mercury capture by existing wet scrubbers with solids removal,
2. Conduct a technology review to determine if any new mercury emissions reduction technologies are available and complete a subsequent BAMRT analysis,
3. Evaluate acquiring mercury reduction credits from another taconite facility if it reduces its mercury emissions beyond what is required by the Minnesota Mercury Rule and MPCA approves that facility's MERP, and
4. Review the MERP and make revisions if iron recovery can be improved with scrubber solids removal, if a new, viable technology is identified through the BAMRT analysis, or if credits will be allocated from reductions from another facility.

Table ES-1 Summary of the BAMRT Analysis Results

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
List available reduction technologies	**Is the technology commercially available?**	**Does the technology operate without impairing pellet quality or production?**	**Does the technology cause excessive corrosion to pellet furnaces or associated ducting or emission control equipment?**	**Does the technology present unacceptable environmental impacts?**	**Can the technology consistently meet the 72% reduction per the rule?**	**Is the technology cost effective?**
Mercury capture by existing wet scrubbers with solids removal	Yes	No – wasting scrubber solids affects production, but carrying through for BAMRT analysis purposes.	No	No	No – Technology proceeds to alternative evaluation (refer to Section 5)	NA - see Step 6
Halide Injection	Yes	Yes	No – See additional future considerations described in Section 4.4	Yes - Increased likelihood of local mercury deposition, eliminated from further consideration (refer to Section 4.5.1)	NA - see Step 5	NA - see Step 5
In-scrubber oxidation – Not considered a potential technology based on previous industry testing (refer to Section 4.1.4.2)	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 (refer to Section 4.2.1)	NA - See Step 2	NA - See Step 2	NA - See Step 2	NA - See Step 2	NA -See Step 2

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 with existing scrubber – Existing scrubbers cannot accommodate additional particulate loading while maintaining compliance with existing permit limits (refer to Section 4.1.5.1)	NA – See Step 1	NA – See Step 1	NA – See Step 1	NA – See Step 1	NA – See Step 1	NA – See Step 1
ACI with baghouse	Yes	Yes	No	No	Yes	No, eliminated from further consideration (refer to Section 4.7.2)
ACI with replacement high efficiency scrubber	Yes	Yes	No	No	Yes	No, eliminated from further consideration (refer to Section 4.7.2)
Fixed carbon bed	Yes	Yes	No	No	Yes	No, eliminated from further consideration (refer to Section 4.7.2)
GORE™	Yes	Yes	No	No	Yes	No, eliminated from further consideration (refer to Section 4.7.2)
Monolithic honeycomb adsorption	No, eliminated from further consideration (refer to Section 4.2.1)	NA - See Step 2	NA -See Step 2	NA - See Step 2	NA - See Step 2	NA -See Step 2

2 Introduction

This section discusses the purpose and background information associated with the BAMRT analysis, and a description of UTAC's indurating furnaces.

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.

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 Hibbing Taconite Company (HTC), ArcelorMittal Minorca Mine (Minorca), Northshore Mining Company, U. S. Steel – Keetac (Keetac), U. S. Steel – Minntac (Minntac), and UTAC. Mercury is a naturally occurring element in taconite ore and certain indurating furnace fuels.

During the development of the Minnesota statewide mercury emission 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 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. However, the State of Minnesota continued to move forward with statewide mercury emission 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.

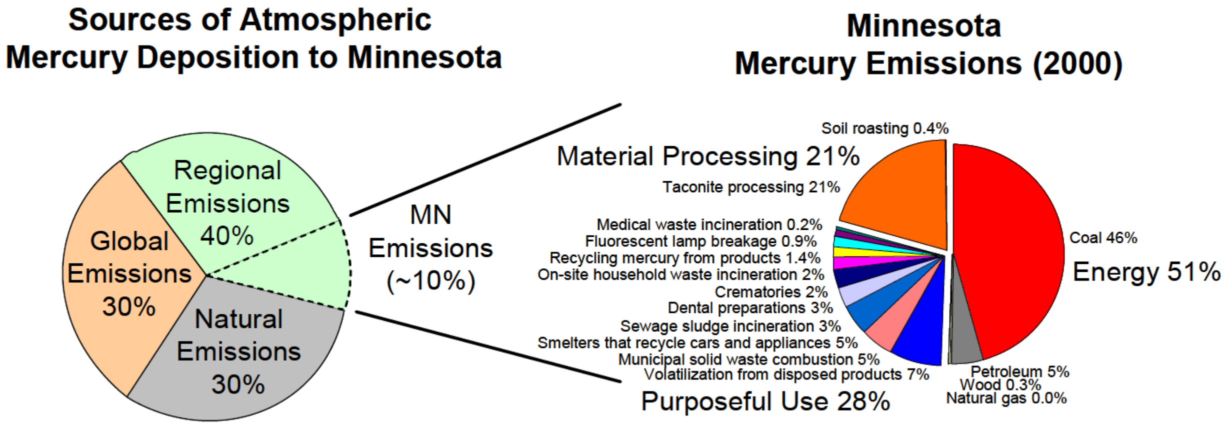


Figure 2-1 **Sources of Mercury Deposition and Estimated Mercury Emission Sources in Minnesota (Reference (2))**

The TMDL proposed a set of outcome based, tiered reduction targets and milestones that were dependent on achieving certain national mercury emission 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, since 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. Figure 2-2 below provides additional information on the sources of international, anthropogenic mercury consumption (units in tons).

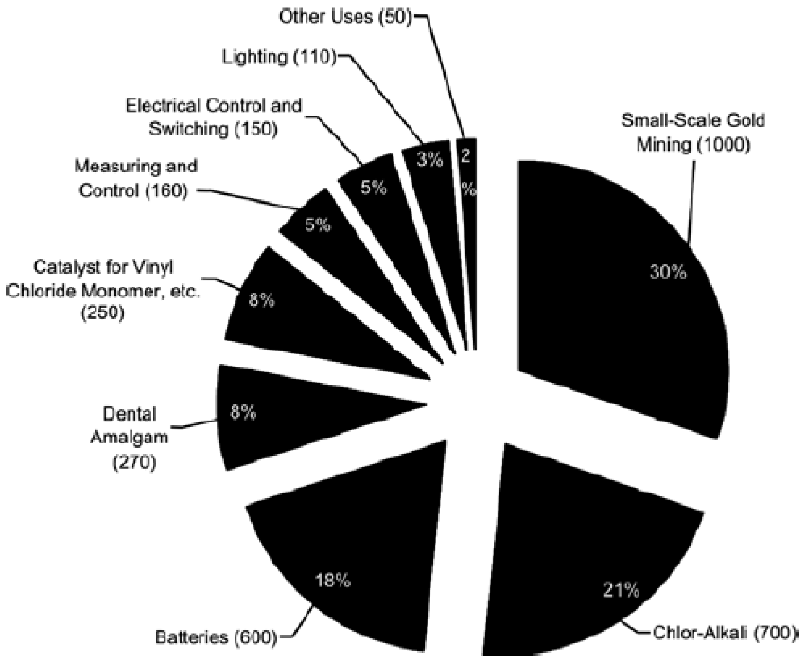


Figure 2-2 Estimates of Global Mercury Consumption (tons) (Reference (12))

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 provides context for the reader when reviewing the BAMRT analysis and MERP submittal by illustrating 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

MPCA proceeded to develop draft rules to require mercury emission 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, it does 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 MERP 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 UTAC, 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 the facility to propose an alternative plan to reduce mercury emissions if the evaluation determines that the 72% reduction threshold is not technically achievable.

2.2 Facility Description

UTAC 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 disc filters, mixed with bentonite and/or other binding agents, and conveyed to balling drums where greenballs are formed. Greenballs are fed to the traveling grate prior to entering the kiln. The traveling grate consists of drying and preheat zones. After greenballs pass through the traveling grate, they enter the kiln where they are heated to approximately 2,400 degrees Fahrenheit, becoming hardened pellets. After the kiln, the fired pellets are sent to an annular cooler where ambient air is blown through the pellets, allowing them to be safely discharged and suitable for handling and shipping. The heated flue gas from the kiln and annular cooler are recovered and used in the drying and heating zones on the traveling grate. The flue gas is then routed to wet scrubbers and vented through associated stacks.

As greenballs enter the indurating process, trace amounts of mercury are liberated from the ore. Stack emissions are dependent on the mercury content of the greenballs and the greenball feed rate. Depending on the furnace configuration, the flue gas can be split between multiple scrubbers and stacks. UTAC operates two preheat grate/induration kiln (grate-kiln) furnaces (Line 1 - EU040/EQUI 45, Line 2–EU042/EQUI 47). Flue gas from Line 1 is controlled by a single venturi wet scrubber (CE056/TREA 91) and is vented through a single stack (SV046/STRU 53). Flue gas from Line 2 is controlled by dual venturi wet scrubbers (CE050/TREA 89, CE049/TREA 90) and is vented through parallel stacks (SV048/STRU 16, SV049/STRU 15).

Figure 2-3 shows a schematic representation of material and air flows throughout the indurating process.

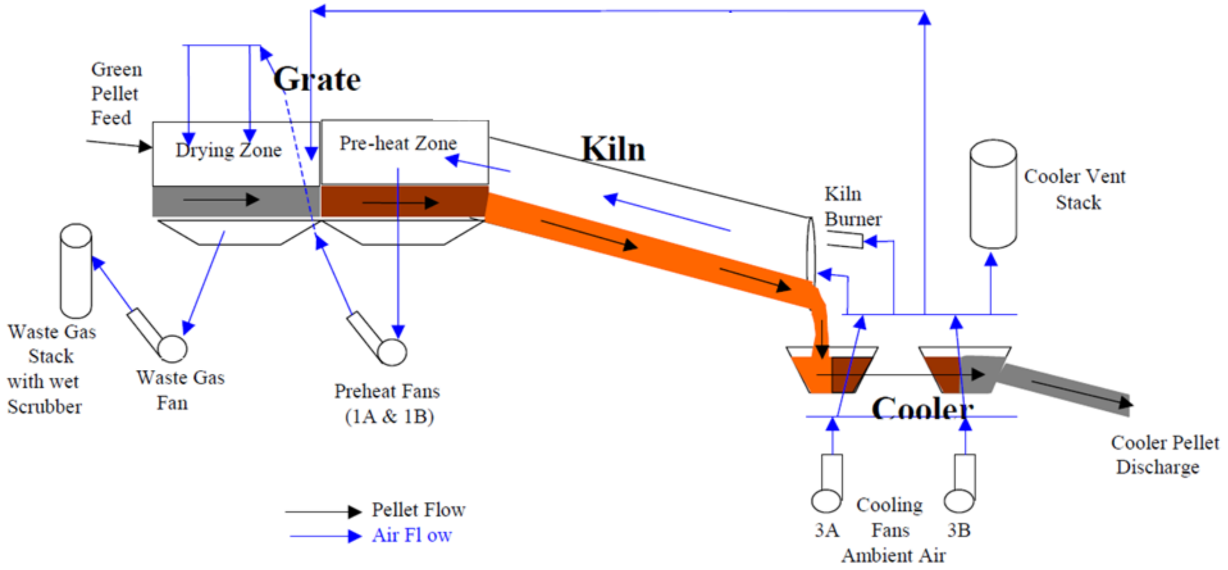


Figure 2-3 Grate-Kiln Furnace Diagram (Reference (16))

3 Analysis of Baseline Mercury Emissions

This section describes the historical UTAC baseline representation as presented in TMDL-related publications and UTAC's methodology for determining the 2008 and 2010 indurating furnace mercury emissions used to establish the baseline mercury emissions for the analysis within the BAMRT.

3.1 UTAC's Historical Annual Mercury Emission Representation

The TMDL Implementation Plan originally estimated UTAC's annual mercury emission representation at 133.6 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 (17)). UTAC has since conducted additional stack testing and 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), facilities must evaluate mercury emission reductions from the 2008 or 2010 baseline mercury emissions, whichever is greater. UTAC's baseline mercury emissions is 148.3 lb/yr based on the associated 2008 line production rates (long ton of pellets per year) and representative production-normalized mercury emission factors (lb mercury per long ton of pellet) as presented in Table 3-1. This facility-wide mercury emissions value is considered to be more representative than the historical TMDL emission rate estimate due to more recent representative stack testing values.

Line 1 combusted natural gas and Line 2 combusted solid fuels, exclusively, in 2008. As such, the associated production-normalized emission factors are based on 2006 Line 1 stack testing while combusting natural gas and 2016 Line 2 stack testing while combusting solid fuels (References (18), (19)). The associated stack tests were performed in accordance with currently approved EPA test methods. Note, the Line 2 emission factors were normalized with production data by evenly dividing the Line 2 production between the two separate stacks (STRU 15 and STRU 16).

Table 3-1 Baseline Mercury Emissions

Parameter	Line 1 (STRU 53)	2A (STRU 16)	2B (STRU 15)	Total
Emission Factor (lb mercury per long ton of pellets)(1),(2)	2.73E-05	3.11E-05	2.86E-05	NA
2008 Pellet Production (long ton per year)(3)	1,275,008	1,901,580	1,901,580	5,078,168
Baseline Emission Rate (lb mercury per year)	34.7	59.0	54.5	148.3

(1) The Line 1 emission factor is based on the May 4, 2006 Line 1 Stack Test while firing natural gas, which is consistent with the fuel combusted during 2008 Line 1 production (Reference (18)).

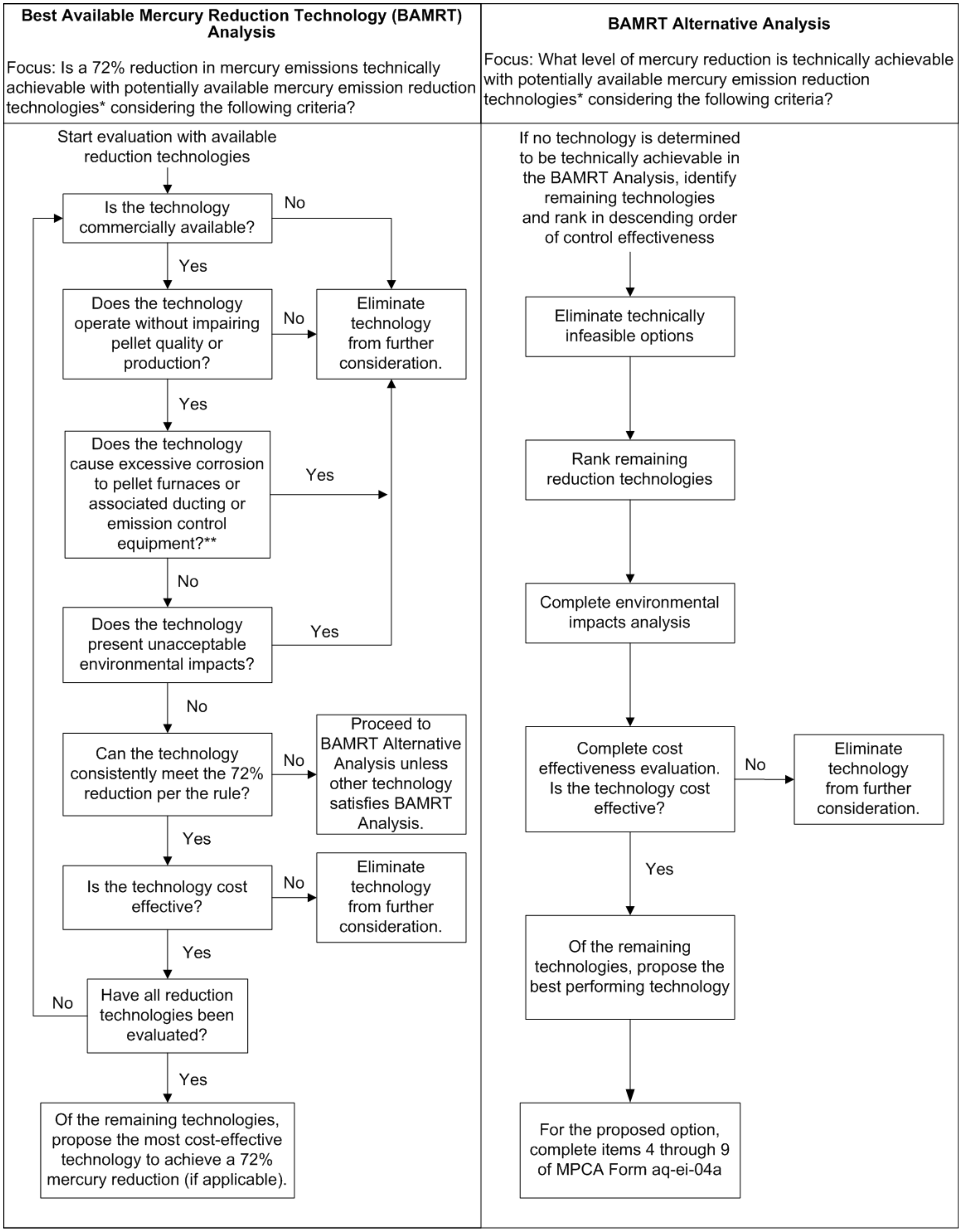
(2) The 2A and 2B emission factors are based on the October 11-12, 2016 Line 2 Stack Test while combusting solid fuels, which is consistent with the combusted during 2008 Line 2 production (Reference (19)).

(3) The 2008 Pellet Production values are consistent with the values used to calculate the annual emissions in the 2008 Annual Emission Inventory submittal.

4 Best Available Mercury Reduction Technology Analysis

The BAMRT analysis evaluated whether potentially available mercury emissions reduction technologies identified at UTAC were technically achievable, without unacceptable environmental impacts, and capable of achieving the 72% mercury 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 criteria and acceptable environmental impacts 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 reductions required by Minn. R. 7007.0502, subp. 6, are technically achievable, using the adaptive management and acceptable environmental impacts criteria. The steps of this evaluation are outlined below. The details of each step, including the methods used to analyze acceptability of each step, are discussed further in Sections 4.1 through 4.8.

The 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 structure allows for a direct evaluation of the adaptive management criteria. Adjusting the sequence would have no impact on the conclusions, while increasing the level of effort and cost of this analysis.

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 emissions 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

The second step in the BAMRT analysis was to determine if the potentially available mercury emissions reduction technologies identified in Step 1 were commercially available (i.e. one requirement to be "technically feasible" per the adaptive management criteria). 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 disposal, water, or air implications). Impacts that can be mitigated through treatment or management methods do not eliminate a technology from further consideration. However, a technology that results in environmental harm that cannot be mitigated or contradicts the goals of the TMDL was removed from additional analysis. 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 (20)). Details on how each technology was evaluated for environmental impacts can be found in Section 4.5. Any technology that presented 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.

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 or 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 UTAC 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 all 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 conducted in partnership with the MPCA and DNR and further analyzed at both the industry and site-specific levels. UTAC has spent approximately 1 million dollars on the various technology evaluation efforts along with thousands of staff hours. The historical review covered each of the following "stages" of mercury reduction studies that have been completed. The associated approximate time periods for each stage are included below:

- Pre-TMDL Implementation Plan DNR Research (Pre-TMDL research), 1997 - 2009
- Phase I – Minnesota Taconite Mercury Control Advisory Committee (Phase I), 2010 - 2012
- Phase II – Extended Testing of ACI (Phase II), 2013
- Gore Technology Demonstrations (GORE™), 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 this 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 potential reduction technologies utilized in other industries. It was 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 (21)).

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 UTAC.

During Phase II testing, the taconite processing industry became aware of an emerging sorbent technology known as GORE™. 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. However, in order to address these issues, UTAC conducted an additional chemical oxidation site-specific evaluation.

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 are addressed in later steps of the BAMRT analysis. Sections 4.1.3 through 4.1.7 summarize each technology in more detail.

Table 4-1 Potentially Available Mercury Emissions Reduction Technologies

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

4.1.3 Mercury Capture by Existing Wet Scrubbers with Solids Removal

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 more capable of removing oxidized and particulate-bound mercury and are not effective at removing elemental mercury (Reference (22)). Mercury that is captured by the existing wet scrubbers either remains in the scrubber water discharge or with the collected solids. Pre-TMDL research and testing evaluated scrubber solids removal as a method of mercury reduction.

At UTAC, scrubber water is sent to a thickener to concentrate the captured solids. The thickened solids are recovered, routed to the pellet plant disc filters and added back into the greenballs. Therefore, to be an effective mercury reduction technique, the solids from the scrubber would have to be removed from the process for disposal. This would prevent captured mercury from being recycled back into the process and re-emitted to the atmosphere. UTAC has the ability to remove scrubber solids from its process and dispose of the solids in the tailings basin where they are permanently sequestered (Reference (22)). This activity reduces the mercury recycling effect and thereby reduces mercury emissions at the indurating furnace waste gas stack. However, scrubber solids removal also discards valuable residual iron units, impeding production and thereby increasing production costs.

4.1.4 Mercury Oxidation for Capture by Wet Scrubbers

Oxidized mercury has a greater potential to be captured in a wet scrubber than elemental mercury because it is water-soluble and it adsorbs to particles (Reference (22)). Therefore, in principle, increased oxidation of mercury in the flue gas should result in increased mercury capture at the 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 oxidization via introduction of halides and in-scrubber oxidation. UTAC conducted additional long-term halide injection testing in 2018 (Reference (19)).

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 directly into the furnace's air stream. A number of chloride and bromide salts were tested in the taconite industry. Specifically, injection locations and halide compounds that were tested at UTAC and other taconite processing facilities are listed below. Note, the term "halide injection" encompasses all chemicals and injection (or addition) locations that have been tested to reduce mercury emissions in the taconite industry discussed below:

- Sodium chloride (NaCl) addition to greenballs – This potential mercury reduction method was tested at HTC Line 3 and at UTAC Line 2 (Reference (16)). 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 (16)). 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) addition to greenballs – This potential mercury reduction method was tested at Minntac Line 3 (Reference (23)). Mercury reduction efficiencies were based on CMMs placed in the scrubber feed duct and on the stack.

- NaBr injection to preheat zone – This potential mercury reduction method was tested at HTC Line 3 (Reference (16)). 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 (16)). 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 flue gas prior to scrubber – This potential mercury reduction method was evaluated at UTAC and HTC during the recent halide injection testing in 2017 and 2018 (Reference (19), (24)). The reduction in mercury emissions was determined using Method 30B. The injection rates tested were 3.0 and 4.5 gal/hr of HBr solution at UTAC and 2 gal/hr of HBr solution at HTC.

- 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 (16), (25)). 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 gallons per minute (gpm) at 48 wt% solution of $CaBr_2$ at Minorca.

  In 2017 and 2018, UTAC tested $CaBr_2$ injection to the preheat zone/grate-kiln transition. Screening tests using $CaBr_2$ were completed at injection rates of 2.5, 3.0, 3.75, 4.5, and 8.5 gal/hr $CaBr_2$ solution and Method 30B stack test results were used to determine the rate required to achieve optimal mercury reduction (Reference (19)). An injection rate of 4.5 gal/hr yielded the highest reduction in mercury emissions and thus was selected for the long-term test. Mercury reductions were determined by comparing the baseline (no halide injection) and long-term injection Method 29 stack test results.

  In 2017, HTC also completed a long term trial of 2 gal/hr $CaBr_2$ injection into the preheat zone (Reference (24)). 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).

Halide injection testing demonstrated that injection to the greenballs is an inferior control method compared to direct injection into the induration furnaces (preheat zone/grate-kiln transition for UTAC, Reference (25)). Of the evaluated chemicals, NaCl and $CaCl_2$ consistently resulted in less mercury reductions compared to brominated salts ($CaBr_2$, NaBr, and HBr). Of these, $CaBr_2$ achieved the highest reductions. Additionally, HBr is a highly toxic chemical, which presents significant safety concerns for handling and use (References (16), (19), (25)). Therefore, $CaBr_2$ injection into the preheat zone/grate-kiln transition was evaluated within the BAMRT analysis.

Concerns with halide injection include potential pellet quality degradation and/or excess corrosion to plant equipment. Oxidizing chemicals may corrode 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 work, the University of North Dakota's Energy & Environmental Research Center (EERC) working in conjunction with the DNR, completed bench-scale exposure experiments, in simulated taconite flue gases, to help understand if and how bromine-induced corrosion occurs. Testing was completed in environments that mimicked the preheat zone, the drying/cooling zone, and the discharge zone. The final report from August 28, 2009 was titled *Assessment of Potential Corrosion Induced by Bromine Species used for Mercury Reduction in a Taconite Facility* (Reference (26)). 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. This testing demonstrated that halide injection can result in equipment corrosion.

Other Pre-TMDL research reports discuss potential corrosion impacts from halide injection, but they do not provide detailed technical concerns nor do they provide actual test results that indicate excessive corrosion or equipment degradation due to halide injection.

As part of the Phase I – Minnesota Taconite Mercury Control Advisory Committee work, one of the research projects (Reference (27)) focused on the evaluation of bromine- and chlorine-induced metal corrosion under simulated taconite operating conditions. It was found that temperature is very critical to corrosion, and under elevated temperatures (500°– 950°C), active oxidation is a main corrosion mechanism. HBr showed a higher rate of corrosion when compared to hydrogen chloride (HCl).

Only one report reviewed discussed the potential impacts to pellet quality. The *Mercury Transport in Taconite Processing Facilities: (I) Release and Capture During Induration* report from August 15, 2005 (Reference (28)) noted that it is "unlikely the iron-oxide mineralogy would be strongly affected by the presence or absence of small amounts of HCl in process gases." However, "small amounts" is a general term and is not quantified.

4.1.4.2 In-scrubber Oxidation

In-scrubber oxidation consists of adding oxidizing chemicals directly to the scrubber water (rather than to the flue gas) as an alternative way of oxidizing flue gas elemental mercury for capture in a wet scrubber. As part of the Pre-TMDL research and portions of the Phase I work, three different oxidizing chemicals were evaluated at taconite processing facilities: hydrogen peroxide (H_2O_2), diethyl dithiocarbamate (DEDTC) and a proprietary reagent (sodium chlorite – $NaClO_2$) on slip-stream furnace off-gases as discussed below:

H_2O_2 Testing at Keetac: Keetac conducted slip-stream testing using H_2O_2. This test demonstrated that H_2O_2 decreased the simulated scrubber solution's ability to oxidize and capture mercury compared to baseline conditions. 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 (16)). H_2O_2 was not further developed or tested again for the taconite processing industry. Therefore, the addition of H_2O_2 to scrubber water was not considered to be a potential reduction technology.

DEDTC Testing at Minntac: Minntac tested DEDTC by dosing scrubber water. However, there was no observable reduction in mercury emissions at the stack during the test (Reference (29)). Therefore, the addition of DEDTC to scrubber water was not considered to be a potential reduction technology.

$NaClO_2$ Testing

- $NaClO_2$ Testing at Keetac: Keetac conducted slip-stream testing using $NaClO_2$. This technology was not tested with the facility's scrubber, but on a simulated laboratory scrubber solution pulling a slip stream. This simulation demonstrated that $NaClO_2$ had the potential to be effective as a scrubber additive to reduce mercury emissions (Reference (16)).

- $NaClO_2$ Testing at Minntac: Minntac added $NaClO_2$ to their wet scrubber on Line 3. Minntac used CMMs to determine a reduction efficiency. Based on Figure 1 in the Pre-TMDL research report "On the Measurement of Stack Emissions at Taconite Processing Plants" (Reference (23)), $NaClO_2$ reduced mercury emissions by approximately 20% (5,000 ng/m^3 to 4,000 ng/m^3). The report postulated that the oxidant addition interfered with the particulate's ability to adsorb mercury.

- $NaClO_2$ Testing at Minorca: Minorca added $NaClO_2$ to their wet scrubber water. Minorca used CMMs to determine a reduction efficiency. Mercury emissions increased by approximately 25% during this test and decreased back to baseline after injection ceased (Reference (30)).

As demonstrated by the testing above, $NaClO_2$ produced inconsistent mercury control and may impede the existing scrubbers' ability to capture mercury from the flue gas as observed during Minorca's $NaClO_2$ trial.

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

4.1.4.3 HEDT

HEDT is an EERC proprietary technology in which reactive halogens are generated at high temperatures outside of the taconite process and injected downstream of the furnace. The technology works by dissociating halogen salts, allowing the use of benign compounds to create halogen radicals that oxidize flue gas mercury (Reference (31)). This technology was tested during the Pre-TMDL research, and was evaluated as a potential reduction technology for UTAC.

Corrosion concerns associated with halide injection are still a concern with HEDT. However, due to the fact the halides with HEDT are injected after the furnace, corrosion impacts may be lessened, as the chemicals are not subjected to the high temperatures of the furnace.

The BAMRT analysis evaluated HEDT as a potential reduction technology for UTAC.

4.1.5 Activated Carbon Injection

4.1.5.1 ACI with Existing Scrubber

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 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 (32)). Oxidized mercury was measured using the Ontario Hydro Method (OHM) and a Horiba mercury analyzer. The reported bench-scale reduction efficiency assumes that the wet scrubber would capture 100% of the oxidized mercury during full scale operations. 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 (33)).

- Preheat zone - Minntac's Line 3 was used to test PAC and brominated PAC injection into the furnace preheat zone (Reference (29)). A CMM and the OHM were used to determine the mercury reduction efficiency. Standard PAC injection rates tested were 50, 100, and 150 lb/hr. Brominated PAC injection rates tested were 50, 75, 100, and 150 lb/hr. Brominated PAC was injected in two separate locations: the preheat fans and the preheat grate. Higher reductions were achieved by injecting the brominated PAC at the preheat grate. As part of the testing, it was identified that PAC was slipping through the scrubber exhaust. Finally, it is important to note that the mercury reductions achieved during standard PAC injection were believed to be due to fluctuations in baseline values and not due to the PAC injection.

- Flue gas - This potential mercury reduction method was tested during Phases I and II (References (34), (35)). 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 wet scrubber. Brominated PACs achieved a greater reduction in mercury (Reference (34)). Therefore, all subsequent testing was with brominated PACs.

As noted by DNR's review of the Phase II report, ACI increases the particulate loading to the wet scrubbers such that mercury bound to PAC particles are released from the stack following the wet scrubbers. As noted by DNR's review of the Phase II report (Reference (36)), "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".

Under normal operating conditions without ACI, UTAC can consistently maintain compliance with its existing Title V operating permit (TVOP) and 40 CFR 63 Subpart RRRRR (Taconite Maximum Achievable Control Technology [MACT]) filterable particulate limits (0.01 gr/dscf). During ACI testing, particulate loading to the scrubbers increased such that the filterable particulate concentration at the stack was at TVOP and MACT limits. This demonstrated that ACI, in addition to the existing particulate concentration from the furnace operations, exceeds the existing scrubbers' particulate loading capacity. Full-scale utilization of ACI would jeopardize UTAC's ability to consistently comply with its existing TVOP and Taconite MACT particulate limits. For this reason, ACI with the existing scrubbers was not considered to be technically achievable reduction technology for UTAC. Therefore, ACI with the existing scrubbers was eliminated for the remainder of the BAMRT analysis.

4.1.5.2 ACI with Baghouse

As discussed above, ACI can adsorb elemental and oxidized mercury from the flue gas to form particulate-bound mercury. However, smaller particulates are less likely to be captured by the existing wet scrubbers. Therefore, smaller PAC particles containing adsorbed mercury have the potential to be emitted as particulate-bound mercury. To address this issue, a new baghouse could replace the existing scrubbers, which would provide increased particulate control efficiency. The net effect of installing a baghouse is to increase the capture efficiency of particulates, 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 (37)) 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.

A significant pressure drop occurs when using a baghouse, which may require the installation of new fans, buildings, and upgrades to the electrical infrastructure. The high flow rate of the furnace exhaust further complicates the issue.

The BAMRT analysis evaluated ACI with a baghouse as a potential reduction technology.

4.1.5.3 ACI with Replacement High Efficiency Scrubber

Similar to Section 4.1.5.2, enhanced particulate control technologies can increase the overall mercury reduction of ACI. UTAC's existing scrubbers do not have the additional particulate loading capacity to support ACI (refer to Section 4.1.5.1). Therefore, the BAMRT analysis evaluated ACI with a replacement high efficiency scrubber as a potential reduction technology for UTAC.

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, a concern still exists 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 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 UTAC present significant installation challenges due to the large footprint required. In addition, installing a fixed carbon bed downstream of the existing wet scrubbers is not appropriate because a water-saturated flue gas stream causes moisture to coat the carbon adsorption sites and reduces the carbon bed's ability to adsorb mercury. However, fixed carbon beds require particulate control prior to the beds to avoid plugging. Therefore, UTAC would be required to install a baghouse to replace the existing wet scrubbers upstream of the fixed carbon beds to achieve sufficient filterable particulate control and avoid issues with water-saturated flue gas.

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 (38)), 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 (39)) to further review the potential of a fixed bed carbon adsorption system. The 2012 results indicated a high level (>75%) of control was achievable based on laboratory scale slip stream testing.

The BAMRT analysis evaluated fixed carbon bed adsorption as a potential reduction technology.

4.1.7 GORE™

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

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

GORE^{TM} pilot testing pulled a slip stream of air through the test skid modules (updraft) and through a fan, which returned the slip stream into the waste gas stack. Demonstrations took place on three different induration furnaces: 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^{TM} 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^{TM} modules' mercury control effectiveness decreases with decreasing SO_2 concentrations as demonstrated by the lower mercury reduction effectiveness from the Minorca pilot test results (lower SO_2 concentrations) and, UTAC and Minntac test results (higher SO_2 concentrations) (Reference (40). Minorca burns inherently low sulfur natural gas in its indurating furnace and was producing flux pellets (SO_2 scrubbing) during the GORE^{TM} pilot testing. In contrast, UTAC and Minntac both burn other higher-sulfur fuels, such as coal, and were producing standard pellets during the GORE^{TM} pilot testing. In addition to reduced mercury removal efficiencies associated with low SO_2 emissions, the increased build-up of solids material in the GORE^{TM} unit due to ineffective cleaning could cause unacceptable differential pressure increases across the GORE^{TM} unit, thereby reducing indurating airflow and jeopardizing pellet quality production.

UTAC recently started producing flux pellets, in addition to standard pellets, as a result of its Mustang project. Therefore, the mercury control achieved during GORE^{TM} pilot testing for standard pellet production may not be achievable for fluxed pellet production. This analysis does not account for design parameter changes for fluxed pellet production as a conservative approach, but fluxed pellet production may require additional costs for a full-scale installation.

In addition, results of mercury concentration in the GORE^{TM} membrane wash water effluent ranged from 2,460 ng/L – 30,300 ng/L as compared to wash water influent mercury concentrations that ranged from non-detect to approximately 10 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^{TM} technology for mercury reduction requires the evaluation of additional wastewater treatment for the increased loading of mercury, sulfate, TDS and other constituents that may be captured by the wash water.

As mentioned above, UTAC conducted GORE™ pilot testing in early 2015 (Reference (41)). During the pilot test, the number of GORE™ modules remained constant and the velocity of the air slip stream varied from 5.5 feet per second (fps) to 12 fps to determine the optimal velocity to achieve a 72% reduction in mercury emissions. The testing indicated that the 8 fps velocity test condition achieved the highest average mercury reduction. This test condition is the design basis for full system scale-up in the BAMRT analysis.

The taconite industry has been in communication with GORE™ since 2015 pilot testing to discuss follow up questions and concerns observed (wash water contamination, plugging, pressure drop, etc.) while using the GORE™ GEN2 modules. The BAMRT analysis is based on the next generation GORE™ GEN3 modules, which have a higher control efficiency per module, thus reducing the overall footprint and capital cost. In September 2018, taconite industry representatives met with GORE™ representatives to discuss recent developments with their technology. Comments from the meeting and updated quotes have been incorporated into the full-scale design and cost evaluation for the BAMRT analysis.

The BAMRT analysis evaluated GORE™ as a potential reduction technology.

4.1.8 Monolithic Honeycomb Adsorption

Monolithic honeycomb adsorption consists of activated carbon and elemental sulfur that are mechanically fixed into a honeycomb structure and may include additives to enhance mercury capture. The monolith cells are capped 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. This technology was previously reviewed as a potential mercury emissions reduction technology, but trials were not conducted at a taconite facility.

BAMRT analysis evaluated Monolithic Honeycomb Adsorption as a potential reduction technology.

4.2 Step 2 – Determine if the Technologies are Commercially Available

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

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

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

HEDT and monolithic honeycomb adsorption were not commercially available and were 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 is 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 (31)). 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, the technology development halted and the technology has not achieved commercially availability (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

Based on information available to date, none of the remaining reduction technologies are expected to materially impact pellet quality. Removing scrubber solids that would otherwise be recycled in the process eliminates valuable, recoverable iron units, thereby impacting pellet production. However, for the purpose of this BAMRT analysis, UTAC is not eliminating scrubber solids removal at this step of the evaluation. Evaluation of scrubber solids removal will be carried through to subsequent steps. UTAC reserves the right to revisit this evaluation and subsequent resulting conclusion if new detrimental information becomes available. 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 the remaining technologies, the taconite industry conducted research to determine if the potential for increased corrosion to production equipment existed (refer to the discussion in Section 4.1.4.1). Of the remaining reduction technologies, halide injection is assumed to have a potential to induce corrosion to the production equipment. However, halide injection is not expected to induce corrosion to production equipment beyond an acceptable threshold, as determined by existing UTAC-specific preventative maintenance practices and based on the available information. UTAC reserves the right to revisit this evaluation and subsequent resulting conclusion if new information becomes available. Therefore, for the purpose of the BAMRT analysis, all remaining technologies proceeded to Step 5.

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

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. 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 capture by existing wet scrubbers with solids removal		No	Yes
Mercury oxidation for capture by wet scrubbers	Halide injection	Yes	No – See Section 4.5.1
Activated carbon injection	With baghouse	No	Yes
	With replacement high efficiency scrubber	No	Yes
Fixed carbon bed		No	Yes
GORE™		No	Yes

Halide injection was determined to pose unacceptable environmental impacts for the reasons discussed in detail below.

4.5.1 Halide Injection

UTAC conducted additional, long-term halide injection testing in late 2017 and 2018 to evaluate mercury reduction potential, resultant mercury emission speciation, and impacts to the pellet production process. Refer to Appendix A for the detailed testing report. During the screening phase of testing, it was determined that injecting $CaBr_2$ at a rate of 4.5 gallons per hour (gph) resulted in the highest mercury reduction potential as measured at the stack using Method 30B (refer to Section 4.1.4.1 for details). Accordingly, $CaBr_2$ injection at 4.5 gph was selected for long-term injection testing (Reference (19)). The long-term test plan consisted of a baseline period (no halide injection), followed by a $CaBr_2$ injection period while producing UTAC's standard pellet for two separate operating conditions: 1) recycling scrubber solids back to the process (current operation), and 2) wasting scrubber solids to the tailings basin. Halide injection was also tested during Mustang pellet (flux pellets, refer to Section 4.1.7) production to evaluate whether pellet chemistry affected halide performance.

EPA Method 29 stack tests were conducted during the long-term testing phases in order to evaluate how the particulate-bound mercury (front half of the stack testing train sample) and the gaseous phase mercury (oxidized and elemental as measured in the back half of the stack testing train sample) changed due to halide injection. The results indicated that total mercury emissions decreased during halide injection testing. However, EPA Method 29 does not differentiate between gas phase, elemental, and oxidized mercury. Other taconite facilities have tested halide injection using Ontario Hydro stack tests, which provides the complete speciation profile between particulate-bound, elemental, and oxidized forms (Reference (20)). UTAC applied the industry average speciation profile to the gas phase testing results from EPA Method 29 to extrapolate the changes in elemental and oxidized mercury. EPA Method 29 testing and the speciation estimate show that the speciation of particulate, elemental, and oxidized mercury changed significantly. This trend was observed for each testing condition (scrubber solids removal and pellet production type), which has unacceptable environmental impacts contrary to the goals of the TMDL. Refer to Table 4-4 for a summary of the results.

Table 4-4 UTAC 2017/2018 Halide Injection Testing – Extrapolated Mercury Emission Speciation and Reduction for Line 2

Parameter	Particulate	Elemental	Oxidized
Standard Pellet Production - Recycling Scrubber Solids			
Baseline, lb/hr (% of total)(1)	0.0001 (0.5%)	0.0183 (99.5%)	
Estimated oxidized and elemental emissions with no halide injection, lb/hr (% of total) (2)	NA	0.0163 (88.3%)	0.0021 (11.2%)
Long-term halide injection, lb/hr (% of total)(3)	0.0008 (7.8%)	0.0098 (92.2%)	
Difference, lb/hr (% of baseline)	0.0007 (733.6%)	-0.0086 (-46.7%)	
Estimated oxidized and elemental emissions with halide injection, lb/hr (% of total) (4)	NA	0.0053 (49.9%)	0.0045 (42.2%)
Estimated oxidized and elemental difference, lb/hr (% of baseline)	NA	-0.0110 (-67.5%)	0.0024 (117.4%)

Parameter	Particulate	Elemental	Oxidized
Increase/Decrease in emissions, lb/yr(5)	**5.82**	**-87.75**	**19.30**
Standard Pellet Production - Scrubber Solids Removal			
Baseline, lb/hr (% of total)(1)	0.0001 (0.7%)	0.0188 (99.3%)	
Estimated oxidized and elemental emissions with no halide injection, lb/hr (% of total) (2)	NA	0.0167 (88.2%)	0.0021 (11.1%)
Long-term halide injection, lb/hr (% of total)(6)	0.0004 (5.8%)	0.0071 (94.2%)	
Difference, lb/hr (% of baseline)	0.0003 (243.1%)	-0.0117 (-62.4%)	
Estimated oxidized and elemental emissions with halide injection, lb/hr (% of total) (4)	NA	0.0038 (51.0%)	0.0032 (43.2%)
Estimated oxidized and elemental difference, lb/hr (% of baseline)	NA	-0.0129 (-77.1%)	0.0011 (53.4%)
Increase/Decrease in emissions, lb/yr(5)	**2.48**	**-102.86**	**9.01**
Mustang Pellet Production - Recycling Scrubber Solids			
Baseline, lb/hr (% of total)(6)	0.0002 (1.9%)	0.0129 (98.1%)	
Estimated oxidized and elemental emissions with no halide injection, lb/hr (% of total) (2)	NA	0.0115 (87.1%)	0.0015 (11.0%)
Long-term halide injection, lb/hr (% of total)(6)	0.0021 (17.5%)	0.0101 (82.5%)	
Difference, lb/hr (% of baseline)	0.0019 (761.0%)	-0.0028 (-21.8%)	
Estimated oxidized and elemental emissions with halide injection, lb/hr (% of total) (4)	NA	0.0055 (44.7%)	0.0046 (37.8%)
Estimated oxidized and elemental difference, lb/hr (% of baseline)	NA	-0.0060 (-52.3%)	0.0032 (219.3%)
Increase/Decrease in emissions, lb/yr(5)	**15.14**	**-48.01**	**25.47**

(1) Emissions are the sum of Method 29 testing data from stacks STRU 15 and STRU 16 because Line 2 flue gas is vented through separate stacks (Reference (19)).

(2) Elemental and oxidized emissions during the baseline are estimated by applying the industry average ratio of elemental-to-oxidized mercury under existing conditions to the gas phase mercury emissions from Method 29 (back-half). Refer to Table 1 of the Taconite Industry Local Deposition Evaluation for details (Reference (20)). Method 29 does not measure elemental and oxidized mercury independently.

(3) Long-term emission rates during halide injection were calculated by averaging Method 29 testing data when scrubber solids were recycled back to the process and multiplying by 2 to reflect the total Line 2 emissions. One stack was tested during the long-term halide injection.

(4) Elemental and oxidized emissions during the long-term test are estimated by applying the industry average ratio of elemental-to-oxidized mercury under halide injection testing conditions to the gas phase mercury emissions from Method 29 (back-half). Refer to Table 1 of the Taconite Industry Local Deposition Evaluation for details (Reference (20)). Method 29 does not measure elemental and oxidized mercury independently.

(5) Assumes 7,992 hours of annual furnace operation based on UTAC's TVOP operating limit.

(6) The Method 29 testing data was multiplied by 2 to represent the combined Line 2 emission rates because only one stack was tested during this testing condition.

Third party technical experts reviewed the impact of mercury reduction technologies (halide injection and ACI) on local mercury deposition (Local Deposition Evaluation, Reference (20)). Screening calculations indicate that increased particulate or oxidized mercury emissions from halide injection would increase local mercury deposition to the Northeast Region (defined by the TMDL, which includes the Iron Range) even if the technology decreased total mercury emissions (Reference (20)). 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 (20)). Therefore, the observed 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 (-48.01 lb/yr for Mustang pellet production) was more significant than the increase in oxidized mercury emissions (25.47 lb/yr for Mustang pellet production). Table 2 of the Local Deposition Evaluation (Reference (20)) demonstrates that even a small increase in oxidized mercury emissions can increase local mercury deposition. In contrast to elemental mercury, oxidized mercury is water soluble and readily deposited through precipitation at the local level (i.e. within a few miles of the emission source) (Reference (20)). 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 (42)) and in New England (References (43), (44)). In the evaluation by Florida Department of Environmental Protection (Reference (42)), 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 (44)). Associated with increased local deposition of mercury, fish tissue mercury concentrations were elevated in nearby water bodies (References (42), (44)). As such, 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 (20)) demonstrates that even a small increase in oxidized mercury emissions can increase local deposition of mercury and loading to the environment. As demonstrated by Table 4-4, halide injection is likely to increase oxidized mercury emissions.

EPA Method 29 testing data and extrapolations in Table 4-4 show that halide injection resulted in significantly increased oxidized mercury emissions at UTAC, which directly contradicts the purpose of the TMDL to reduce mercury concentrations in fish tissue. Since the environmental impacts at a reduced halide injection rate were considered unacceptable, then the increased halide injection rates used during the Pre-TMDL research would yield similar or more severe environmental impacts.

In addition, the increase in particulate-bound mercury (Table 4-4) 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 (20)). 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 (20)).

Halide injection increases oxidized and particulate mercury emissions and directly contradicts the purpose of the TMDL to reduce mercury concentrations in fish tissue. Therefore, halide injection is considered to cause unacceptable environmental impacts and was eliminated from further consideration.

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

Table 4-5 summarizes the control effectiveness of the remaining mercury reduction technologies.

Table 4-5 Control Effectiveness of Remaining Mercury Emissions Reduction Technologies

Reduction Technology		Total Mercury Control Efficiency	Continue to Next Step?
Mercury capture by existing wet scrubbers with solids removal		10%(1)	No
Activated carbon injection	With baghouse	88.1%(2)	Yes
	With replacement high efficiency scrubber	82%(3)	Yes
Fixed carbon bed		99%(4)	Yes
GORE^{TM}		72%(5)	Yes

(1) Mass balance supported by scrubber solids mercury sampling, and assuming one pound of mercury in scrubber solids equates to one pound reduction in mercury air emissions (Reference (45)).

(2) Slip stream baghouse testing at Keetac (Reference (37)) indicated that brominated PAC could reduce mercury emissions by 88.1%. UTAC has not tested this technology, but will assume for the BAMRT analysis that an 88.1% reduction can be achieved.

(3) Keetac installed a new high efficiency scrubber in 2006 and conducted Phase II ACI testing similar to UTAC. Keetac obtained an 82% reduction in vapor phase mercury emissions at a PAC injection rate of 7 lb/MMacf (Reference (46)). The total mercury reduction was lower than 82% because the increased particulate loading to the wet scrubber increased the particulate emissions at the stack. However, UTAC assumes that a new high efficiency scrubber could be designed to accommodate the increased particulate loading from ACI. Therefore, UTAC assumes a total mercury reduction of 82% is achievable at an injection rate of 7 lb/MMacf.

(4) Vendor estimated control efficiency and most literature for fixed bed control efficiency values reference a control efficiency greater than 99%. This has never been tested on a full-scale at a taconite facility. Therefore, UTAC assumes a 99% control efficiency for the purposes of this analysis.

(5) Testing conducted at UTAC indicated that a 72% mercury reduction level may be achievable (Reference (40)). UTAC assumes a 72% mercury reduction value for the purposes of this analysis.

Only mercury capture by existing wet scrubbers with solids removal cannot meet the reductions required by Minn. R. 7007.0502, subp. 6. Therefore, this technology will be evaluated in the facility's BAMRT Alternative Analysis, if necessary. All remaining mercury emissions reduction technologies listed in Table 4-5 are believed to be capable of meeting the 72% mercury emission reduction target and were further evaluated in Step 7.

4.7 Step 7 – Determine if the Technology is Cost Effective

ACI with a baghouse, ACI with a replacement high efficiency scrubber, fixed carbon beds, and GORE^{TM} are the remaining technologies in the BAMRT analysis and were evaluated for cost effectiveness.

4.7.1 Cost Effectiveness Threshold

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

In rule development for the Mercury Cell Chlor-Alkali Plant MACT, EPA stated that “EPA has not established a clear cost effectiveness level for mercury reductions that are considered acceptable” (Reference (47)). 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 (48)).

Table 4-6 Cost Effectiveness Values Considered by EPA in MACT Rule Development

Cost Effectiveness ($ per lb mercury)	Accepted by EPA	Regulation	Standard Considered
$1,300 (Reference (49))	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 (50))	Yes	Portland Cement MACT 40 CFR 63 Subpart LLL	Recalculated floor from 58 to 55 lb mercury/MMtons clinker
$7,100 (Reference (48))	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 (48))	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 (51))	Proposed	Mercury Cell Chlor-Alkali Plant MACT 40 CFR 63 Subpart IIIII	Non-mercury technology option
$27,016 (Reference (52))	Yes	Mercury and Air Toxics Standards (MATS) (existing Electrical Generating Units [EGUs]) 40 CFR 63 Subpart UUUUU	Beyond the floor standard of 4 lb mercury/ TBtu using brominated ACI
$44,000 (Reference (49))	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 (53))	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 (54))	No	Taconite MACT 40 CFR 63 Subpart RRRRR	Beyond the floor, wet scrubbers wasting
$61,000 - $183,500 (Reference (55))	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 (56))	No	Sewage Sludge Incinerator MACT	Beyond the floor, afterburners, ACI, and fabric filters
$100,000 (Reference (49))	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 (57))	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 reduction options, the taconite processing industry reviewed the cost effectiveness of mercury reduction 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 reduction, based on the strong similarities between the taconite processing source category and the ferromanganese production source category regulated under the Ferroalloys Production MACT. The $7,100 cost effectiveness value is equal to the cost effectiveness value EPA found to be acceptable for new and reconstructed ferromanganese production furnaces using brominated activated carbon injection with a polishing baghouse in the Ferroalloys Production MACT.

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

From the review of MACT standards (Table 4-6), 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 does not provide a strong basis of comparison because the mercury reduction option being considered was a completely new process that eliminated the use of mercury altogether. The $27,016 cost effectiveness value for the Mercury Air Toxics Standard at existing electric generating units also is not a clear analogue because power generation is a much larger market and cost increases can more readily be passed on to consumers, unlike the taconite industry.

4.7.2 Economic Evaluation of Remaining Mercury Reduction Technologies

The annualized cost includes both capital and operating costs. Economic impacts were analyzed using the procedures found in the EPA Air Pollution Control Cost Manual (CCM, References (58), (59)). 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 4-7 details the expected costs associated with the installation of the above mercury reduction technologies for installations on each furnace. Equipment design is based on mercury control efficiencies outlined in Table 4-5, baseline values determined in Section 3, vendor estimates, and the CCM (References (58), (59)). 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

7,992 hours, based on UTAC's TVOP. Operating costs of consumable materials, such as electricity, water, and chemicals were established based on the CCM and Barr's 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) was included in the costs to account for the retrofit installation. Retrofit installations have increased difficult 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.). The use of a retrofit factor has been justified by previous BART projects and with UTAC and the MPCA (References (60), (61)). 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 (58), (59)). Retrofits can impose additional costs to "shoe-horn" equipment in existing plant space, which is true for UTAC.

A site-specific estimate of site preparation and ductwork was added to arrive at the total installed cost. Finally, based on the scale and complexity of the proposed equipment installations, it was assumed that it would take 14 more days than an annual 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 was 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, which contains a significant amount of contingency to account for unknowns without detailed engineering (Reference (62)). Note, the CCM does not consider contingencies to be the same as uncertainty or retrofit factor costs and are treated separately (References (58), (59)).

For ACI with baghouse, the wet scrubbers would be replaced by a new baghouse. Installing a baghouse downstream of a wet scrubber is infeasible because the water-saturated flue gas stream presents bag-plugging concerns.

Installing a fixed carbon bed downstream of the existing wet scrubbers is not appropriate because a water-saturated flue gas stream causes moisture to coat the carbon adsorption sites and reduces the carbon bed's ability to adsorb mercury. Fixed carbon beds require enhanced particulate control to avoid plugging. Therefore, UTAC would be required to install a baghouse to replace the existing wet scrubbers upstream of the fixed carbon beds to achieve sufficient filterable particulate control and avoid issues with water-saturated flue gas.

For fixed carbon bed and ACI with baghouse technologies, UTAC 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 scrubbers.

Finally, UTAC recently started producing flux pellets, in addition to standard pellets, as a result of its Mustang project. Therefore, as discussed in Section 4.1.7, the mercury control achieved during GORE^{TM} pilot testing for standard pellet production may not be achievable for fluxed pellet production. This analysis does not account for design parameter changes for fluxed pellet production as a conservative approach, but fluxed pellet production may require additional costs for a full-scale installation.

Table 4-7 Cost Effectiveness of Mercury Reduction Technologies

Mercury Reduction Technology	Total Capital Investment with Retrofit Factor ($)	Total Annual Cost ($/yr)	Annualized Pollution Control Cost ($/lb)
Line 1			
ACI with Baghouse	$32,850,000	$6,120,000	$200,200
ACI with replacement high efficiency scrubbers	$33,010,000	$6,885,000	$242,000
Fixed Carbon Bed	$47,030,000	$7,676,000	$223,500
GORE^{TM}	$40,510,000	$5,167,000	$206,800
Line 2A/B			
ACI with Baghouse	$61,750,000	$11,630,000	$116,300
ACI with replacement high efficiency scrubbers	$63,570,000	$13,420,000	$144,200
Fixed Carbon Bed	$86,590,000	$14,350,000	$127,700
GORE^{TM}	$81,560,000	$10,380,000	$127,000

Appendix B contains the detailed cost analysis. The cost effectiveness of the four remaining reduction technologies for the facility varies from $116,300 to $242,000 per pound of mercury removed. None of these technologies are cost effective because the costs exceeded the $7,100 per pound of mercury removed threshold (refer to Section 4.7.1). Therefore, the four remaining technologies were eliminated from further consideration.

4.8 Step 8 – Determination of BAMRT for UTAC

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, ACI with replacement high efficiency scrubbers, 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, with the exception of mercury capture by existing wet scrubbers with solids removal, which is further evaluated under the BAMRT Alternative Analysis in Section 5.

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, UTAC proceeded to evaluate certain mercury reduction technologies that may achieve an alternate removal rate, according to Minn. R. 7007.0502, subp. 5(A)(2).

Only one technology, mercury capture by existing wet scrubbers with solids removal, did not reduce emissions by 72% but still satisfied the other adaptive management and environmental impacts criteria and was therefore subject to the BAMRT Alternative Evaluation process. The purpose of the BAMRT Alternative Evaluation was to determine what percent reduction of mercury air emissions is technically achievable from UTAC's indurating furnaces, again using appropriate evaluative criteria. Figure 4-1 (Section 4) summarizes this process and its connection to the overall BAMRT analysis. The MPCA's Mercury Reduction Plan submittal (Ferrous mining/processing) form (MPCA Form aq-ei2-04a), Item 3(a) provides six steps to evaluate reduction technologies and determine which control strategy to include in UTAC's MERP; details are included in Sections 5.1 through 5.6 below.

5.1 Step 1 – Identify and Rank Technologies from BAMRT

UTAC sends scrubber discharge water to a thickener to concentrate captured solids. The thickened solids are recovered, routed to the pellet plant disc filters and added back into the greenballs. UTAC has the ability to remove scrubber solids from its process and dispose of the solids in the tailings basin where they are permanently sequestered (Reference (22)). This is the only technology in the BAMRT Alternative Evaluation and thus ranking is not appropriate. This technology continues onto Step 2.

5.2 Step 2 – Eliminate Technically Infeasible Technologies

Mercury capture by existing wet scrubbers with solids removal is technically feasible and proceeded to Step 3 of the BAMRT Alternative Evaluation.

5.3 Step 3 – Rank Remaining Technologies

Mercury capture by existing wet scrubbers with solids removal remains the only technology under consideration at this step, and it was evaluated under Step 4 of the BAMRT Alternative Evaluation.

5.4 Step 4 – Complete an Environmental Impacts Analysis

UTAC evaluated the reduction technology's environmental impacts. The MPCA's Mercury Reduction Plan submittal (Ferrous mining/processing) form describes evaluating environmental impacts other than direct impacts due to emissions of mercury, such as solid or hazardous waste generation, discharges of polluted water from a control device, demand on local water resources, and emissions of other regulated air pollutants.

Table 5-1 Environmental Impacts Analysis – Mercury Capture by Existing Wet Scrubbers with Solids Removal

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

Mercury capture by existing wet scrubbers with solids removal is not anticipated to cause material adverse environmental impacts. Therefore, the technology proceeded to Step 5 of the BAMRT Alternative Evaluation.

5.5 Step 5 – Complete a Cost Effectiveness Evaluation

UTAC determined mercury capture by existing wet scrubbers with solids removal was not cost effective because it is greater than the cost effectiveness threshold ($34,000 compared to $7,100), eliminating this control strategy from further consideration. Table 5-2 summarizes the control costs for mercury capture by existing wet scrubbers with solids removal; the methodology and assumptions used to determine the control costs are discussed in Section 4.7.2.

Table 5-2 Cost Effectiveness of Mercury Reduction Technologies

Mercury Reduction Technology	Total Capital Investment with ($)	Total Annual Cost ($/yr)	Annualized Pollution Control Cost ($/lb)
Facility Total			
Mercury capture by existing wet scrubbers with solids removal	N/A – Existing equipment has the ability to route scrubber solids to the tailings basin already	$504,000(1)	$34,000

(1) Annual cost is a result of the lost iron units calculated based on UTAC's total mass of scrubber solids removed in 2013 (11,680 long ton/12-month) and the finished pellet costs ($43.11/long ton - refer to Appendix B for details). The total mass of scrubber solids removed value was calculated based on the data gathered during the associated time period in accordance with UTAC's TVOP Appendix G methodology.

5.6 Step 6 – Select Control Strategy

Mercury capture by existing wet scrubbers with solids removal was determined to not be technically achievable because the reduction technology was not cost effective.

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: United Taconite LLC - Fairlane Plant

1.b. AQ facility ID number: 13700113

1.c. Facility contact for this reduction plan: Candice Maxwell

1.d. Agency Interest ID number: 140099

1.e. Facility contact email address: Candice.Maxwell@clevelandcliffs.com

1.f. Facility contact phone number: (218) 744-7849

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.

UTAC sends scrubber discharge water to a thickener to concentrate captured solids. The thickened solids are recovered, routed to the pellet plant disc filters and added back into the greenballs. UTAC has the ability to remove scrubber solids from its process and dispose of the solids in the tailings basin where they are permanently sequestered. This is the only technology in the BAMRT Alternative Evaluation and thus ranking is not appropriate. This technology continues onto Step 2.

Refer to Section 5.1 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.

Mercury capture by existing wet scrubbers with solids removal is technically feasible and proceeded to Step 3 of the BAMRT Alternative Evaluation.

Refer to Section 5.2 of the attached Best Available Mercury Reduction Technology Analysis.

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

Mercury capture by existing wet scrubbers with solids removal remains the only technology under consideration at this step, and it was evaluated under Step 4 of the BAMRT Alternative Evaluation.

Refer to Section 5.3 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.

Mercury capture by existing wet scrubbers with solids removal is not anticipated to cause material adverse environmental impacts. Therefore, the technology proceeded to Step 5 of the BAMRT Alternative Evaluation.

Refer to Section 5.4 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.

UTAC determined mercury capture by existing wet scrubbers with solids removal was not cost effective because it is greater than the cost effectiveness threshold ($34,000 compared to $7,100), eliminating this control strategy from further consideration.

Refer to Section 5.5 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.

Mercury capture by existing wet scrubbers with solids removal was determined to not be technically achievable because the reduction technology was not cost effective.

Refer to Section 5.6 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.

UTAC's Baseline Emissions = 148.3 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 = 148.3 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)**
Line 1 (EQUI 45 / EU040), Line 2A/B (EQUI 47 / EU042)	Evaluate engineering solutions for iron unit recovery from scrubber solids removal	TBD	See Section MERP-1.2.1

Facility-wide	Technology review and BAMRT analysis, as needed	TBD	See Section MERP-1.2.2
N/A	Evaluate acquiring mercury reduction credits from other taconite facilities	TBD	See Section MERP-1
Refer to Section MERP-1.2 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)
Line 1 (EQUI 45 / EU040), Line 2A/B (EQUI 47 / EU042)	Evaluate engineering solutions for iron unit recovery from scrubber solids removal	NA – UTAC will evaluate engineering solutions by June 30, 2021. UTAC will revise and resubmit the MERP by June 30, 2022 should the cost effectiveness determination change.				
Facility-wide	Literature review and/or vendor screening with BAMRT analysis	N/A - UTAC will conduct a literature review and/or vendor screening between May 1, 2020 and July 31, 2020. UTAC will revise and resubmit the MERP by June 30, 2022 if a new, viable technology is identified through the BAMRT analysis.				
N/A	Evaluate acquiring mercury reduction credits from other taconite facilities	N/A – UTAC will evaluate acquiring mercury reduction credits from other facilities prior to June 30, 2022 (when the revised MERP would otherwise be due).				
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
Line 1 (EQUI 45 / EU040)	2.73 E-05 lb / long ton of pellets	May 4, 2006 Stack Test	34.7 lb / yr	May 4, 2006 Stack Test

Line 2A/B (EQUI 47 / EU042)	2A = 3.11 E-05 lb / long ton of pellets 2B = 2.86 E-05 lb / long ton of pellets	October 11-12, 2016 Stack Test	2A = 59.0 lb / yr 2B = 54.5 lb / yr	October 11-12, 2016 Stack Test
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 proposed alternative actions. UTAC would revise this section if any reduction technologies are found to be cost effective in the future.

Refer to 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
Line 1 (EQUI 45 / EU040), Line 2A/B (EQUI 47 / EU042)	NA	NA	Mercury stack emissions	Periodic stack testing	N/A	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:

UTAC determined that it is not appropriate to use CMMs for continuous compliance determination (neither the sorbent tube system nor a CMM). For periodic testing, EPA 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, UTAC proposes to enter into an enforceable compliance agreement to meet the proposed strategies and associated deadlines described in items 4 and 5 (Sections MERP-1.2 and MERP-1.3). Should mercury capture by existing wet scrubbers with scrubber solids removal or other identified New Technologies as described in items 4 and 5 (Sections MERP-1.2 and MERP-1.3), above, become technically achievable in the future, UTAC will submit regulatory permit applications, as deemed appropriate.

The stack testing frequency proposed under the monitoring and recordkeeping (item 7b and Section MERP-1.5.2) is already an enforceable requirement under UTAC's existing TVOP.

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 UTAC'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: Chad Asgaard
Title: General Manager Date 12/19/18
Signature:
Phone: (218) 744-6052 Fax: (218) 744-7874

Co-permittee responsible official (if applicable)

Print name:
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 development of UTAC's MERP. UTAC determined that none of the proposed reduction technologies were technically achievable or without unacceptable environmental impacts in the BAMRT analysis. UTAC proposes the following alternative actions in the MERP:

1. UTAC will evaluate engineering solutions to improve iron unit recovery during scrubber solids removal by June 30, 2021.
2. UTAC 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.

3. If another taconite facility reduces its mercury emissions beyond what is required by the Minnesota Mercury Rule and MPCA approves that facility's MERP, UTAC will evaluate acquiring those mercury emission reduction credits and applying them towards UTAC's mercury reduction program.
4. UTAC proposes to revise and resubmit the MERP by June 30, 2022 should an engineering solution identify a strategy that changes the cost effectiveness determination for scrubber solids removal, if a viable, New Technology is identified through the updated BAMRT process, or if excess mercury emission reduction credits become available through another taconite facility's approved MERP. UTAC will not re-evaluate technologies or outcomes already considered in the 2018 BAMRT or MERP. If no new technologies are identified, UTAC will submit notification to 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 Mercury Reduction Plan submittal (Ferrous mining/processing) 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 UTAC's emissions before and after employing the proposed alternative actions.

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

Emission Unit	Baseline Emissions lb/yr	Percent Reduction	Estimated Emissions lb/yr
Line 1 (EQUI 45 / EU040)	34.7	NA(1)	34.7
Line 2A (EQUI 47 [STRU 16] / EU042 [SV048])	59.0	NA(1)	59.0
Line 2B (EQUI 47 [STRU 15] / EU042 [SV049])	54.5	NA(1)	54.5
TOTAL	**148.3**	NA(1)	**148.3**

(1) 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 Mercury Reduction Plan submittal (Ferrous mining/processing) form, item 4 states the following and UTAC'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 Emissions Reduction Plan Action

Emission Unit	Reduction Element(1)	Reduction, control efficiency, emission limit, operating limit, or work practice(2)	Describe element in detail(3)
Line 1 (EQUI 45 / EU040), Line 2A/B (EQUI 47 / EU042)	Evaluate engineering solutions for iron unit recovery from scrubber solids removal	TBD	See Section MERP-1.2.1
Facility-wide	Technology review and BAMRT analysis, as needed	TBD	See Section MERP-1.2.2
NA	Evaluate acquiring mercury reduction credits from other taconite facilities	TBD	See Section MERP-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 Improve Iron Unit Recovery for Mercury Capture by Existing Wet Scrubbers with Solids Removal

UTAC proposes to evaluate engineering solutions to improve iron unit recovery during scrubber solids removal, which, in turn, could improve the mercury capture by existing wet scrubbers with solids removal cost effectiveness. One such engineering solution is magnetic separation. The pre-TMDL research indicated that magnetic separation could potentially reject 76-85% of the captured mercury at UTAC and potentially recover 42-68% of iron (Reference (63)). UTAC will evaluate the feasibility and cost effectiveness of various engineering solutions, including magnetic separation, by June 30, 2021. UTAC proposes to review, revise, and resubmit the MERP by June 30, 2022 should the engineering solutions change the cost effectiveness determination for scrubber solids removal.

MERP-1.2.2 Literature Review and/or Vendor Screening with BAMRT Analysis

UTAC will conduct a literature review and/or vendor screening between May 1, 2020 and July 31, 2020 to determine if any new mercury emission 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, UTAC 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 Mercury Reduction Plan submittal (Ferrous mining/processing) form, item 5 states the following and UTAC'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
Line 1 (EQUI 45 / EU040), Line 2A/B (EQUI 47 / EU042)	Evaluate engineering solutions for iron unit recovery from scrubber solids removal	NA – UTAC will evaluate engineering solutions by June 30, 2021. UTAC will revise and resubmit the MERP by June 30, 2022 should the cost effectiveness determination change.				
Facility-wide	Literature review and/or vendor screening with BAMRT analysis	N/A - UTAC will conduct a literature review and/or vendor screening between May 1, 2020 and July 31, 2020. UTAC will revise and resubmit the MERP by June 30, 2022 if a new, viable technology is identified through the BAMRT analysis.				
N/A	Evaluate acquiring mercury reduction credits from other taconite facilities	N/A – UTAC will evaluate acquiring mercury reduction credits from other facilities prior to June 30, 2022 (when the revised MERP would otherwise be due).				

MERP-1.4 Calculation Data (MPCA Form item 6)

The MPCA's Mercury Reduction Plan submittal (Ferrous mining/processing) 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.

An editable spreadsheet with the mercury emission reduction calculations are included in Appendix C.

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

The MPCA's Mercury Reduction Plan submittal (Ferrous mining/processing) 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).

Emission factors used to calculate the baseline mercury emissions are included in Section 3 of the BAMRT analysis.

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 Mercury Reduction Plan submittal (Ferrous mining/processing) 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 proposed alternative actions. UTAC would revise this section if any reduction technologies are found to be cost effective 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. UTAC operates the existing wet scrubbers in accordance with the TVOP, including the associated operating and maintenance plans, and good air pollution control practices.
2. UTAC will continue to operate and maintain control equipment and the indurating furnace in a manner consistent the TVOP, including the associated operating and maintenance plans, good air pollution control practices and with manufacturer and industry best management practices.

3. UTAC's TVOP permit conditions 5.35.13, 5.35.14, 5.37.13, and 5.37.14 allow the indurating furnaces to combust solid fuel (pulverized coal and blends of coal and petroleum coke), distillate oil, and natural gas as fuel sources. UTAC is required to routinely switch fuel sources to manage compliance with associated NO_x and SO_2 Title I conditions. Therefore, UTAC optimizes the fuel sources as much as technically feasible while maintaining compliance with the associated TVOP emission limits. Additionally, the indurating furnaces fuel sources are immaterial to the overall mercury emissions as demonstrated as part of UTAC's TVOP Appendix G: Waste Gas Scrubber Solids and Mercury Analysis Plan requirements.
4. UTAC mines taconite ore near its indurating furnace from controlled and limited mineral deposits. It is not feasible for UTAC 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 Mercury Reduction Plan submittal (Ferrous mining/processing) 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).

UTAC proposes to conduct stack testing once every five years using EPA approved test methods, consistent with Minn. R. 7019.3050(E)(5) and UTAC's existing TVOP.

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
Line 1 (EQUI 45 / EU040), Line 2A/B (EQUI 47 / EU042)	NA	NA	Mercury stack emissions	Periodic stack testing	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 (MPCA Form item 7c)

The MPCA's Mercury Reduction Plan submittal (Ferrous mining/processing) 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.

UTAC 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 (25), (35)). 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. UTAC used modified EPA Method 30B to compare and confirm results of the temporary extractive CMMs during Phase II testing (Reference (35)).

UTAC has also used EPA Method 30B for mercury reduction screening during recent halide injection trials (Reference (19)). UTAC used Method 30B data to compare emissions while varying injection rates because of the ability to determine results on-site.

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

- **Appropriateness of monitoring frequency**

  Minn. R. 7007.0502 and the MPCA's Mercury Reduction Plan submittal (Ferrous mining/processing) 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 impacted by stack gas moisture which is typically near the saturation point in most taconite facilities' flue 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 (64)) is used, it is possible that the quality control criteria could allow the monitor to differ from the actual emissions value by a large margin of error that could impact data accuracy at the expected low-level concentrations.

- **Cost prohibitive**

  The capital investment costs are high, especially at facilities with more than one stack.

  CMMs are challenging to install and operate and require knowledgeable on-site staff for calibrations, maintenance, sample analysis, etc.

MERP-1.6 MERP Enforceability (MPCA Form item 8)

The MPCA's Mercury Reduction Plan submittal (Ferrous mining/processing) form, item 7c 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, UTAC proposes to enter into an enforceable compliance agreement to meet the proposed strategies and associated deadlines described in Sections MERP-1.2 and MERP-1.3. Should mercury capture by existing wet scrubbers with scrubber solids removal or other identified New Technologies as described in Sections MERP-1.2 and MERP-1.3, above, become technically achievable in the future, UTAC will submit regulatory permit applications, as deemed appropriate.

The stack testing frequency proposed under the monitoring and recordkeeping (Section MERP-1.5.2 or MPCA Form item 7b) is already an enforceable requirement under UTAC's existing TVOP.

MERP-1.7 Additional Information (MPCA Form item 9)

The MPCA's Mercury Reduction Plan submittal (Ferrous mining/processing) 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 UTAC's MERP.

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Appendix A

Historical Mercury Reduction Research Reports

See Appendix A_UTAC BAMRT and MERP FINAL File

Appendix B

Mercury Reduction Technology Control Cost Workbook

Appendix B-1

Mercury Reduction Technology Control Cost Workbook – Line 1

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 1 - Cost Evaluation Summary for Line 1

Hg Control Technology Description

Technology Name		Fixed Carbon Beds	GORE	ACI with High Efficiency Scrubber	ACI with Baghouse
Expected Equipment Life (years)	[1]	20	20	20	20
Expected Utilization Rate (% of Capacity)	[1]	100%	100%	100%	100%
Expected Annual Hours of Operation (hr/year)	[1]	7,992	7,992	7,992	7,992
Notes on Technology					

Control Equipment Costs

Capital Costs					
Direct Capital Costs (DC)	[2]	$25,552,650	$20,926,382	$17,664,169	$17,949,785
Indirect Capital Costs (IC)	[2]	$6,007,643	$5,906,629	$4,481,799	$4,096,773
Total Capital Investment (TCI = DC + IC)	[2]	$31,560,293	$26,833,011	$22,145,968	$22,046,558
Total Capital Investment (TCI = DC + IC) with Retrofit Factor	[2]	$47,034,887	$40,508,035	$33,008,766	$32,849,711
Operating Costs					
Direct Operating Costs ($/year)	[3]	$1,648,208	$208,194	$2,477,297	$1,905,315
Indirect Operating Costs ($/year)	[3]	$6,028,243	$4,958,611	$4,408,132	$4,215,045
Total Annual Cost ($/year)	[4]	$7,676,451	$5,166,805	$6,885,429	$6,120,360

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]

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 1 - Cost Evaluation Summary for Line 1

Hg Emission Controls

Baseline Hg Emission Rate (lb/year)	[6]	34.7

Hg Control Efficiency (mass%)	[7]	99.00%	72.00%	82.00%	88.10%
Controlled Hg Emission Rate (lb Hg/year)	[8]	0.35	9.72	6.25	4.13
Hg Mass Removed from Exhaust (lb Hg/year)	[9]	34.35	24.98	28.45	30.57
Hg Control Cost Effectiveness ($/lb Hg removed)	[10]	$223,458	$206,805	$241,985	$200,203

Footnotes

[1] Documentation of technology parameters noted

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

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 1 - Cost Evaluation Summary for Line 1

[2] See Table 2 - Capital Costs

[3] See Table 3 - Operating Costs

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

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

[6] Line 1 baseline mercury emissions based on 2008 throughput data and 2006 Line 1 (natural gas) stack test emission factor. Refer to the BAMRT analysis for details.

[7]

Documentation of Hg Control Efficiency for each control technology.	Vendor stated that they typically guarantee >99% control. This is consistent with most sources, which cite 99% control or higher.	GORE testing at Cleveland Cliffs United Taconite indicated that a 72% reduction per the rule may be achievable. UTAC will assume that this technology can reduce mercury emissions by 72%.	*Minnesota Taconite Mercury Reduction Research - Phase II Summary* report indicated that brominated PAC could achieve an 82% gas phase mercury reduction at U. S. Steel Keetac with a high efficiency scrubber. UTAC will assume that the new scrubber could achieve the same total mercury reduction due to the increased particulate control.	*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. UTAC 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
United Taconite (UTAC)
Table 2 - Capital Costs for Installations for Line 1

Hg Control Technology Description

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

Current Chemical Engineering Plant Cost Index (CEPCI)		572.9	572.9	572.9	572.9
CEPCI of Equipment Cost Estimate Year		N/A	N/A	N/A	N/A
Direct Capital Costs (DC)		**$25,552,650**	**$20,926,382**	**$17,664,169**	**$17,949,785**
Purchased Equipment Costs					
Equipment Costs	[1]	$6,846,317	$8,355,974	$5,931,247	$5,086,000
Instrumentation	[2]	$684,632	$835,597	$593,125	$0
Sales Tax	[3]	$470,684	$574,473	$407,773	$349,663
Freight	[4]	$342,316	$417,799	$296,562	$254,300
Generalized Installation Costs					
Basis for Installation Costs	[5] [6]	Fabric Filter	Carbon Adsorber System	Venturi Scrubber	Fabric Filter
Foundations and Supports	[5]	$333,758	$814,707	$433,722	$227,599
Handling & Erection	[5]	$4,171,974	$1,425,738	$2,891,483	$2,844,981
Electrical	[5]	$667,516	$407,354	$72,287	$455,197
Piping	[5]	$83,439	$203,677	$361,435	$56,900
Insulation	[5]	$584,076	$101,838	$216,861	$398,297
Painting	[5]	$333,758	$101,838	$72,287	$0
Site-Specific Installation Costs					
Site Preparation (Grade & Level)	[13]	$59,000	$36,000	$36,000	$47,000
Ductwork	[13]	$2,000,633	$1,688,281	$1,688,281	$1,891,903
Buildings	[13]	$1,986,700	$621,800	$621,800	$1,078,100
Initial Carbon Charge	[13]	$1,728,000	N/A	N/A	N/A
Total Dry SO2 Control Costs	[13]	$1,218,542	N/A	N/A	$1,218,542
GORE Wastewater Treatment	[13]	N/A	$1,300,000	N/A	N/A
Lost Production During Installation	[13]	$4,041,304	$4,041,304	$4,041,304	$4,041,304
Extended Downtime Days for Tie-in and Restart	[13]	14	14	14	14

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 2 - Capital Costs for Installations for Line 1

Indirect Capital Costs (IC)		**$6,007,643**	**$5,906,629**	**$4,481,799**	**$4,096,773**
Basis for Installation Costs	[5] [6]	Fabric Filter	Carbon Adsorber System	Venturi Scrubber	Fabric Filter
Engineering & Supervision	[5]	$834,395	$1,018,384	$722,871	$568,996
Construction & Field Expenses	[5]	$1,668,790	$509,192	$722,871	$1,137,993
Contractor Fees	[5]	$834,395	$1,018,384	$722,871	$568,996
Start-Up Costs	[5]	$83,439	$203,677	$72,287	$56,900
Performance Test	[5]	$83,439	$101,838	$72,287	$56,900
Contingency	[5]	$2,503,185	$3,055,153	$2,168,612	$1,706,989
Contingency Percentage - Site-Specific	[5]	30%	30%	30%	30%

Retrofit Factor	[7]	1.60	1.60	1.60	1.60
Total Capital Investment (TCI)	[7]	**$31,560,293**	**$26,833,011**	**$22,145,968**	**$22,046,558**
Total Capital Investment (TCI) with Retrofit Factor	[7]	**$47,034,887**	**$40,508,035**	**$33,008,766**	**$32,849,711**

Capital Recovery

Interest Rate	[8]	7.0%	7.0%	7.0%	7.0%
Expected Equipment Life		20	20	20	20
Capital Recovery Factor (CRF)	[9]	9.44%	9.44%	9.44%	9.44%
Cost of Replacement Parts	[10]	$2,381,322	$4,002,000	$429,264	$429,264
Adjusted TCI for Capital Recovery	[11]	$44,653,565	$36,506,035	$32,579,502	$32,420,447
Capital Recovery Cost (CRC)	[12]	$4,214,981	$3,445,911	$3,075,275	$3,060,261

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 2 - Capital Costs for Installations for Line 1

Footnotes

[1]	Documentation of Capital Cost for Hg control technology.	Vendor estimate for fixed bed equipment and baghouse scaled for UTAC airflows. Fan costs were scaled using *Chemical Engineering Economics* , by Donald E, Garrett, Appendix 1 page 281. Vendor quote for new stack scaled for UTAC Line 1. Air compressor capital is split between Line 1 (1/3) and Line 2 (2/3) based on throughput percentage.	Vendor quote provided for GORE system. Fan costs were calculated using *Chemical Engineering Economics* , by Donald E, Garrett, Appendix 1 page 281. Vendor quote for new stack scaled for UTAC Line 1.	Vendor quote provided for a high efficiency scrubber. Fan costs were scaled using *Chemical Engineering Economics* , by Donald E. Garrett, Appendix 1 page 281. Vendor quote for a new stack scaled for UTAC Line 1. Includes ACI injection system.	Vendor quotes for new baghouses, fans, motors, and activated carbon injection system. Vendor quote for new stack scaled for UTAC Line 1. Air compressor capital is split between Line 1 (1/3) and Line 2 (2/3) based on throughput percentage.

[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 (typically 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 (typically 5%).

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 2 - Capital Costs for Installations for Line 1

[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 United Taconite 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 venturi scrubber.	Installed technology is a fabric filter. Instrumentation and painting costs are not referenced because the vendor quote already included these items.

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

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

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

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

Where: i = interest rate
n = number of years

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 2 - Capital Costs for Installations for Line 1

[10] See 'Table 4 - Replacement Parts for Line 1' 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	Site-specific engineering estimate
Ductwork	Site-specific engineering estimate	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	Site-specific engineering estimate
Initial Carbon Charge	Initial carbon loading cost provided by vendor	N/A	N/A	N/A
Total Dry SO2 Control Costs	Site-specific engineering estimate; scaled based on data from the 2009 UTAC Dry ESP Feasibility Study; includes equipment and installation costs	N/A	N/A	Site-specific engineering estimate; scaled based on data from the 2009 UTAC Dry ESP Feasibility Study; includes equipment and installation costs
GORE Wastewater Treatment	N/A	Design and cost estimate for treatment of the GORE effluent is an engineering estimate based on previous project experience. Value is installed capital cost multiplied by 1/3 since the treatment facility will accommodate approximately 1/3 of the total waste from Line 1.	N/A	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.	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 annual outage.	Estimate based on engineering experience. The downtime is the number of days beyond a typical annual outage.	Estimate based on engineering experience. The downtime is the number of days beyond a typical annual outage.	Estimate based on engineering experience. The downtime is the number of days beyond a typical annual outage.

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 3 - Operating Costs for Line 1

Hg Control Technology Description

Technology Name	**Fixed Carbon Beds**	**GORE**	**ACI with High Efficiency Scrubber**	**ACI with Baghouse**
Expected Utilization Rate (%)	100%	100%	100%	100%
Expected Annual Hours of Operation (hr/year)	7,992	7,992	7,992	7,992
Notes on Technology				

Direct Annual Costs (DAC, $/year)			**$1,648,208**	**$208,194**	**$2,477,297**	**$1,905,315**
Raw Materials						
Powdered Activated Carbon (HPAC)	Demand (lb/year)	[1]			1,433,285.28	225,230.54
	Retail Price ($/lb)	[2]			$1.12	$1.12
	Cost Per Year ($/year)	[3]			$1,605,279.51	$252,258
Hydrated Lime	Demand (ton/year)	[1]	901.17			901.17
	Retail Price ($/ton)	[2]	$250.00			$250.00
	Cost Per Year ($/year)	[3]	$225,293.74			$225,293.74
Utilities						
Electricity	Demand (kW-hr/year)	[4]	1,589,235.8	1,116,648.9	6,539,859.2	1,589,235.8
	Retail Price ($/kW-hr)	[2]	$0.068	$0.068	$0.068	$0.068
	Cost Per Year ($/year)	[3]	$108,624	$76,323	$446,999	$108,624
Makeup Water	Demand (1000 gal/year)	[4]			191,808	
	Retail Price ($/1000 gal)	[2]			$0.32	
	Cost Per Year ($/year)	[3]			$61,559	

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 3 - Operating Costs for Line 1

Operating Labor						
Operator	Worked Hours Per Year (hr/year)	[5]	1,998	500	4,995	1,998
	Cost Per Hour ($/hr)	[2]	$65.27	$65.27	$65.27	$65.27
	Cost Per Year ($/year)	[3]	$130,409	$32,602	$326,024	$130,409
Supervisor	Cost Per Year ($/year)	[6]	$19,561	$4,890	$48,904	$19,561
Maintenance						
Labor	Worked Hours Per Year (hr/year)	[7]	999	500	1,499	999
	Cost Per Hour ($/hr)	[2]	$65.27	$65.27	$65.27	$65.27
	Cost Per Year ($/year)	[3]	$65,205	$32,602	$97,807	$65,205
Materials	Cost Per Year ($/year)	[8]	$65,205	$32,602	$97,807	$65,205
Waste Management						
Non-Haz Solid Waste Offsite Disposal	Waste Production Rate (ton/year)	[9]	23,598.27			23,710.89
	Transport Demand (ton-mile/year)	[10]	0.00			0.00
	Disposal Fee ($/ton)	[2]	$43.06			$43.06
	Transport Fee ($/ton-mile)	[2]				
	Cost Per Year ($/year)	[11]	$1,016,036			$1,020,884
GORE Wastewater Treatment	Waste Production Rate (mgal/year)	[9]				
	Disposal Fee ($/mgal)	[2]				
	Cost Per Year ($/year)	[3]		$66,667		
Product Loss						
Taconite Pellets	Product Lost (ton/year)	[12]	4,360.62		4,360.62	4,360.62
	Retail Price ($/ton)	[2]	$38.49		$38.49	$38.49
	Cost Per Year ($/year)	[3]	$167,845		$167,845	$167,845

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 3 - Operating Costs for Line 1

Indirect Annual Costs (IAC, $/year)		**$6,028,243**	**$4,958,611**	**$4,408,132**	**$4,215,045**
Overhead	[13]	$168,228	$61,618	$342,325	$168,228
Administration	[14]	$631,206	$536,660	$442,919	$440,931
Property Tax	[15]	$315,603	$268,330	$221,460	$220,466
Insurance	[16]	$315,603	$268,330	$221,460	$220,466
Capital Recovery for Replacement Parts	[17]	$382,623	$377,760	$104,694	$104,694
Capital Recovery	[18]	$4,214,981	$3,445,911	$3,075,275	$3,060,261

Total Annual Costs (TAC = DAC + IAC, $/year)	**$7,676,451**	**$5,166,805**	**$6,885,429**	**$6,120,360**

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)			*Minnesota Taconite Mercury Reduction Research - Phase II Summary* report indicated that brominated PAC could achieve an 82% control at U. S. Steel Keetac with a high efficiency scrubber at an injection rate of 7 lb/mmacf. UTAC assumed the same injection rate.	*Project 4: Evaluation of a Slipstream Baghouse for the Taconite Industry* indicated that brominated PAC could achieve an 88.1% control at U. S. Steel Keetac with a 1.1 lb/mmacf injection rate. UTAC assumed the same injection rate.
Hydrated Lime	Lime injection rate for dry SO2 control conservatively estimated based on the 2009 UTAC Dry ESP Feasibility Study report and scaled for current Line 1 air flowrate.			Lime injection rate for dry SO2 control conservatively estimated based on the 2009 UTAC Dry ESP Feasibility Study report and scaled for current Line 1 air flowrate.

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 3 - Operating Costs for Line 1

[2] See 'Table 5 - Raw Material, Utility, and Waste Disposal Costs for Line 1' 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	No incremental electricity needs above existing conditions for fans. Electricity associated with the baghouse compressor is split between Lines 1 (1/3) and 2 (2/3) based on throughput percentage.	Assumed 1.22" pressure drop through modules based on vendor quote for vertical arrangement. Also included pressure drop due to ducting. EPA Air Pollution Control Cost Manual 6th Ed 2002, Chapter 1 equation 1.14. Electricity demand is only the incremental amount above baseline conditions.	Assumed 30" pressure drop per scrubber vendor quote minus the 20" pressure drop the existing fans can accommodate. Also included pressure drop due to ducting. EPA Air Pollution Control Cost Manual 6th Ed 2002, Chapter 1 equation 1.14. Electricity demand is only the incremental amount above baseline conditions.	No incremental electricity needs above existing conditions for fans. Electricity associated with the baghouse compressor is split between Lines 1 (1/3) and 2 (2/3) based on throughput percentage.
Makeup Water			Makeup water cost for high efficiency scrubber assumed to be $0.32 / 1000 gal per EPA Air Pollution Control Cost Manual 6th Ed 2002.	

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 3 - Operating Costs for Line 1

[5] Assumed 0.5, 2.0, and 5.0 hrs of operator attention per 8 hr shift of unit operation for units with a carbon adsorber, baghouse/fabric filter, and venturi scrubber, respectively.

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

[7] Assumed 0.5, 1.0, and 1.5 hrs of operator attention per 8 hr shift of unit operation for units with a carbon adsorber, baghouse/fabric filter, and venturi scrubber, 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. Includes solid waste due to dry sorbent (lime) injection for SO2 control.			Assumes that all of the solids captured by the baghouse would be disposed of as solid waste. Includes solid waste due to dry sorbent (lime) injection for SO2 control.
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. Cost has been multiplied by 1/3 because Line 1 accounts for 1/3 of the total waste.		

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 3 - Operating Costs for Line 1

[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	UTAC site-specific estimate of the lost iron production if pollution control dust is no longer recycled back to the pellet plant. Captured dust would be disposed of as solid waste due to the addition of SO2 control reagents.		UTAC site-specific estimate of the lost iron production if pollution control dust is no longer recycled back to the pellet plant. Scrubber solids would need to be removed to avoid recycling captured PAC and mercury.	UTAC site-specific estimate of the lost iron production if pollution control dust is no longer recycled back to the pellet plant. Captured dust would be disposed of as solid waste to avoid recycling captured PAC, SO2 control reagents, and mercury.

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

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

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

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

[17] See 'Table 4 - Replacement Parts for Line 1' for details.

[18] See 'Table 2 - Capital Costs for Installations for Line 1' for details.

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 4 - Replacement Parts for Line 1

Hg Control Technology Description

Technology Name		**Fixed Carbon Beds**	**GORE**	**ACI with High Efficiency Scrubber**	**ACI with Baghouse**
Notes on Technology					

Cost of Replacement Parts ($)		**$2,381,322**	**$4,002,000**		**$429,264**
Capital Recovery for Replacement Parts($/year)		**$382,623**	**$377,760**		**$104,694**
Replacement Part Name		Filter Bags	Gore Module		Filter Bags
Interest Rate	[1]	7.0%	7.0%		7.0%
Expected Life of Replacement Part (years)	[2]	5.00	20.00		5.00
Cost of Replacement Part ($/replacement)	[2]	$394,435	$3,927,000		$394,435
Cost of Labor for Replacement ($/replacement)	[2]	$34,829	$75,000		$34,829
CRF_P	[3]	24.39%	9.44%		24.39%
CRC_P ($/year)	[4]	$104,694	$377,760		$104,694
Replacement Part Name		Carbon Change			
Interest Rate	[1]	7.0%			
Expected Life of Replacement Part (years)	[2]	10			
Cost of Replacement Part ($/replacement)	[2]	$1,737,226			
Cost of Labor for Replacement ($/replacement)	[2]	$214,832			
CRF_P	[3]	14.24%			
CRC_P ($/year)	[4]	$277,929			

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 4 - Replacement Parts for Line 1

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. Equipment life of 5 years at $110/bag. Cost includes solid waste disposal of bags. Scaled linearly for UTAC L1 air flow.	Vendor quote for module cost. Includes vendor estimated disposal cost of $45/module.		Provided by baghouse manufacturer. Equipment life of 5 years at $110/bag. Cost includes solid waste disposal of bags. Scaled linearly for UTAC L1 air flow.
Documentation of Labor Costs for Replacement Part	EPA Air Pollution Control Cost Manual 6th Ed 2002 Chapter 1.5.1.4. Assumes 10 minutes per bag and UTAC specific labor rates.	Vendor quote		EPA Air Pollution Control Cost Manual 6th Ed 2002 Chapter 1.5.1.4. Assumes 10 minutes per bag and UTAC specific labor rates.

Mercury Control Cost Effectiveness
United Taconite (UTAC)
Table 4 - Replacement Parts for Line 1

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
United Taconite (UTAC)
Table 5 - Raw Material, Utility, and Waste Disposal Costs for Line 1

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
Makeup Water	$0.20	1000 gal	2002	[5]	Assume 3% Inflation	100	160	$0.32

Labor Costs

Occupation	*Cost Per Unit*	*Unit*	*Year Basis*	*Footnote*	*Cost Index*	*Cost Index for Base Year*	*Cost Index for 2018*	*Adjusted Cost ($/Unit)*
Operator	$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] UTAC site-specific labor cost (includes benefits).
[3] UTAC site-specific electricity cost.
[4] UTAC site-specific natural gas cost.
[5] *EPA Air Pollution Control Cost Manual* , 6th Ed 2002, Section 5.2 Chapter 1 example problem.
[6] UTAC 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] UTAC 2018 sales margin of $43.11/Lton for finished pellets (price converted to short tons) from the 2018 3Q Cleveland Cliffs earnings report.
[9] Filter bag cost provided by vendor.
[10] Vendor quoted price for hydrated lime delivered.

Appendix B-2

Mercury Reduction Technology Control Cost Workbook – Line 2

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 1 - Cost Evaluation Summary for Line 2

Hg Control Technology Description

Technology Name		**Fixed Carbon Beds**	**GORE**	**ACI with High Efficiency Scrubber**	**ACI with Baghouse**
Expected Equipment Life (years)	[1]	20	20	20	20
Expected Utilization Rate (% of Capacity)	[1]	100%	100%	100%	100%
Expected Annual Hours of Operation (hr/year)	[1]	7,992	7,992	7,992	7,992
Notes on Technology					

Control Equipment Costs

		Fixed Carbon Beds	**GORE**	**ACI with High Efficiency Scrubber**	**ACI with Baghouse**
Capital Costs					
Direct Capital Costs (DC)	[2]	$47,391,059	$42,224,490	$34,447,428	$33,747,988
Indirect Capital Costs (IC)	[2]	$10,930,109	$11,734,898	$8,270,240	$7,835,383
Total Capital Investment (TCI = DC + IC)	[2]	$58,321,169	$53,959,389	$42,717,667	$41,583,371
Total Capital Investment (TCI = DC + IC) with Retrofit Factor	[2]	$86,589,833	$81,554,985	$63,568,231	$61,753,357
Operating Costs					
Direct Operating Costs ($/year)	[3]	$3,372,105	$461,602	$5,239,226	$3,838,880
Indirect Operating Costs ($/year)	[3]	$10,979,571	$9,918,208	$8,180,823	$7,790,043
Total Annual Cost ($/year)	[4]	$14,351,677	$10,379,810	$13,420,049	$11,628,924

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 Control Cost Effectiveness
United Taconite (UTAC)
Table 1 - Cost Evaluation Summary for Line 2

Hg Emission Controls

Baseline Hg Emission Rate (lb/year)	[6]	113.5

Hg Control Efficiency (mass%)	[7]	99.00%	72.00%	82.00%	88.10%
Controlled Hg Emission Rate (lb Hg/year)	[8]	1.14	31.78	20.43	13.51
Hg Mass Removed from Exhaust (lb Hg/year)	[9]	112.37	81.72	93.07	99.99
Hg Control Cost Effectiveness ($/lb Hg removed)	[10]	$127,724	$127,017	$144,193	$116,297

Footnotes

[1] Documentation of technology parameters noted

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

Hg Control Cost Effectiveness

United Taconite (UTAC)

Table 1 - Cost Evaluation Summary for Line 2

[2] See Table 2 - Capital Costs

[3] See Table 3 - Operating Costs

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

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

[6] Line 2 baseline mercury emissions based on 2008 throughput data and 2016 Line 2 (solid fuel) stack test emission factors. Refer to the BAMRT analysis for details.

[7]	Documentation of Hg Control Efficiency for each control technology.	Vendor stated that they typically guarantee >99% control. This is consistent with most sources, which cite 99% control or higher.	GORE testing at Cleveland Cliffs United Taconite indicated that a 72% reduction per the rule may be achievable. UTAC will assume that this technology can reduce mercury emissions by 72%.	*Minnesota Taconite Mercury Reduction Research - Phase II Summary* report indicated that brominated PAC could achieve an 82% control at U. S. Steel Keetac with a high efficiency scrubber. UTAC will assume that the new scrubber could achieve the same total mercury reduction due to the increased particulate control.	*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. UTAC 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

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 2 - Capital Costs for Installations for Line 2

Hg Control Technology Description

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

Current Chemical Engineering Plant Cost Index (CEPCI)		572.9	572.9	572.9	572.9
CEPCI of Equipment Cost Estimate Year		N/A	N/A	N/A	N/A
Direct Capital Costs (DC)		**$47,391,059**	**$42,224,490**	**$34,447,428**	**$33,747,988**
Purchased Equipment Costs					
Equipment Costs	[1]	$12,455,965	$16,601,094	$10,944,899	$9,727,353
Instrumentation	[2]	$1,245,597	$1,660,109	$1,094,490	$0
Sales Tax	[3]	$856,348	$1,141,325	$752,462	$668,756
Freight	[4]	$622,798	$830,055	$547,245	$486,368
Generalized Installation Costs					
Basis for Installation Costs	[5] [6]	Fabric Filter	Carbon Adsorber System	Venturi Scrubber	Fabric Filter
Foundations and Supports	[5]	$607,228	$1,618,607	$800,346	$435,299
Handling & Erection	[5]	$7,590,354	$2,832,562	$5,335,638	$5,441,238
Electrical	[5]	$1,214,457	$809,303	$133,391	$870,598
Piping	[5]	$151,807	$404,652	$666,955	$108,825
Insulation	[5]	$1,062,650	$202,326	$400,173	$761,773
Painting	[5]	$607,228	$202,326	$133,391	$0
Site-Specific Installation Costs					
Site Preparation (Grade & Level)	[13]	$119,000	$71,000	$71,000	$93,900
Ductwork	[13]	$3,821,367	$4,040,804	$4,357,110	$3,174,918
Buildings	[13]	$3,973,500	$1,243,600	$1,243,600	$2,156,200
Initial Carbon Charge	[13]	$3,240,000	N/A	N/A	N/A
Total Dry SO2 Control Costs	[13]	$1,856,033	N/A	N/A	$1,856,033
GORE Wastewater Treatment	[13]	N/A	$2,600,000	N/A	N/A
Lost Production During Installation	[13]	$7,966,728	$7,966,728	$7,966,728	$7,966,728
Extended Downtime Days for Tie-in and Restart	[13]	14	14	14	14

Hg Control Cost Effectiveness
United Taconite (UTAC)

Table 2 - Capital Costs for Installations for Line 2

Indirect Capital Costs (IC)		**$10,930,109**	**$11,734,898**	**$8,270,240**	**$7,835,383**
Basis for Installation Costs	[5] [6]	Fabric Filter	Carbon Adsorber System	Venturi Scrubber	Fabric Filter
Engineering & Supervision	[5]	$1,518,071	$2,023,258	$1,333,910	$1,088,248
Construction & Field Expenses	[5]	$3,036,142	$1,011,629	$1,333,910	$2,176,495
Contractor Fees	[5]	$1,518,071	$2,023,258	$1,333,910	$1,088,248
Start-Up Costs	[5]	$151,807	$404,652	$133,391	$108,825
Performance Test	[5]	$151,807	$202,326	$133,391	$108,825
Contingency	[5]	$4,554,212	$6,069,775	$4,001,729	$3,264,743
Contingency Percentage - Site-Specific	[5]	30%	30%	30%	30%

Retrofit Factor	[7]	1.60	1.60	1.60	1.60
Total Capital Investment (TCI)	[7]	**$58,321,169**	**$53,959,389**	**$42,717,667**	**$41,583,371**
Total Capital Investment (TCI) with Retrofit Factor	[7]	**$86,589,833**	**$81,554,985**	**$63,568,231**	**$61,753,357**

Capital Recovery

Interest Rate	[8]	7.0%	7.0%	7.0%	7.0%
Expected Equipment Life		20	20	20	20
Capital Recovery Factor (CRF)	[9]	9.44%	9.44%	9.44%	9.44%
Cost of Replacement Parts	[10]	$4,525,674	$7,929,000	$865,565	$865,565
Adjusted TCI for Capital Recovery	[11]	$82,064,159	$73,625,985	$62,702,666	$60,887,792
Capital Recovery Cost (CRC)	[12]	$7,746,276	$6,949,772	$5,918,688	$5,747,377

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 2 - Capital Costs for Installations for Line 2

Footnotes

[1]	Documentation of Capital Cost for Hg control technology.	Vendor estimate for fixed bed equipment and baghouse scaled for UTAC airflow. Fan costs were scaled using *Chemical Engineering Economics* , by Donald E, Garrett, Appendix 1 page 281. Vendor quote for new stack scaled for UTAC line 2A/B. Air compressor capital is split between Line 1 (1/3) and Line 2 (2/3) based on throughput percentage.	Vendor quote provided for GORE system. Fan costs were calculated using *Chemical Engineering Economics* , by Donald E, Garrett, Appendix 1 page 281. Vendor quote for new stack scaled for UTAC Line 2A/B.	Vendor quote provided for a high efficiency scrubber; installation of 2 scrubbers required for Line 2A & 2B. Fan costs were calculated using *Chemical Engineering Economics* , by Donald E. Garrett, Appendix 1 page 281. Vendor quote for a new stack scaled for UTAC Line 2A/B. Includes ACI injection system.	Vendor quotes for new baghouses, fans, motors, and activated carbon injection system scaled for UTAC airflows. Vendor quote for new stack scaled for UTAC line 2A/B. Air compressor capital is split between Line 1 (1/3) and Line 2 (2/3) based on throughput percentage.

[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 (typically 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 (typically 5%).

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 2 - Capital Costs for Installations for Line 2

[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 United Taconite 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 venturi scrubber.	Installed technology is a fabric filter. Instrumentation and painting costs are not referenced because the vendor quote already included these items.

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

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

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

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

Where: i = interest rate

n = number of years

[10] See 'Table 4 - Replacement Parts for Line 2' 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	Site-specific engineering estimate
Ductwork	Site-specific engineering estimate	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	Site-specific engineering estimate
Initial Carbon Charge	Initial carbon loading cost provided by vendor	N/A	N/A	N/A
Total Dry SO2 Control Costs	Site-specific engineering estimate; scaled based on data from the 2009 UTAC Dry ESP Feasibility Study; includes equipment and installation costs.	N/A	N/A	Site-specific engineering estimate; scaled based on data from the 2009 UTAC Dry ESP Feasibility Study; includes equipment and installation costs.
GORE Wastewater Treatment	N/A	Design and cost estimate for treatment of the GORE effluent is an engineering estimate based on previous project experience. Value is installed capital cost multiplied by 2/3 since the treatment facility will accommodate approximately 2/3 of the total waste from Line 2.	N/A	N/A

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 2 - Capital Costs for Installations for Line 2

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.	Lost production for extended downtime to install new retrofit equipment. Based on production rates and Cleveland Cliffs publically available financial data.
Lost Production During Installation	Estimate based on engineering experience. The downtime is the number of days beyond a typical annual outage.	Estimate based on engineering experience. The downtime is the number of days beyond a typical annual outage.	Estimate based on engineering experience. The downtime is the number of days beyond a typical annual outage.	Estimate based on engineering experience. The downtime is the number of days beyond a typical annual outage.

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 3 - Operating Costs for Line 2

Hg Control Technology Description

Technology Name	**Fixed Carbon Beds**	**GORE**	**ACI with High Efficiency Scrubber**	**ACI with Baghouse**
Expected Utilization Rate (%)	100%	100%	100%	100%
Expected Annual Hours of Operation (hr/year)	7,992	7,992	7,992	7,992
Notes on Technology				

Direct Annual Costs (DAC, $/year)			**$3,372,105**	**$461,602**	**$5,239,226**	**$3,838,880**
Raw Materials						
Powdered Activated Carbon (HPAC)	Demand (lb/year)	[1]			2,890,067.04	454,153.39
	Retail Price ($/lb)	[2]			$1.12	$1.12
	Cost Per Year ($/year)	[3]			$3,236,875	$508,652
Hydrated Lime	Demand (ton/year)	[1]	1,817.12			1,817.12
	Retail Price ($/ton)	[2]	$250.00			$250.00
	Cost Per Year ($/year)	[3]	$454,280.82			$454,280.82
Utilities						
Electricity	Demand (kW-hr/year)	[4]	3,934,194.6	3,300,244.3	14,235,569.9	3,178,471.7
	Retail Price ($/kW-hr)	[2]	$0.068	$0.068	$0.068	$0.068
	Cost Per Year ($/year)	[3]	$268,902	$225,572	$973,001	$217,249
Makeup Water	Demand (Mgal/year)	[4]			383,616	
	Retail Price ($/Mgal)	[2]			$0.32	
	Cost Per Year ($/year)	[3]			$123,118	

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 3 - Operating Costs for Line 2

Operating Labor						
Operator	Worked Hours Per Year (hr/year)	[5]	1,998	500	4,995	1,998
	Cost Per Hour ($/hr)	[2]	$65.27	$65.27	$65.27	$65.27
	Cost Per Year ($/year)	[3]	$130,409	$32,602	$326,024	$130,409
Supervisor	Cost Per Year ($/year)	[6]	$19,561	$4,890	$48,904	$19,561
Maintenance						
Labor	Worked Hours Per Year (hr/year)	[7]	999	500	1,499	999
	Cost Per Hour ($/hr)	[2]	$65.27	$65.27	$65.27	$65.27
	Cost Per Year ($/year)	[3]	$65,205	$32,602	$97,807	$65,205
Materials	Cost Per Year ($/year)	[8]	$65,205	$32,602	$97,807	$65,205
Waste Management						
Non-Haz Solid Waste Offsite Disposal	Waste Production Rate (ton/year)	[9]	47,214.68			47,441.76
	Transport Demand (ton-mile/year)	[10]	0.00			0.00
	Disposal Fee ($/ton)	[2]	$43.06			$43.06
	Transport Fee ($/ton-mile)	[2]				
	Cost Per Year ($/year)	[11]	$2,032,852			$2,042,629
GORE Wastewater Treatment	Waste Production Rate (mgal/year)	[9]				
	Disposal Fee ($/mgal)	[2]				
	Cost Per Year ($/year)	[3]		$133,333		
Product Loss						
Taconite Pellets	Product Lost (ton/year)	[12]	8,721.24		8,721.24	8,721.24
	Retail Price ($/ton)	[2]	$38.49		$38.49	$38.49
	Cost Per Year ($/year)	[3]	$335,690		$335,690	$335,690

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 3 - Operating Costs for Line 2

Indirect Annual Costs (IAC, $/year)		**$10,979,571**	**$9,918,208**	**$8,180,823**	**$7,790,043**
Overhead	[13]	$168,228	$61,618	$342,325	$168,228
Administration	[14]	$1,166,423	$1,079,188	$854,353	$831,667
Property Tax	[15]	$583,212	$539,594	$427,177	$415,834
Insurance	[16]	$583,212	$539,594	$427,177	$415,834
Capital Recovery for Replacement Parts	[17]	$732,220	$748,442	$211,103	$211,103
Capital Recovery	[18]	$7,746,276	$6,949,772	$5,918,688	$5,747,377

Total Annual Costs (TAC = DAC + IAC, $/year)	**$14,351,677**	**$10,379,810**	**$13,420,049**	**$11,628,924**

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)			*Minnesota Taconite Mercury Reduction Research - Phase II Summary* report indicated that brominated PAC could achieve an 82% control at U. S. Steel Keetac with a high efficiency scrubber at an injection rate of 7 lb/mmacf. UTAC assumed the same injection rate.	*Project 4: Evaluation of a Slipstream Baghouse for the Taconite Industry* indicated that brominated PAC could achieve an 88.1% control at U. S. Steel Keetac with a 1.1 lb/mmacf injection rate. UTAC assumed the same injection rate.
Hydrated Lime	Lime injection rate for dry SO2 control conservatively estimated based on the 2009 UTAC Dry ESP Feasibility Study report and scaled for current Line 2 total air flowrate.			Lime injection rate for dry SO2 control conservatively estimated based on the 2009 UTAC Dry ESP Feasibility Study report and scaled for current Line 2 total air flowrate.

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 3 - Operating Costs for Line 2

[2] See 'Table 5 - Raw Material, Utility, and Waste Disposal Costs for Line 2' 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. Also included pressure drop due to ducting. EPA Air Pollution Control Cost Manual 6th Ed 2002, Chapter 1 equation 1.14. Electricity is incremental above existing operations. Electricity associated with the baghouse compressor is split between Lines 1 (1/3) and 2 (2/3) based on throughput percentage.	Assumed 1.22" pressure drop through modules based on vendor quote for vertical arrangement. Also included pressure drop due to ducting. EPA Air Pollution Control Cost Manual 6th Ed 2002, Chapter 1 equation 1.14	Assumed 30" pressure drop per scrubber vendor quote minus the 20" pressure drop the existing fans can accommodate. Also included pressure drop due to ducting. EPA Air Pollution Control Cost Manual 6th Ed 2002, Chapter 1 equation 1.14. Electricity demand is only the incremental amount above baseline conditions.	No incremental electricity needs above existing conditions. Electricity associated with the baghouse compressor is split between Lines 1 (1/3) and 2 (2/3) based on throughput percentage.
Makeup Water			Makeup water cost for high efficiency scrubber assumed to be $0.32 / 1000 gal per EPA Air Pollution Control Cost Manual 6th Ed 2002. Makeup water usage is for the two scrubbers associated with Line 2A & 2B.	

[5] Assumed 0.5, 2.0, and 5.0 hrs of operator attention per 8 hr shift of unit operation for units with a carbon adsorber, baghouse/fabric filter, and venturi scrubber, respectively.

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

[7] Assumed 0.5, 1.0, and 1.5 hrs of operator attention per 8 hr shift of unit operation for units with a carbon adsorber, baghouse/fabric filter, and venturi scrubber, 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. Includes solid waste due to dry sorbent (lime) injection for SO2 control.			Assumes that all of the solids captured by the baghouse would be disposed of as solid waste. Includes solid waste due to dry sorbent (lime) injection for SO2 control.
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. Cost has been multiplied by 2/3 since because Line 2 accounts for 2/3 of the total waste.		

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United Taconite (UTAC)
Table 3 - Operating Costs for Line 2

[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	UTAC site-specific estimate of the lost iron production if pollution control dust is no longer recycled back to the pellet plant. Captured dust would be disposed of as solid waste due to the addition of SO2 control reagents.		UTAC site-specific estimate of the lost iron production if pollution control dust is no longer recycled back to the pellet plant. Scrubber solids would need to be removed to avoid recycling captured PAC and mercury.	UTAC site-specific estimate of the lost iron production if pollution control dust is no longer recycled back to the pellet plant. Captured dust would be disposed of as solid waste to avoid recycling captured PAC, SO2 control reagents, and mercury.

[13] Overhead estimated as 60% of total labor and maintenance materials per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.
[14] Administration estimated as 2% of Total Capital Investment (TCI) per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.
[15] Property tax estimated as 1% of Total Capital Investment (TCI) per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.
[16] Insurance estimated as 1% of Total Capital Investment (TCI) per *EPA Air Pollution Control Cost Manual,* 6th Ed., 2002.
[17] See 'Table 4 - Replacement Parts for Line 2' for details.
[18] See 'Table 2 - Capital Costs for Installations for Line 2' for details.

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 4 - Replacement Parts for Line 2

Hg Control Technology Description

Technology Name	**Fixed Carbon Beds**	**GORE**	**ACI with High Efficiency Scrubber**	**ACI with Baghouse**
Notes on Technology				

Cost of Replacement Parts ($)		**$4,525,674**	**$7,929,000**		**$865,565**
Capital Recovery for Replacement Parts($/year)		**$732,220**	**$748,442**		**$211,103**
Replacement Part Name		Filter Bags	Gore Module		Filter Bags
Interest Rate	[1]	7.0%	7.0%		7.0%
Expected Life of Replacement Part (years)	[2]	5.00	20.00		5.00
Cost of Replacement Part ($/replacement)	[2]	$795,336	$7,854,000		$795,336
Cost of Labor for Replacement ($/replacement)	[2]	$70,229	$75,000		$70,229
CRF_P	[3]	24.39%	9.44%		24.39%
CRC_P ($/year)	[4]	$211,103	$748,442		$211,103
Replacement Part Name		Carbon Change			
Interest Rate	[1]	7.0%			
Expected Life of Replacement Part (years)	[2]	10			
Cost of Replacement Part ($/replacement)	[2]	$3,257,299			
Cost of Labor for Replacement ($/replacement)	[2]	$402,809			
CRF_P	[3]	14.24%			
CRC_P ($/year)	[4]	$521,117			

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 4 - Replacement Parts for Line 2

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. Equipment life of 5 years at $110/bag. Cost includes solid waste disposal of bags. Scaled linearly for UTAC L2 total air flowrate.	Vendor quote for module cost. Includes vendor estimated disposal cost of $45/module.		Provided by baghouse manufacturer. Equipment life of 5 years at $110/bag. Cost includes solid waste disposal of bags. Scaled linearly for UTAC L2 total air flowrate.
Documentation of Labor Costs for Replacement Part	EPA Air Pollution Control Cost Manual 6th Ed 2002 Chapter 1.5.1.4. Assumes 10 minutes per bag and UTAC specific labor rates.	Vendor quote		EPA Air Pollution Control Cost Manual 6th Ed 2002 Chapter 1.5.1.4. Assumes 10 minutes per bag and UTAC specific labor rates.

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 4 - Replacement Parts for Line 2

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

Hg Control Cost Effectiveness
United Taconite (UTAC)
Table 5 - Raw Material, Utility, and Waste Disposal Costs for Line 2

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
Makeup Water	$0.20	Mgal	2002	[5]	Assume 3% Inflation	100	160	$0.32

Labor Costs

Occupation	*Cost Per Unit*	*Unit*	*Year Basis*	*Footnote*	*Cost Index*	*Cost Index for Base Year*	*Cost Index for 2018*	*Adjusted Cost ($/Unit)*
Operator	$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] UTAC site-specific labor cost (includes benefits).

[3] UTAC site-specific electricity cost.

[4] UTAC site-specific natural gas cost.

[5] *EPA Air Pollution Control Cost Manual* , 6th Ed 2002, Section 5.2 Chapter 1 example problem.

[6] UTAC 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] UTAC 2018 sales margin of $43.11/Lton for finished pellets (price converted to short tons) from the 2018 3Q Cleveland Cliffs earnings report.

[9] Filter bag cost provided by vendor.

[10] Vendor quoted price for hydrated lime delivered.

Appendix C

Mercury Emissions Reduction Calculations

United Taconite (UTAC)
Mercury Emissions Reduction Plan
Appendix C
Mercury Emissions Reductions - MPCA Form Item 6

Mercury Emissions Reductions Under UTAC's MERP

Emission Unit	Baseline Emissions lb/yr	Percent Reduction	Estimated Emissions lb/yr
Line 1 (EQUI 45 / EU040)	34.7	0%	34.7
Line 2A/B (EQUI 47 / EU042)	113.5	0%	113.5
TOTAL	148.3	0%	148.3

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