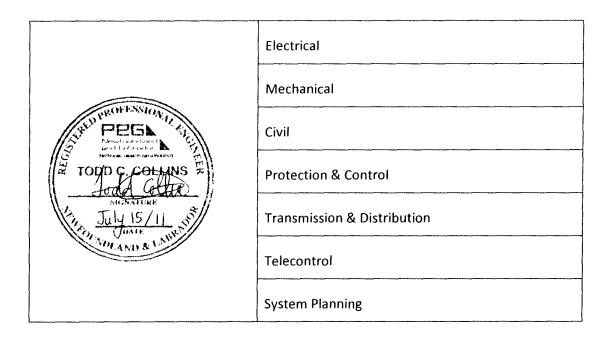
A REPORT TO THE BOARD OF COMMISSIONERS OF PUBLIC UTILITIES



UPGRADE UNIT 1 STACK BREECHING

Holyrood Thermal Generating Station

July 2011



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1 INTRODUCTION

The Holyrood Thermal Generating Station (Holyrood) is an essential part of Newfoundland and Labrador Hydro's (Hydro's) Island Interconnected System, with three units providing a total capacity of 490 MW.



Figure 1: Holyrood Thermal Generating Station

The three main components of each generating unit are the boiler, turbine, and generator. During operation, stack breeching conveys the boiler hot flue gas safely outside the plant to the boiler exhaust stack where it is then discharged into the atmosphere. After exiting the boiler, the hot flue gas passes through heat exchangers, known as air pre-heaters, which are used to heat the incoming combustion air before entering the boiler furnace. The boiler is equipped with two air pre-heaters known as the East and West air pre-heaters. The Unit 1 stack breeching, referred to as the East and West stack breeching, is connected to the outlet of each air pre-heater and conveys the hot flue gas to the boiler exhaust stack. The Unit 1 East and West stack breeching is illustrated in Figure 2.



Figure 2: Unit 1 Stack Breeching

In Order No. P.U. 38(2010), the Board of Commissioners of Public Utilities (the Board), expressed a number of concerns with this project as originally submitted as part of Hydro's 2011 Capital Budget Application.

These concerns have been addressed, as referenced below:

- "The Board was unable to conclude that it was necessary or appropriate to replace the support structure rather than repair it." Appendix C contains updated information on this matter.
- The Board indicated that Hydro had not shown that the proposed long-term solution was appropriate. Please refer to Section 4.3: Cost Benefit Analysis, where other alternatives have been considered, and the least cost option is recommended.

2 PROJECT DESCRIPTION

This project is required to upgrade the stack breeching serving Unit 1. The existing stack breeching was constructed from carbon steel with an exterior protective coating and insulated internally with borosilicate (glass) blocks. Hydro completed thickness scanning on Unit 1 stack breeching steel casing in August 2010 (see Appendix A: Unit 1 Stack Breeching Thickness Scanning Report). The scan indicated that the casing was generally in good condition but localized areas required steel plate replacement due to corrosion. In addition, Hydro also completed thickness scanning on the Unit 1 stack breeching steel support structure in January 2011 and the scanning results indicated that the west support structure should be replaced immediately due to extensive corrosion and recommended a refurbishment of the east support structure (see Appendix C: Unit Stack Breeching Support Structure Scanning Report). This project will refurbish the steel casing based on the results of the plate thickness scan, replace the expansion joints and the corroded support structure, and insulate the breeching externally complete with water tight cladding and flashing. Ice protection shelters will also be constructed above the breeching in order to protect the external insulation from damage caused by ice falling from the stack and the plant power house. The project will be completed simultaneously with the regular annual maintenance work for Unit 1 boiler.

3 EXISTING SYSTEM

The general arrangement of the existing Unit 1 stack breeching is illustrated above in Figure 2. The breeching has a rectangular cross section that is constructed from carbon steel plate and is insulated internally on the sides and top with borosilicate (glass) block. The breeching sections are coated externally with a protective film to inhibit corrosion. In addition, the breeching sections have a silicate concrete floor. A typical cross section of the Unit 1 stack breeching is illustrated in Figure 3.



Figure 3 - Typical Stack Breeching Cross Section

The existing Unit 1 stack breeching was installed in 1990 replacing the original stack breeching installed when Unit 1 was commissioned in 1970. In 1988, Unit 1 was up-rated to

produce 170 MW. At that time, it was necessary to increase the capacity of the two Forced Draft (FD) fans in order to increase the volumetric flow rate of combustion air to the boiler servicing Unit 1. Each FD fan contains air intake and discharge ductwork which is connected to the fan casing air intake and discharge zones, respectively. During operation, the intake ductwork conveys ambient air to the FD fan from both inside and outside the plant. After this air passes through the FD fan, the discharge ductwork then conveys it to the boiler furnace where it is mixed with the boiler fuel oil for combustion. Following combustion, the hot flue gas exits the boiler and passes through the air pre-heaters prior to entering the stack breeching.

After the modifications to the FD fans were complete and the Unit 1 breeching had been in service for a one-year period, an internal inspection of the breeching took place. The inspection revealed considerable erosion damage to the borosilicate insulation. Some of the borosilicate blocks had fallen away from the walls and ceiling. The erosion was attributed to the increased FD fan capacity which delivered an increased volume of air at a higher average flue gas velocity of 50 feet per second compared to the original velocity at 43 feet per second. Erosion of the internal borosilicate insulation liner has been an ongoing issue inside the Unit 1 stack breeching since Unit 1 was up-rated.

In addition to the erosion of the borosilicate insulation, cracks in the internal insulating liner and concrete floor have developed. Cracks in the concrete floor and insulation blocks falling away from the walls and ceiling allow flue gas to contact the steel plates underneath the insulation and concrete. The flue gas condenses to form sulfuric acid which causes localized corrosion that necessitates steel plate repairs. The internal insulation liner and steel plates underneath have required repairs on an annual basis that have resulted in high maintenance costs (see Table 1) during scheduled annual outages. Typical steel plate and insulating block repairs are illustrated below in Figures 4 and 5, respectively. Concrete floor cracking is illustrated in Figure 6.



Figure 4 – Unit 1 Breeching Plate Repairs

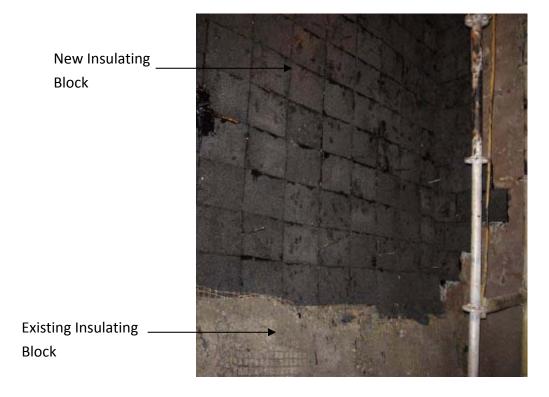


Figure 5 – Unit 1 Insulating Block Replacement

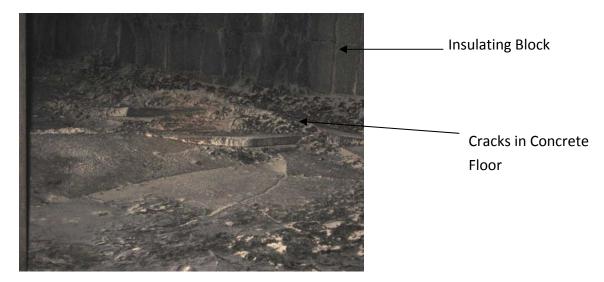


Figure 6 - Unit 1 Breeching Concrete Floor

Also, failure of the internal insulation blocks is caused by the breakdown of the adhesive membrane that bond the blocks to the breeching plate. The temperature limit of the membrane is 200 degrees Fahrenheit. This limit is exceeded by the actual flue gas outlet temperature which is approximately 311 degrees Fahrenheit when Unit 1 is operated at full load.

In addition, controlling outlet flue gas temperature from the air pre-heaters has contributed to deterioration of the stack breeching on Unit 1. Unit 1 utilizes steam coil air heaters (SCAH) to maintain the outlet temperature of the flue gas to a minimum requirement as it exits the air pre-heaters and enters the stack breeching. The flue gas temperature should be at least 50 degrees Fahrenheit above the sulfuric acid dew point of the gas. Sulfuric acid dew point is the temperature at which condensation occurs to cause the formation of sulfuric acid which is an extremely corrosive liquid. Sulfuric acid dew point is a function of the sulfur content in the boiler fuel oil and will increase as the fuel oil sulfur content increases. Increasing the dew point increases the likelihood of forming sulfuric acid during operation. SCAHs have been used to keep the average outlet gas temperature entering the stack breeching above the sulfuric acid dew point. However, during past operation, poor

control of the flue gas outlet temperature through the SCAHs in conjunction with burning fuel oil with a sulfur content of 2.0 to 2.5 percent has contributed to the deterioration of the breeching by allowing corrosive sulfuric acid to form inside the breeching when the gas temperature is below the acid dew point. In January 2009, Hydro switched to fuel oil with a sulfur content of 0.7 percent. This reduced the possibility of forming sulfuric acid thereby decreasing the rate of further deterioration however damage incurred to that point in time remains.

3.1 Age of Equipment or System

Unit 1 was commissioned in 1970. The existing oil fired boiler and steam turbine are now 41 years old. The original stack breeching servicing Unit 1 was replaced in 1990 after 20 years of service. The existing stack breeching is now approximately 21 years old. However, the existing breeching support structure was not replaced in 1990 and is now 41 years old.

3.2 Major Work and/or Upgrades

The original stack breeching was replaced under a 1990 capital program at a cost of \$656,777.

3.3 Anticipated Useful life

The anticipated useful life of Unit 1 has been forecasted to extend to the year 2020. The document entitled "Holyrood Thermal Generating Station Requirements 2011 to 2020" filed with this Application gives further detail concerning the anticipated future use of Holyrood.

3.4 Maintenance History

Stack breeching maintenance is a component of the annual maintenance strategy for Unit 1.

During the annual shutdown, Hydro uses a boiler service contractor, Alstom Power, to
perform preventative maintenance inspections and corrective maintenance repairs on the

stack breeching. Typical maintenance repairs have included replacing missing or loose borosilicate insulating blocks on the breeching interior, the installation of steel plate patches on the breeching exterior to cover holes caused by extensive corrosion, and applying protective coatings to the breeching exterior. The cost of maintenance for the stack breeching is a component of the total maintenance cost for the whole unit. The ten year maintenance history for the Unit 1 stack breeching is shown in Table 1.¹ Maintenance records are not available prior to the year 2000.² However, a maintenance routine took place between the years 1992 and 2000 that was comparable to the maintenance routine that took place after the year 2000.³

Table 1: Maintenance History⁴

Year	Preventive Maintenance (\$000)	Corrective Maintenance (\$000)	Total Maintenance (\$000)
2010	1.0	11.3	12.3
2009	1.0	0.0	1.0
2008	1.0	36.0	37.0
2007	1.0	8.0	9.0
2006	1.0	320.0	321.0
2005	1.0	3.0	4.0
2004	1.0	15.0	16.0
2003	1.0	5.0	6.0
2002	1.0	64.0	65.0
2001	1.0	0.0	1.0
2000	1.0	70.0	71.0

Alstom Power completed a preventative maintenance inspection of the stack breeching in 2009. The inspection revealed that extensive repairs to the internal insulating liner were required and the cost to complete the repairs was estimated to be \$100,000. However,

¹ Reference IC-NLH-20

² Reference PUB-NLH-4

³ Reference PUB-NLH-5

⁴ Reference IC-NLH-20

Hydro decided not to complete the repairs in 2009 in light of the stack breeching upgrade capital project scheduled for 2011. Therefore, no corrective maintenance repairs were completed in 2009. Minimum corrective maintenance repairs were completed on the stack breeching during the annual 2010 Unit 1 outage anticipating that major refurbishment would take place in 2011. An inspection was completed on the internal insulating liner during the annual 2010 Unit 1 outage and the cost to complete the repairs has increased to \$230,000.⁵

3.5 Outage Statistics

There have been no outages on Unit 1 caused by problems with the stack breeching.

3.6 Industry Experience

In 2009, Hydro had a condition assessment of the Holyrood stack breeching completed by Alstom Power. The assessment report (Appendix B, page B12) indicates that breeching systems in the utility industry are mainly constructed from carbon steel with external insulation, although in some cases internal insulation liners are utilized. Externally insulated breeching is generally much easier to inspect, clean, and maintain.

All previous versions of the Alstom Engineering Report identified as that of December 18, 2008, Rev. 1 – March 4, 2009; Rev. 2 – August 28, 2009; and Rev. 3 – March 25th, 2010 are also filed in Appendix B. ⁶

⁵ Reference IC-NLH-20

⁶ Reference IC-NLH-21

3.7 Maintenance or Support Arrangements

Hydro currently has a service contract with Alstom Power to perform boiler maintenance during the annual scheduled outage. Unit 1 stack breeching repairs are included under the boiler service contract.

3.8 Vendor Recommendations

Based on the twenty year service life of the existing Unit 1 stack breeching and the extended exposure to past prevailing conditions along with the history of plate corrosion/thinning and extensive internal insulation block repairs, Alstom Power indicates that deterioration may continue at the same pace or worsen if some upgrades are not implemented (see Appendix B, page B12).

Alstom Power states that the preferred long-term solution for refurbishing the breeching is to install external insulation on the steel casing with the internal insulation lining left alone at this time and removed during future Unit 1 annual outages as the silicate block degradation continues (see Appendix B, page B14). The construction of ice protection shelters above the breeching will protect the external insulation and cladding from damage caused by falling ice. However, in order to minimize the rate of future corrosion, Hydro will continue to monitor and adjust the flue gas temperature inside the stack breeching through improved control of the SCAH's during boiler operation, as it has done since the last breeching replacement project was performed to ensure that it does not drop below the sulfuric acid dew point. This mitigates deterioration of the breeching caused by corrosion but does not eliminate it. Also, in January 2009, Hydro switched to fuel oil with a sulfur content of 0.7 percent which has reduced the sulfuric acid dew point of the flue gas, thereby reducing the likelihood of forming sulfuric acid during operation.

3.9 Availability of Replacement Parts

Replacement parts for the existing Unit 1 stack breeching have been supplied by Alstom Power.

3.10 Safety Performance

There are no safety code violations with the current operation of the existing Unit 1 stack breeching. However, continued deterioration of the breeching plate and expansion joints could potentially allow boiler flue gas containing sulfur dioxide to escape inside the plant and become a major safety concern for plant personnel. Most of the breeching expansion joints are located outside the powerhouse building. However, several are located inside the powerhouse wall where the breeching passes through the exterior wall. Leaking expansion joints inside the building would expose workers to hazardous gases.

3.11 Environmental Performance

There are no environmental code violations with the operation of the existing Unit 1 stack breeching.

3.12 Operating Regime

Holyrood operates in a seasonal regime. The full plant capacity is needed to meet the winter electrical requirements on the Island Interconnected System. The stack breeching is an integral component of Unit 1.

4 JUSTIFICATION

The stack breeching servicing Unit 1 has been in service for twenty-one years and has deteriorated to a point where refurbishment is necessary to ensure reliable operation of Unit 1. The utility industry recognizes that boiler stack breeching has a limited life span and needs replacement periodically, either completely or partially, after twenty years (see Appendix B, page B12: Alstom Engineering Report - Condition Assessment of Stack Breeching at Holyrood G.S. Units # 1, 2, & 3). Past operating conditions have led to corrosion of the breeching plates and deterioration of the internal insulating liner and concrete floor. Hydro conducted thickness scanning on the breeching steel casing in August 2010 (see Appendix A: Unit 1 Stack Breeching Thickness Scanning Report). The scanning results indicated that various sections of the steel casing have localized thinning due to corrosion and require replacement in order to restore the structural integrity. In addition, Hydro also conducted thickness scanning on the Unit 1 stack breeching steel support structure in January 2011 and the scanning results indicated that the West support structure should be replaced immediately due to extensive corrosion and recommended a refurbishment of the East support structure (see Appendix C: Unit Stack Breeching Support Structure Scanning Report).

Failure of the breeching support structure during operation can result in an unplanned unit outage of a four-week duration. An unscheduled unit outage during the peak winter load demand would result in a loss of 170 MW of generation capacity to the Island Interconnected System which represents approximately 11 percent of the Island Interconnected System's capacity. This would necessitate Hydro to operate standby gas turbine generators located at Hardwoods and Stephenville in order to meet the customer load demand, resulting in additional operating cost as high as \$2,736,739 (see Section 4.3: Cost Benefit Analysis). Also, an additional forced outage on the Island Interconnected System while Unit 1 is offline will increase the potential for unsupplied energy to the system, due to the unavailability of additional standby generation.

This project is required to maintain the reliability of generating Unit 1 at Holyrood.

4.1 Net Present Value

A Net Present Value (NPV) calculation was not done. However, a cost benefit analysis (CBA) was completed on seven alternatives over a study period of nine years. See Section 4.3: Cost Benefit Analysis for details.

4.2 Levelized Cost of Energy

The levelized cost of energy is a high level means to compare costs of developing two or more alternative generating sources. Therefore, the levelized cost of energy is not applicable in this case.

4.3 Cost Benefit Analysis

A CBA was completed on six alternatives and compared to the status quo base case. The study period for the CBA was nine years. This is the minimum service life expected of the breeching system which is dependant on the future of Holyrood as a generating station. If the development of the Lower Churchill (LC) project proceeds, it is estimated that Holyrood will be required as a generating station until 2020. However, if the LC project does not proceed, it is projected that Holyrood will be required to continue operating as a generating station beyond 2020 for the foreseeable future.

The assumptions and considerations for the operation of Unit 1 and the CBA between the stack breeching replacement and refurbishment are the same for the period 2011-2016 as compared to the standby period of 2016-2020. During the standby period of 2016-2020, it is possible that Holyrood may need to continue to operate as a generation facility with a capacity factor during that time period of at least what would be experienced in the 2011-2016 time period. ⁷

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⁷ Reference IC-NLH-17.

Alternative 1 - Status Quo: 8

This alternative includes operating the Unit 1 stack breeching in its present condition with no upgrades to improve plant reliability or safety. Considering the present day condition of the support structure (see Appendix C: Unit Stack Breeching Support Structure Scanning Report), it is projected that a failure will occur sometime within the next several years. This alternative allows for such a failure to occur in 2013. A detailed condition assessment performed by engineering consulting firm Hatch on the support structures of the breeching indicates they are in very poor condition and recommends they be immediately replaced or refurbished (see Appendix C). For the purposes of this calculation, it was assumed that the forced outage would occur during the peak winter load requirement. This is the time period when the generating unit would be operating at peak power production with peak stress loading on the breeching system. It is expected that the probability of failure to a deteriorated breeching would be highest during that condition. In order to meet the requirements of the Island Interconnected System during the peak load, a forced outage on Unit 1 would necessitate Hydro to operate gas turbines at Hardwoods and Stephenville. The duration of the forced outage was estimated to be a four-week period and was assumed to take place in 2013 during the highest four-week load forecast for that year. The additional cost to operate the gas turbines during the outage period was calculated at \$2,736,739 based on an energy requirement of 23 GWh during the forced outage period using the incremental cost of consuming diesel fuel as opposed to No.6 fuel oil. The annual operating and maintenance (O&M) cost for Alternative 1 was estimated at \$49,391 per year which is based on an average of the 11 year maintenance history presented in Section 3.4: Maintenance History, Table 1. Also, in the event of a support structure failure, it is anticipated that replacement of 50 percent of the breeching would be required with cost estimated at \$2.0 M. The \$2.0 M replacement cost is considered in the CBA. There are no quantifiable benefits associated with Alternative 1. The Cumulative Present worth (CPW) of this alternative is a cost of \$4,070,371.

⁸ Reference IC-NLH-22

If Alternative 1 scenario did take place, Hydro would be in violation of its system planning criteria as it would not be able to supply the total load on the Avalon Peninsula for approximately 120 hours during this period. This would result in approximately 2.3 GWh of unsupplied energy.

Alternative 2 – Refurbish Unit 1 Stack Breeching Casing, Replace Expansion Joints, Replace Support Structure, Install an External Insulation System, and Install Ice Protection: ⁹
This alternative refurbishes the existing breeching and modifies the design by partially removing the internal insulation, replacing a limited amount of steel casing with similar grade material, replacing the expansion joints, installing new support structures, installing an external insulation system, and installing an ice protection shield. Upon completion of Alternative 2, the annual O&M cost was estimated at \$4,000 per year. This was based on removing loose or fallen internal insulating blocks and cleaning the breeching internally.

There are no quantifiable benefits associated with Alternative 2. The CPW of this alternative is a cost of \$1,880,130.

<u>Alternative 3 – Refurbish Unit 1 Stack Breeching Casing, Replace Expansion Joints, Replace Support Structure, and Continue to Maintain the Internal Insulation Liner:</u> ¹⁰

This alternative refurbishes the existing breeching by replacing the internal insulation liner as required, replacing the expansion joints, replacing a limited amount of steel casing with similar grade material, and installing new support structures. Upon completion of Alternative 3, the annual O&M cost was estimated at \$49,391 per year which is based on an average of the 11-year maintenance history presented in Section 3.4: Maintenance History, Table 1.

⁹ Reference IC-NLH-22

¹⁰ Reference IC-NLH-22

There are no quantifiable benefits associated with Alternative 3. The CPW of this alternative is a cost of \$2,092,783.

Alternative 4 – Refurbish Unit 1 Stack Breeching Casing, Replace Expansion Joints, Replace Support Structure, Remove Internal Insulation Liner, Install an External Insulation System, and Install Ice Protection (Option A3 In the Alstom Engineering Report):¹¹

This alternative refurbishes the existing breeching and modifies the design by completely removing the internal insulation, replacing a limited amount of steel casing with similar grade material, replacing the expansion joints, installing new support structures, installing an external insulation system, and installing an ice protection shield. Upon completion of Alternative 4, the annual O&M cost was estimated at \$2,000 per year. This was based on cleaning the breeching internally. ¹²

There are no quantifiable benefits associated with Alternative 4. The CPW of this alternative is a cost of \$1,948,115.

Alternative 5 – Replace Unit 1 Stack Breeching, Support Structure, and Install Ice Protection: This alternative replaces the existing breeching with a new system incorporating a better design that is more common to the industry today and is estimated to have a minimum service life of 20 years. The replacement breeching will be fabricated from high temperature carbon steel and will be insulated externally with water repellent insulation complete with water tight cladding and flashing. Ice protection shelters will also be constructed above the replacement breeching in order to protect the external insulation from damage caused by ice falling from the stack and the plant power house. Upon completion of Alternative 5, the annual O&M cost was estimated at \$2,000 per year which would cover stack breeching preventative maintenance inspections. It is anticipated that corrective maintenance repairs to the Unit 1 stack breeching will not be required during the

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¹¹ Reference IC-NLH-19

¹² Reference IC-NLH-22

nine-year study period. There are no quantifiable benefits associated with Alternative 5. The CPW of this alternative is a cost of \$3,528,715. 13

Alternative 6 – Refurbish Unit 1 Stack Breeching Casing, Replace Expansion Joints,

Replace/Refurbish the Support Structure, Install an External Insulation System, and Install

Ice Protection:

This alternative refurbishes the existing breeching and modifies the design by partially removing the internal insulation, replacing a limited amount of steel casing with similar grade material, replacing the expansion joints, replacing the west support structure, refurbishing the east support structure, installing an external insulation system, and installing an ice protection shield. It is identical to Alternative 2, with the exception of refurbishing/replacing the support structure as opposed to completely replacing the support structure. Hydro completed thickness scanning on the support structure in January 2011 and the scanning results indicated that the West support structure should be replaced immediately due to extensive corrosion but recommended a refurbishment of the East support structure (see Appendix C: Unit Stack Breeching Support Structure Scanning Report). Upon completion of Alternative 6, the annual O&M cost was estimated at \$4,000 per year. This was based on removing loose or fallen internal insulating blocks and cleaning the breeching internally.

There are no quantifiable benefits associated with Alternative 6. The CPW of this alternative is a cost of \$1,902,730.

Alternative 7 – Refurbish Unit 1 Stack Breeching Casing, Replace Expansion Joints,

Replace/Refurbish Support Structure, and Continue to Maintain the Internal Insulation

<u>Liner:</u>

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¹³ Reference IC-NLH-22

This alternative refurbishes the existing breeching by replacing the internal insulation liner as required, replacing the expansion joints, replacing a limited amount of steel casing with similar grade material, and refurbishing/replacing the support structure. It is identical to Alternative 3, with the exception of refurbishing/replacing the support structure as opposed to completely replacing the support structure. Hydro completed thickness scanning on the support structure in January 2011 and the scanning results indicated that the West support structure should be replaced immediately due to extensive corrosion but recommended a refurbishment of the East support structure (see Appendix C: Unit Stack Breeching Support Structure Scanning Report). Upon completion of Alternative 7, the annual O&M cost was estimated at \$49,391 per year which is based on an average of the ten-year maintenance history presented in Section 3.4: Maintenance History, Table 1.

There are no quantifiable benefits associated with Alternative 7. The CPW of this alternative is a cost of \$ 2,116,083.

Results and Discussion

Unit 1 stack breeching was replaced 20 years ago with the exception of the support structures. Economic conditions in the province and through out the world have changed significantly over that time period such that the cost of performing industrial construction has increased dramatically due in particular to increased labour and material costs. In addition, performing work in accordance with today's regulations and work procedures is often more time consuming with associated extra cost. When Hydro prepared the cost estimate for the 2011 project, it consulted with a contractor, ALSTOM, which is a widely recognized company in the industry for performing such installations. ALSTOM has in-house engineering ability, experience in performing this type of work throughout North America, and is very familiar with site conditions at Holyrood as they have held the maintenance service contract for the boilers at the plant for 13 years. The cost estimate provided by

ALSTOM is considered to be realistic for this project in today's environment. 14

Alternative 1 has no initial capital cost, has high annual maintenance cost and predicts that a significant refurbishment cost and forced outage will be incurred within the nine-year study period. This is supported by the condition of the breeching steel support structure. In January 2011, Hydro completed thickness scanning on the support structure and the results indicated that the West support structure should be replaced immediately due to extensive corrosion and the East support structure should be refurbished or replaced (see Appendix C: Unit 1 Stack Breeching Support Structure Scanning Report). Alternative 3 will provide a solution to upgrade the breeching servicing Unit 1 for the next nine years that will require slightly less initial capital cost as compared to Alternative 2 but has significantly higher O&M cost. Similarly, Alternative 4 will provide a solution to upgrade the breeching servicing Unit 1 for the next nine years as compared to Alternative 2 but has slightly higher initial capital cost due to the requirement to completely remove the internal insulating block. Alternative 5 will provide new breeching and ensure reliability for the next nine years. It will require less attention to maintain and will provide a system that is projected to have at least an additional ten years of service life available if it is required. However, Alternative 5 requires significant initial capital cost as compared to Alternative 2. Alternative 6 is identical to Alternative 2 with the exception of how it remedies deterioration of the breeching support structures. It includes a complete replacement of the West support structure due to extensive corrosion and refurbishment of the East support structure. Compared to Alternative 2, which provides for replacing both support structures with new, it has a slightly higher initial capital cost due to higher labour cost associated with refurbishing the East support structure as compared to replacing it with new (see Appendix D). Alternative 7 is identical to Alternative 3 with the exception of how it remedies deterioration of the breeching support structures. It includes a complete replacement of the West support structure due to extensive corrosion and refurbishment of the East support structure.

¹⁴ Reference IC-NLH-16 and PUB-NLH-6

Compared to Alternative 3, which provides for replacing both support structures with new, it has a slightly higher initial capital cost due to higher labour cost associated with refurbishing the East support structure as compared to replacing it with new.

Alternative 2 is the least cost option and is the recommended alternative. The results of the CBA are illustrated below in Table 2.

Holyrood - Upgrade Stack Breeching Alternative Comparison Cumulative Net Present Value to the Year 2020 **CPW Difference Cumulative Net** between Alternative **Alternatives Present Value** and the Least Cost (CPW) **Alternative** 4,070,371 2,190,241 1. Status Quo 2. Refurbish - Option 1 1,880,130 3. Refurbish – Option 2 2,092,783 212,653 4. Refurbish - Option 3 1,948,115 67,985 5. Replace - Option 4 3,528,715 1,648,585 6. Refurbish - Option 5 1,902,730 22,600 7. Refurbish - Option6 235,953

2,116,083

Table 2: Cost Benefit Analysis¹⁵

Legislative or Regulatory Requirements 4.4

There are no current legislative or regulatory requirements to upgrade the Unit 1 stack breeching.

Historical Information 4.5

The original stack breeching servicing Unit 1 was installed in 1967, constructed from onequarter inch carbon steel plate, and insulated externally. The cladding on the insulation was damaged by ice falling from the stack and the power house. This allowed moisture to

¹⁵ Reference IC-NLH-19

penetrate the insulation which led to a break down of the insulation that enabled severe corrosion of the carbon steel breeching. In addition, poor control of the flue gas temperature exiting the air pre-heaters allowed the temperature to drop below the sulfuric acid dew point, enabling the formation of acid inside the breeching.

The condition of the original breeching had deteriorated to a point where a complete replacement was deemed necessary. In 1987, Hydro conducted a study to evaluate various options for the stack breeching replacement. Following the study, a design that included carbon steel breeching insulated internally with borosilicate blocks and a protective coating on the exterior was selected. The original stack breeching was replaced under the capital program in 1990 at a cost of \$656,777. However, the breeching support structure was not replaced in 1990 and is original equipment. Since 1990, breeching problems such as erosion and cracking of the internal insulating blocks and concrete floor have developed. Insulation blocks have fallen away from the ceiling and walls and have allowed the flue gas to contact the steel plates underneath. The cooling of the flue gas formed acidic condensate causing localized corrosion and thinning of the plates.

4.6 Forecast Customer Growth

Customer load growth does not affect this project.

4.7 Energy Efficiency Benefits

There are no energy efficiency benefits resulting from this project.

4.8 Losses during Construction

There are no associated losses during the construction of this project as it will be scheduled during the annual planned unit outage.

4.9 Status Quo

The status quo is not an option. An upgrade to the stack breeching is necessary to ensure reliable operation of Unit 1. A forced outage on Unit 1 due to failure of a breeching support structure would result in significant downtime on Unit 1. An unscheduled failure during the peak winter load demand could result in a loss of 170 MW of power which represents approximately 11 percent of the Island Interconnected System's capacity. This would necessitate Hydro to operate standby gas turbine generators located at Hardwoods and Stephenville in order to meet the customer load demand, resulting in additional operating cost as high as \$2,736,739 (see Section 4.3: Cost Benefit Analysis). Also, an additional forced outage on the Island Interconnected System while Unit 1 is offline will increase the potential for unsupplied energy to the system, due to the unavailability of additional standby generation.

4.10 Alternatives

Please see Section 4.3 above. Alternative 2 has been chosen as it is the least cost option.

5 CONCLUSION

This project is an upgrade of the existing stack breeching servicing Unit 1 at Holyrood. The breeching and the breeching support structures are 21 years old and 41 years old, respectively, and have deteriorated to a point where refurbishment is necessary in order to maintain the reliability of Unit 1. In addition, the condition of the existing breeching is a safety concern for Holyrood personnel.

Failure to upgrade the breeching increases the likelihood of unscheduled downtime on Unit 1 and increases the risk of being unable to meet customer demands during the peak winter load requirement.

5.1 Budget Estimate

The budget estimate for this project is shown in Table 3.

Table 3: Budget Estimate

Project Cost: (\$ x1,000)	<u>2011</u>	<u>2012</u>	<u>Beyond</u>	<u>Total</u>
Material Supply	0.0	0.0	0.0	0.0
Labour	114.4	0.0		114.4
Consultant	0.0	0.0	0.0	0.0
Contract Work	1,481.6	0.0	0.0	1,481.6
Other Direct Costs	2.0	0.0	0.0	2.0
O/H, AFUDC & Escin.	96.1	0.0	0.0	96.1
Contingency	159.8	0.0	0.0	159.8
TOTAL	1,853.9	0.0	0.0	1,853.9

5.2 Project Schedule

The anticipated project schedule is shown in Table 4. It should be noted that considerable effort has been expended to ensure this schedule is reasonable, in light of the other workload of the required personnel.

Table 4: Project Milestones

Activity	Milestone
Project Kick-off Meeting	July 2011
Complete Design Transmittal	July 2011
Issue Tender & Award Contract	July 2011
Installation	October 2011
Commissioning	October 2011
Project Final Documentation and Closeout	November 2011

APPENDIX A

Units 1 Stack Breeching Thickness Scanning Report

Holyrood Thermal Generating Station



NF HYDRO UNIT #1 AIRHEATER TO STACK DUCTING





TABLE OF CONTENTS

- 1.0 General
 - 1.1 Description
 - 1.2 Introduction
 - 1.3 Access
- 2.0 Inspection
 - 2.1 West breeching
 - 2.2 East breeching
- 3.0 Photographs
- 4.0 Summary



1.1 Description

Unit # 1 Airheater to Stack Ducting. East and West Breeching.

1.2 Introduction

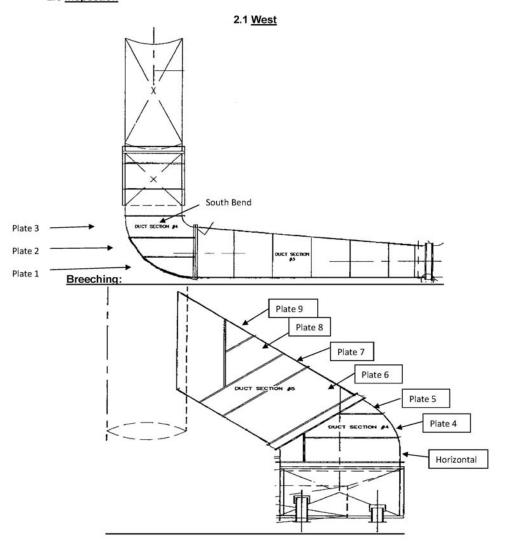
As request by Mr. Derek French of Hatch, Team Industrial conducted an Visual and Ultrasonic Thickness inspection of the east and west breeching on Unit #1. The external inspection was conducted on all accessible areas that were identified by Mr. John Adams of Alstom.

1.3 Access

External access was by means of fixed scaffolding.



2.0 Inspection





UNIT #1 WEST AIRHEATER TO STACK DUCTING

SECTION # 3 EAST

L	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Т	.254	.253	.253	.251	.212	.254	.254	.249	.250	.250	.251	.269	.269	.262
В	.252	.253	.245	.253	.253	.248	.253	.240	.231	.250	.249	.268	.268	.269
М	.243	.250	.254	.249	.246	.250	.245	.250	.239	.252	.238	.269	.263	.264

SECTION #3 WEST

L ₃	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Т	.253	.254	.251	.252	.252	.254	.253	.254	.250	.244	.251	.269	.269	.268
В	.253	.254	.239	.254	.250	.253	.254	.249	.252	N/A	N/A	N/A	N/A	N/A
М	.249	.233	.249	.247	.251	.252	.253	.251	.251	N/A	N/A	N/A	N/A	N/A

SECTION #3 TOP

L	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Α	.246	.248	.249	.245	.248	.248	.248	.248	.246	.247	.245	.261	.266	.258
В	.247	.248	.247	.248	.248	.248	.249	.248	.247	.249	.236	.262	.251	.245
С	.248	.248	.247	.248	.246	.249	.247	.247	.232	.248	.230	.262	.269	.268
D	.246	.245	.247	.247	.248	.246	.248	.249	.230	.247	.248	.262	.236	.248
Е	.246	.247	.246	.246	.247	.243	.245	.219	.246	.248	.246	.264	.244	.218

SECTION #3 BOTTOM

L	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Α	.247	.246	.246	.245	.242	.246	.244	.244	.244	.245	.248	.266	.266	.257
В	.244	.247	.244	.246	.246	.245	.243	.244	.243	.243	.246	.266	.267	.261
С	.240	.248	.248	.246	.237	.246	.246	.246	.245	.245	.243	.261	.266	.260
D	.249	.244	.249	.240	.247	.248	.249	.240	.246	.246	.246	.261	.261	.257
Е	.247	.246	.247	.246	.242	.249	.248	.237	.242	.238	.243	.266	.260	.258

- Location #1 starts I ft. from plant, remainder @ 2 ft. intervals.
- Top & Bottom locations only, A is on the west.
- All reading recorded in inches.
- L is the location



SECTION # 4 (WEST)

Working South to North

Plate #1

Location	Α	В	С	D
1	.249	.252	.253	N/A
2	.248	.250	.250	.252

Plate #2

Location	Α	В	С	D
1	.246	.253	.251	.252
2	.250	.250	.251	.250

Plate #3

Location	Α	В	С	D	Е
1	.249	.253	.249	.253	.246
2	.249	.251	.250	.248	.248
3	N/A	.253	.254	.253	.247

Horizontal

Location	Α	В	С	D
1	.249	.255	.251	.247
2	.250	.249	.250	.240
3	.254	.250	.249	.251

Plate #4

Location	Α	В	С	D
1	.250	.250	.250	.231
2	.252	.255	.255	.250
3	.253	.256	.257	.251

Plate #5

Location	Α	В	С	D
1	.248	.248	.251	.256
2	.228	.229	.251	.250



SECTION # 4 (EAST)

Working South to North

Plate #1

Location	Α	В	С	D
1	.251	.251	.250	N/A
2	N/A	N/A	N/A	.250

Plate #2

Location	Α	В	С	D
1	.247	.253	.248	.250
2	.248	.251	.252	.249

Plate #3

Location	Α	В	С	D	E
1	.249	.250	.253	.253	.251
2	.250	.254	.253	.251	.249
3	N/A	.255	.254	.246	.251

Horizontal

Location	Α	В	С	D
1	.249	.250	.250	.249
2	.229	.172	.197	.190

Plate #4

N/A

Plate #5

N/A



SECTION # 4 (NORTH)

Working East to West

Plate # 1

Location	Α	В	С	D
1	.250	.251	.250	.251
2	.250	.248	.249	.250
3	.251	.250	.249	.251
4	.252	.258	.248	.249

Plate # 2

Location	Α	В	С	D
1	.252	.253	.258	.258
2	.254	.244	.226	.258
3	.252	.230	.203	.195

Plate #3

Location	Α	В	С	D
1	.209	.227	.228	.191
2	.234	.249	.227	.219
3	.227	.234	.235	.208

Horizontal

Location	Α	В	С	D
1	.228	.231	.250	.244
2	.199	.253	.254	.250
3	.204	.251	.250	.251

Plate #4

Location	Α	В	С	D
1	.249	.251	.252	.250
2	.255	.253	.250	.251

Plate # 5

Location	Α	В
1	.220	.249



SECTION # 4 (SOUTH)

Working East to West

South Bend

Location	Α	В	С	D
1	.245	.250	.252	.253

Horizontal

Location	Α	В	С	D
1	.251	.240	.249	.250
2	.246	.250	.250	.249
3	241	249	247	250

Plate # 4

Location	А	В	С	D
1	.209	.250	.251	.254
2	.220	.254	.254	.253

Location	Α	В
1	.230	.250



SECTION # 5 (NORTH)

Working East to West

Plate # 6

Location	Α	В	С	D
1	.240	.237	.249	.248
2	.249	.249	.254	.251
3	.248	.248	.251	.247

Location	А	В	С	D
1	.250	.250	.251	.249
2	.252	.249	.248	.248
3	.252	.251	.250	.250

Plate #8

Location	Α	В	С
1	.251	.251	.249
2	.251	.250	.248
3	.247	.245	.241

Plate #9

Location	Α	В
1	.249	.251
2	249	252



SECTION # 5 (SOUTH)

Working West to East

Plate # 6

Location	Α	В	С	D
1	.245	.248	.241	.247
2	.250	.246	.250	.250
3	.250	.246	.250	.250

Location	А	В	С	D
1	.247	.250	.247	.247
2	.246	.246	.245	.245
3	.247	.246	.247	.246

Plate #8

Location	Α	В	С
1	.250	.250	.245
2	.250	.249	.249
3	.251	.246	.251

Plate #9

Location	Α	В
1	.247	.251
2	.240	.251



SECTION # 5 (WEST)

Working North to South

Plate # 6

Location	А	В	С	D
1	.252	.235	.250	.210
2	.250	.250	.248	.235
3	.251	.250	.255	.255

Plate #7

Location	А	В	С	D
1	.234	.255	.250	.252
2	.252	.244	.244	.250
3	.252	.250	.253	.244

Plate #8

Location	Α	В	С	D
1	.210	.230	.229	.241
2	.215	.229	.240	.248

Location	Α	В	С	О
1	.250	.248	.250	.246
2	.251	.247	.251	.250



SECTION # 5 (EAST)

Working North to South

Plate # 6

Location	Α	В	С	D
1	.251	N/A	N/A	.239

• Location #1 located at bottom.



2.1 East Breeching

UNIT #1 EAST AIRHEATER TO STACK DUCTING

SECTION # 3 EAST

L	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Т	.250	.252	.246	.249	.246	.250	.247	.253	.251	.249	.247	.246	.218	.229
В	.249	.251	.239	.250	.249	.252	.249	.251	.249	.242	.239	.236	.242	.239
М	.249	.249	.250	.245	.250	.236	.249	.248	.246	.246	.233	.244	.229	.240

SECTION #3 WEST

L	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Т	.249	.259	.258	.259	.257	.247	.255	.258	.257	.249	.255	.227	.239	.239
В	.249	.255	.257	.258	.257	.256	.255	.257	.259	.255	.255	.181	.219	.194
М	.246	.251	.249	.258	.253	.252	.257	.255	.255	.252	.257	.214	.199	.240

SECTION #3 TOP

L	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Α	.249	.251	.250	.249	.247	.252	.248	.249	.249	.243	.249	.202	.221	.198
В	.250	.250	.250	.249	.252	.250	.244	.246	.249	.191	.249	.214	.172	.226
С	.249	.249	.209	.249	.256	.256	.259	.254	.251	.248	.235	.225	.210	.199
D	.247	.241	.251	.254	.252	.244	.256	.249	.255	.251	.234	.197	.223	.196
E	.242	.246	.248	.244	.236	.235								

SECTION #3 BOTTOM

L	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Α	.252	.232	.249	.256	.262	.262	.259	.251	.258	.255	.251	.249	.247	.247
В	.251	.250	.248	.252	.260	.260	.258	.258	.259	.254	.254	.190	.192	.210
С	.246	.247	.246	.247	.259	.260	.241	.247	.252	.250	.251	.175	.170	.171
D	.250	.235	.248	.251	.260	.261	.259	.240	.250	.253	.253	.248	.249	.221
Е	.247	.249	.248	.251	.261	.260								

- Location #1 starts I ft. from plant, remainder @ 2 ft. intervals.
- Top & Bottom locations only, A is on the west.
- · All reading recorded in inches.
- L is the location



SECTION # 4 (EAST)

Working South to North

Plate #1

	Location	Α	В	С	D
Ī	1	.252	.250	.246	N/A
ſ	2	.243	.249	.253	.255

Plate #2

1	Location	Α	Ш	O	О
	1	.253	.253	.248	N/A
	2	.253	.251	.252	.242

Plate #3

Location	Α	В	С	D	Е
1	.229	.249	.249	.249	.227
2	.251	.255	.253	.253	.249
3	N/A	.254	.254	.251	.244

Horizontal

Location	Α	В	С	D
1	.255	.255	.253	.252
2	.248	.250	.253	.249
3	.252	.253	.249	.239

Plate #4

Location	Α	В	С	D
1	.198	.255	.255	Hole
2	.251	.244	.253	.239
3	.199	.254	.253	.225

Plate #5

Location	Α	В	С	D
1	.254	.199	.199	.219
2	.248	.209	.229	.218



SECTION # 4 (WEST)

Working South to North

Plate #1

Location	Α	В	С	D
1	.198	.252	.255	N/A
2	.238	.251	.250	.250

Plate #2

Location	Α	В	С	D
1	.252	.253	.253	N/A
2	.253	.255	.255	.251

Plate #3

Location	Α	В	С	D	Ш
1	.208	.217	.252	.253	.248
2	.228	.250	.250	.254	.237
3	N/A	.230	.253	.245	.252

Horizontal

Location	Α	В	С	D
1	.199	N/A	N/A	.250
2	.201	N/A	N/A	.251

Plate #4

N/A

Plate #5

N/A



SECTION # 4 (NORTH)

Working East to West

Plate # 1

Location	Α	В	С	D
1	.217	.255	.251	.255
2	.195	.246	.250	.255
3	.206	.253	.254	.250
4	.181	.252	.252	.248

Plate # 2

Location	Α	В	С	D
1	.229	.249	.249	.249
2	.251	.255	.253	.253
3	N/A	.254	.254	.251

Plate #3

Location	Α	В	С	D
1	.254	.253	.249	.244
2	.250	.249	.244	.209
3	.244	.244	.249	.217

Horizontal

Location	Α	В	С	D
1	.250	.248	.246	.248
2	.165	.177	.171	.198
3	.249	.246	.198	.239

Location	Α	В	С	О
1	.250	.253	.254	.241
2	.254	.243	.162	.189

Plate # 5

Location	Α	В
1	.199	.197



SECTION # 4 (SOUTH)

Working East to West

South Bend

Location	Α	В	С	D
1	.252	.250	.253	.249

Horizontal

Location	Α	В	С	D
1	.253	.253	.252	.252
2	.160	.232	.232	.249
3	.149	.226	.254	.236

Plate #4

Location	Α	В	С	D
1	.254	.255	.253	.223
2	.255	.250	.228	.199

Location	Α	В
1	.196	.210



SECTION # 5 (NORTH)

Working East to West

Plate # 6

Location	Α	В	C	D
1	.248	.251	.250	.250
2	.250	.235	.253	.251
3	.251	.240	.254	.250

Plate #7

Location	Α	В	С	D
1	.239	.250	.254	.249
2	.210	.255	.254	.250
3	.222	.223	.254	.252

Location	Α	В	С
1	.250	.227	.250
2	.221	.240	.240
3	.240	.244	.252

Plate # 9

Location	Α	В
1	.196	.174
2	.199	.194



SECTION # 5 (SOUTH)

Working East to West

Plate # 6

Location	Α	В	С	D
1	.249	.253	.220	.249
2	.245	.251	.249	.250
3	.251	.250	.250	.253

Location	А	В	С	D
1	.250	.252	.250	.250
2	.251	.251	.250	.250
3	.250	.255	.254	.251

Plate #8

Location	Α	В	С
1	.250	.221	.253
2	.251	.248	.245
3	.195	.253	.250

Plate #9

Location	Α	В
1	.239	.199
2	231	240



SECTION # 5 (EAST)

Working South to North

Plate # 6

Location	Α	В	C	D
1	.189	.216	.207	.246
2	.250	.249	.194	.241
3	.249	.245	.241	.176

Plate #7

Location	Α	В	С	D
1	.244	.237	.250	.248
2	.250	.250	.249	.250
3	.251	.248	.241	.198

Plate #8

Location	А	В	С	D
1	.250	.253	.240	.236
2	.253	.239	.236	.242

Location	Α	В	С	D
1	.230	.183	.179	.218
2	.231	.218	.213	.221



SECTION # 5 (WEST)

Working North to South

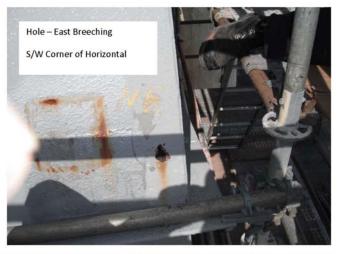
Plate # 6

	Α	В	С	D
1	.249	N/A	N/A	.235

• Location #1 located at bottom.

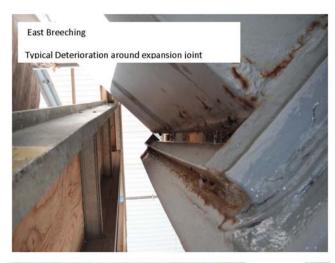


3.0 Photographs:

















TEAM [®]Industrial Services







ULTRASONIC

EXAMINATION REPORT 150 9001:2008
Branch Office: 41 Sagona Ave, Mt. Pearl, NFLD. AlN 4P9 Telephone: 709-745-1818 * Fax 709-745-5401

Job Number: 5	2080 6 38			Client Specifications: QA/QC				
Client Name: Hatch				Acceptance: Client info				
Tarana and				Procedure: UT- GP- 01 REV 1 Technique: ASME V				
Type of Fabri	cation:	Weld	Casting	Forgin	g Pla	tex O	her	
Part/Assy No.:	J/A	DwgNo.:	N.	Heat No.:	'A	Patiern No.:	'A	
Scope: This	report covers	the ultrasonic	thickness mea	surements and	visual inspect	tion		
		k Ducting loca				K05000		
Only accessibl	e areas were i	, P						
Total Parts Inspected			Total Parts Accepted N/A			Total Parts Rejected		
N/A N Scan: 0 deg.				J/A N/A				
Surface Finisl	Ÿ.							
ULTRASONIC EQUIPMENT				TRANSDUCER				
Make	Model	S/N	Cal. Date	Angle	Size	Frequency	S/N	
Panametrics	37DLPlus	071524109	Aug 24,2010	0	.434	5MHz	600648	
		1		10			V	
Calibration Blo	ock: 0.100"-	0.500"		Serial No.: 06-6438				
Couplant: E:	kosen 30			Batch No.: 11006303				
foruce. All conficues audit	or reports suc due result of th	ork performed in conferman	a telde applicable apocifica	nous and standards to the be	at of our skeley and current.	z povřemeneg dna tveké tvlatde fall Hotvovov, dno ozmapany tvíli mot kv	complete de exact com responsible for deviso	
TEAM TECHN	PriotiNa	me .	ode acceptance shall re Symtore	Certi	fication: 4353 3 48.9712 Level	ACCP	Level II 🗖 Level II X	

HEAD OFFICE 389 Davis Road, Oakville, Ontario L6J 2X2 Telephone: (905) 845-9542 * F sx (905) 845-9551

 ${\tt Page} \ \underline{1} \ {\tt of} \ \underline{1}$ 007UIR0

CLIENT REPRESENTATIVE FINAL ACCEPTANCE: N/A



5.0 Summary

The ultrasonic thickness survey was completed on all accessible areas of both the east and west breeching. Several thickness measurements were taken at each location with the lowest recorded. There are isolated areas that have wall loss less than .200 inches. It appears that the nominal wall thickness was .250 inches. The overall paint condition is fair to good with deterioration noted around the stiffeners. All observed holes were covered with Devon and painted. There is a lot of deterioration around both expansion joints.

APPENDIX B

Condition Assessment of Stack Breeching

At Holyrood Thermal Generating Station

Units 1, 2, and 3



Final Report

to

Newfoundland & Labrador Hydro

of an

Engineering Study

on

Condition Assessment of Stack Breeching at Holyrood G.S. Units #1, 2, & 3

Prepared by

Alstom Canada Inc. Ottawa, ON

Reference # 40833010

DISCLAIMER STATEMENT

This document was carefully prepared on the basis of Alstom observation and analyses, and any conclusions and recommendations are based on Alstom experience and judgement.

The Company disclaims all warranties in respect to services rendered in connection with this Contract whether express, statutory, oral, written or implied.

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Should the Purchaser subsequently retain Alstom to perform any of the work related to recommendations contained in this report, a separate contract governing such work shall be executed appropriately.

This document is furnished for the Purchaser's benefit only, and not for the benefit of any third party.

This report was prepared by Pavel Kratina, P. Eng. and was reviewed by John McMillan, P.Eng. Revisions 1 -4 were edited by Jim Kearns, P. Eng.



EXECUTIVE SUMMARY

Environmental and operational conditions in Holyrood G.S. have precipitated severe corrosion of the original, externally insulated breeching that has necessitated intensive and costly maintenance. Initially, the corrosion of the ductwork was more prevalent in Units 1 and 2, since Unit 3 was built ten years later. In replacing the breeching at the time of the 1989 boiler upgrades, Newfoundland & Labrador Hydro has turned to an alternative design featuring internal borosilicate lining along with an outside protective coating, which carried a promise of low maintenance cost.

Although the changeover to internal insulation partially solved the corrosion predicament, it has created a worse problem of having to repair and replace the broken and dislodged glass insulation blocks; during winter operation, gas cooling below the dew point may be occurring at those locations causing corrosion of the duct shell. The cost of maintaining the internal liner in a serviceable condition is becoming prohibitive, and it seems to be far offsetting the benefits of eliminating the icefall damage of the breeching exterior. Less expensive and more reliable materials could probably replace the current insulating blocks and refractory, but the underlying concern – no access for inspection of the duct plate and potential for localized corrosion - would remain.

A more serious root cause of the internal corrosion may have been the operating conditions of the units that prevailed until the recent change to a more sulphur "friendly" fuel (1% max. limit). At the full-load operation and with no controls employed, the outlet gas temperatures would come very close to the sulphuric acid dew point of fuels containing 2.5% or more sulphur, and the situation would become worse at low-load operation. The steam coils, used to control the average cold end temperature (ACET) of the pre-heaters, did not have adequate capacity for winter operation until the boiler uprates in 1998 when they were upgraded.

It is conceivable that the initial corrosion and maintenance problems would not have been so severe under the current operating conditions, i.e., lower sulphur content and improved outlet gas temperature control, providing the external insulation was protected from the elements and well maintained.

A number of options are provided with varying capital costs and associated anticipated maintenance requirements as shown in the "SUMMARY AND RECOMMENDATIONS" section. Also included is an overview of the condition of the Unit 3 expansion joints and suggested options to deal with the problems.

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INTRODUCTION AND PROBLEM DEFINITION

Units 1 and 2 at the Newfoundland and Labrador Hydro (NLH) Holyrood G.S. are pressurized units of Alstom (formerly CE) design from 1968; Unit 3 is a B&W boiler, constructed in 1979. Units 1 and 2 were up-rated from 150 to 175 MW in 1989, and part of the upgrade was a replacement of the breeching section between the air pre-heater and the stack.

The original breeching was a typical back end duct design constructed of 1/4" carbon steel and insulated externally. From the information available it appears that the cladding was continually damaged by ice falling from the powerhouse and stacks, allowing moisture to penetrate in insulation, which led to insulation break down and severe corrosion of the carbon steel ducting. The cost of repairing/replacing the corroded duct sections was deemed to be too high and a decision was made by the plant management to replace the breeching.

A NLH internal study opted for a design that provided for internal insulation of borosilicate blocks and a protective coating on the breeching exterior. The promise of the new system was a much-reduced maintenance cost by comparison to the original ducting. Replacement of the breeching of the two Alstom units was completed in late 1990. Since there is no specific information available one can only speculate that it was done at the same time as Units 1 and 2.

Early into the operation (1991), the new ducts developed problems such as erosion wastage and cracking of the insulation and the concrete layer. Later, problems with the liner began to mount – the insulation blocks would break and fall out allowing the gas to penetrate to the duct plate, cool and cause localized corrosion of the duct plate. As the records show, the internal liner requires frequent repairs, and the cost of keeping the insulation blocks in good order has proven to be considerably higher then anticipated. One of the reasons for the internal liner degrading may be the specified service temperature limit of the adhesive membrane of about 200°F that is easily exceeded if in contact with the flue gas (through cracks initially), which in turn may explain dislodged silicate blocks.

To make the situation worse, the exact sites of the corrosion damage are difficult to find under the insulation layers and the protective coating outside until the plate is corroded through. Cleaning the duct floors has become difficult with the floor concrete layer broken or otherwise damaged.

Alstom was commissioned to evaluate the current situation, reflect on the latest practices in the industry, and propose alternatives to minimize the breeching corrosion problems and high maintenance cost.

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CONDITIONS LEADING TO DUCT REPLACEMENT

The decision to replace the breeching was made in 1987-88, and concerned mainly units 1 and 2. The move was driven by corrosion related maintenance problems and associated maintenance cost. Unit 3 ducting, which is of a different layout, was eventually replaced as well although it was only 10 years old at the time and presumably had not experienced the same degree of deterioration. The underlining problem seemed to have been a severe corrosion condition created by formation of acidic condensate due to flue gas temperatures dropping below the acid dew point. The sub-cooled gas temperatures may have been a result of boiler operation and/or a contact with poorly insulated ducting.

It appears the condition of the external insulation contributed significantly or may have even been instrumental to the ductwork deterioration. As it happened, insulating materials on the two older units were not identical: Unit 1 was insulated with 2-1/2" of calcium silicate rigid insulation with a 1/8" flintcote 110-26 mastic applied over the blocks and reinforced with fibreglass mesh set in the mastic; Unit 2 was covered with soft bat exterior insulation and protective cladding. It is not known if there were differences in the degree of deterioration and maintenance between the two ducts.

Based on the information available (plant personnel recollection and a 1990 technical paper presented at CEA workshop), the problems with the original breeching stemmed from damaged external insulation leading to a severe corrosion of the duct plate. Moisture would penetrate into the insulation through damaged outer protection (mastic or cladding) – presumably damaged by ice falling from the stack and powerhouse (Fig. 6-7), rending the insulation ineffective. In addition, the wet insulation on sidewalls likely sagged, creating pockets of no or very little insulating material. It is believed that the degraded condition of the insulation caused considerable corrosion of ducting from outside. To further exacerbate the situation, a lack of insulating allowed the gas in contact with the duct plate to cool below the acid dew point causing in turn widespread internal corrosion (Fig's 1-5). Deterioration of expansion joints was an added irritant, which needed to be addressed.

In 1987 the condition of breeching was such that replacement was deemed necessary. An in-house study produced four replacement alternatives:

- 1) Modified existing design (modifications referred to expansion joints)
- 2) Borosilicate lining inside and corrosion resistant coating on the exterior
- Sheets of corrosion resistant alloy material welded to the carbon steel ducting plate c/w external insulation
- 4) Liquid fluorocarbon coating inside and insulation outside.

Based on cost analysis, the plant management favoured to second option mainly because of the promise of dependable service and low maintenance cost. The breeching ducting was replaced in 1989-1990 with ducts insulated inside with borosilicate (glass) insulation blocks and additional layer of silicate concrete on the floor. The new breeching went into operation at the end of 1990.

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CONDITION ASSESSMENT OF CURRENT BREECHING

Shortly after start up, the new breeching developed erosion and cracking problems requiring costly repairs, which later escalated as the concrete floors began breaking up and the insulation blocks falling out. Following is an overview of the problem history of the current breeching, based on information made available (see also Fig's 8-26):

Past history of problems

Inspection of breeching in 1991- brief summary:

(Ref.: Internal inspection report, Wayne Rice, Nov. 1991)

- Installation of the new breeching in Unit 1 was completed in the fall of 1990
- The unit operated from Dec 1990 to April 1991; subsequent inspection of the ducting uncovered erosion wastage of the lining in the upper half of the elbow – the material loss amounted to 1/4" to 1/2" over a 4-month period
- Test blocks were selected to monitor the erosion rate; second measurement in October 1991 showed loss of another 1/16" to 3/16"
- The problem was linked to the fans capacity increase required for the boiler uprate, delivering higher air volume, which in turn increased the gas velocities to 50 fps from the previous 43 fps.
 For comparison, the supplier (Autochem) affirmed the material suitability for up to 120 fps flow
- Unit 2 was first inspected in the fall of 1990 and no erosion was found. The unit operated
 erosion free for one year with the original impeller until the fan was upgraded during the 1991
 outage (possibly April or May). An inspection in October 1991 uncovered similar lining loss as in
 Unit 1
- Erosion affected approximately 3% off the total surface area of each duct in question
- Repair cost for both units was quoted at \$55,000 by a contractor on site
- Some cracks in the lining were found and repaired
- External protective coating started to show signs of rust discoloration

Operating period 1992-2000

No inspection and maintenance records available for review

Summary of breeching repair work 2000-2008:

(Ref.: Breeching history summary, J. Adams, Alstom)

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Unit 1:

After eleven years in operation, extensive repairs to the insulation blocks were required. There was no significant work done in 2001, but repairs were required in the following years. In 2006, a new floor was poured by C&E Refractories. Another major insulation block replacement was carried out in 2008.

Unit 2:

In 2000, approximately 750 ${\rm ft}^2$ of insulation was replaced. Some insulation block replacement was done in the years 2003-2005. The floor has deteriorated significantly, but to date no major work was done to correct the situation.

Unit 3:

Very little repair work was carried out until 2002. After that, insulation blocks were replaced and holes patched as required. In 2007 a new material was used for replacements, Pennguard 55 (as opposed to Pennguard 28), on trial basis. Inspection in 2008 found the Pennguard blocks in very good condition.

Current breeching condition - inspection summary

(Ref.: 2008 Inspection Report, J. Adams, Alstom Canada)

Unit 1:

West breeching

A large quantity of ash was found on top of the duct floor, but the refractory was intact. The horizontal section appeared to be in good condition - there were no holes found and no evidence of leaks. The sidewall insulation blocks were in excellent to good condition. The ceiling was good overall, but there were a few small isolated sections requiring repair - about 10 blocks were replaced. All bracing was found in good condition.

The pantleg (inclined) section had a few blocks fallen off from the overhead panel between the expansion (EJ) joint and the stack, and up to 6-10 blocks near the EJ were damaged or fallen out. A few blocks were loose and others in questionable condition on the sidewalls. The refractory at the upward bend was in acceptable condition.

East breeching

Ash has accumulated on the floor, but the refractory appeared in good condition. No major damage was found in the horizontal section, only a few isolated small sections overhead were slightly damaged needing repair. Above the up-bend, about 60 blocks had fallen off exposing the mesh. Ash and debris has accumulated between the refractory and the casing. Initially two through holes were spotted, but 12 holes were found when the loose blocks were removed and the casing cleaned.

The expansion joint has deteriorated considerably: cover plates were hanging loose, mostly separated from the sides. Behind the cover plates, the inner layers of the fabric element (insulation layers) and the inside of what appeared to be the outer belt could be seen.

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The condition of the liner above the expansion joint was difficult to ascertain because no scaffolding was erected for access. However, there appeared to be loose blocks overhead and on the sides that should be replaced. This could amount to a significant repair work. Loose blocks in area of EJ were replaced, holes in breeching were patched from outside and rods were welded to the inside of the duct shell to secure the mesh for refractory, and the EJ cover plates were repaired.

A hole was found in the bottom corner of the expansion joint and repaired. The ladder inside the breeching is severely corroded and should be removed completely. A total of about 230 blocks were installed in the east breeching.

External breeching inspection

A great degree deterioration of the expansion joints is obvious – failed corners, evidence of leaks. A more detailed inspection is needed, but that would require removal of the cover plates. Corrosion was visible under the coating.

Unit 2:

West breeching

There were a number of blocks to be replaced on the south and north walls under the air heater. The breeching floor was cracked near the hopper and lifting up. It is quite thin – only about 1‡" to 2". This floor was done in 2005, and may have to be replaced again in the near future.

Overall, the internal lining was in acceptable condition. There were isolated small areas requiring attention. The pantleg area appeared to be in good condition except for a section of relatively new blocks on the north wall that seemed to be separating from the duct. There was no access for a closer look – scaffolding was not erected. Very little ash was found on the duct floor. One brace in the horizontal section had separated from the duct on the bottom.

Approximately 15 blocks were replaced. Three other small locations with loose blocks were identified but could not be stripped due to the slime deposit on all surfaces (condensation). Two of these were in the horizontal section while the other was in the pantleg. Without scaffold it was difficult to better assess the pantleg condition. However, each location appeared to require between 4 and 6 block replacements.

East breeching

The floor was in poor condition, but the rest of the block liner was sound with only a 9-block section replaced. However, the blocks appeared wet and soft overhead at the beginning of the up-bend. No leaks were found.

External breeching inspection

On the east side, the expansion joint had a leak at the bottom flange. The cover plate does not cover the entire flange to provide adequate protection from the environment. Also there are many locations on top

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of the cover where water is allowed to pool. The fabric element behind the cover plate appeared to be intact, but it would be necessary to remove the cover plate for a proper assessment.

On the west side, the protective coating broke down in small, localized areas and at a brace attachment showing corrosion. The expansion joint element has failed along the top, and a leak was found in the flange at the bottom. Again, water was pooling on top of the cover plate. Relatively minor rust discoloration was noted on the coating of the horizontal section. Also, a patch on top of the flue, welded from the inside, had not been sealed from outside.

Unit 3:

Internal breeching

Test patches of Pennguard 55 insulation material, installed in 2007, do not exhibit any deterioration or damage. Another new material, Smoothkote refractory, may also be a viable option, as the test patch remained in good condition after one year of operation. The Pennguard 55 block differs very little from the normally used Pennguard 28, and is about 30% cheaper. However, the currently used material may have been in equally good condition after one year of operation, and more time is required to draw a conclusion regarding possible use in the future.

Overall, the block liner is in acceptable condition. The blocks, replaced previous year, show no appreciable damage. However, there were new sites identified where the lining has degraded: the inspection identified about 40 silicate blocks requiring replacement.

It was noted that ash has accumulated in the expansion joint near the stack and this was causing the cover plates to be pushed outward. It was recommended that the plates be removed temporarily to allow the ash to be removed. Not much ash was found in the breeching.

External breeching inspection

The breeching appears in good condition from the outside. There were no indications of leaks in the corner areas or on top where they have been found in recent years. On the west side, a hole could be seen that had been patched from the inside, but not sealed from the outside, which allows moisture to pool inside the cavity and cause external corrosion. Also, the top of the breeching near the stack should be re-painted. The crotch area looked good.



UNIT OPERATION CONSIDERATIONS

Operation of the boiler and back end equipment is believed to have contributed significantly to creating conditions leading to deterioration of the original breeching as well as of the breeching installed as part of units 1 and 2 upgrade. The back end system, as designed, relies on steam coil air heaters (SCAH) to control the gas temperature leaving the Ljungstrom air pre-heater. The general recommendation is that the flue gas temperature be at least 28°C (50°F) above the sulphuric acid dew point of a fuel.

Although the target sulphur content in the fuel has always been 2.2% according to Alstom personnel on site, the Holyrood records typically refer to 2.5% sulphur content (an analysis of a 1987 bunker C oil sample showed as much as 2.8% sulphur content) for which the acid dew point was calculated to be 148°C (298°F), commanding a "safe" temperature of the gas of at least 177°C (350°F). Fluctuations in sulphur content is echoed in the increase or decrease of the safe temperatures needed to avoid acid formation in the duct. The current limit on sulphur content in the fuel stands at 1%, which corresponds to 138°C (280°F) and 166°C (330°F) dew point and safe outlet gas temperatures respectively.

Without SCAH intervention, the acid dew point of the flue gas would come close to the gas design outlet temperature of approximately 150°C (302°F) for the original MCR (150 MW) and approximately 155°C (311°F) for the uprated load condition (175 MW). The temperature would drop below the dew point at low loads in off peak operating periods, possibly falling to 115-120°C. The boilers seldom operate at full load; typical loads may vary between 70 and 140 MW, but could operate as low as 50 MW (30% MCR), which means that gas temperatures would be below the dew point for a large portion of the unit operating time. As an example, in 2007 the averaged output of Unit 1 was 70 MW (40 %MCR), Unit 2 put out 110 MW (63 %MCR) and Unit 3 put out 89 MW (69 %MCR).

The steam coils have always been used in Holyrood striving to keep the average cold end temperature (ACET) of the air pre-heater at a target temperature of approximately 107°C (235°F) with a corresponding gas outlet temperature of 164°C (327°F). This would not have been a safe gas temperature for the pre-2006 fuel (needed 177°C), but would be acceptable for the new fuel composition criterion. By comparison, the target ACET for 1.0% sulphur oil is 105°C (221°F).

It was recognized in the early years of the units' operating life that the SCAH's did not have adequate capacity to support the air pre-heater requirements in winter operation with the cold air drawn from the outside, which in turn caused the outlet gas temperatures be much lower than the design. The remedy was to draw the combustion air from inside the powerhouse at the expense of creating another set of problems – because of the considerable vacuum created by the fan intake, air from outside the building would enter from all available openings and cause frequent freeze-ups throughout the plant, and opening of doors was difficult causing the doors slam shut endangering the plant personnel (Re: 1990 CEA paper). The SCAH's have been upgraded following the uprate in 1989 - a second bank was added effectively doubling their capacity. Also, a "warm air make-up system" has since been added that helps feed the combustion air into the plant in a controlled fashion that helps to avoid the freeze-up problems.

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SUMMARY AND RECOMMENDATIONS

In the utility boiler industry, it is a recognized fact that breeching ducting has a limited life and may need replacement periodically, either completely or partially. Although a twenty-year life span of ducting is not unusual, controlling or preventing the adverse conditions leading to early deterioration, both inside and outside, can extend it.

Most breeching systems employed by the utilities surveyed are of carbon steel plate construction with adequate external insulation, and only in extreme cases or in some old utilities internal insulation liners are employed. Externally insulated ducts are generally much easier to inspect, maintain and clean. Alstom does have a standard design for internal lining, typically consisting of 4" calcium silicate blocks with expanded metal mesh and 3/4" layer of Super 3000 (Alstom hi-temp refractory) on top, but the design is rarely used being maintenance intensive. Internal insulation or corrosion resistant steel liners are used in pulp and paper industry and by HRSG's. From the operation perspective, there is no advantage to insulating ducts inside rather then externally.

The chronic corrosion of the original breeching in Holyrood appears to have been rooted in deteriorated external insulation, and in operating conditions, such as low-load operation, that drove the gas outlet temperatures below the sulphuric acid dew point.

The new breeching, fitted with internal borosilicate lining, was expected to alleviate both the corrosion problems and the high maintenance cost, but failed to do either. Not only did the internal and external corrosion problems continue, although at a reduced rate, but the corroded sites became difficult to inspect and access for repairs, and the bulk of the maintenance has shifted to replacing and repairing the internal liner blocks. The projected annual maintenance cost burgeoned from the expected \$8K per duct (extracted from the 1988 internal cost analysis) to a sizable multiple of that at times (e.g., in 2003, replacement of 350 sq.ft. of the silicate block liner in Unit 2 cost \$90K). For comparison, the projected cost of maintaining a breeching as per the original design was \$21K per year per duct.

To have a real chance of succeeding in minimizing the corrosion problem, any solution alternative selected has to embrace continuous gas temperature control at all loads. That means the ACET should be subordinate to maintaining the gas outlet temperature at 166°C (330°F) or higher at all times to avoid formation of sulphuric acid, assuming the upper limit of sulphur in the fuel (1%) is adhered to. External corrosion problems have to be addressed in parallel with controlling the internal conditions.

Considering the fact that the acid dew point has been lowered by virtue of a lower maximum allowed sulphur content in the fuel, the conditions for acid corrosion would have been somewhat mitigated already, which should reflect in lower duct maintenance in the future. However, due to the length of the service life (almost twenty years) and extended exposure to the past prevailing conditions, deterioration of the current liner may continue at the same pace or worse, if some upgrades are not implemented. The low service temperature of the adhesive membrane is likely to remain a contributing factor to the insulation block failures.

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The breeching expansion joints are in a poor condition and need a major overhaul as an interim solution, but a replacement in kind should be in the planning.

A separate issue to be dealt with is the deteriorating condition of the seven metallic expansion joints – all bellows type joints – on the hot air outlet duct from the air pre-heater. These are the original components and have been in operation for almost 30 years. Although air duct expansion joints are not exposed to as harsh environment as the gas touched components, time and service demands eventually took their toll - they all appear heavily rusted and are cracking, likely due to fatigue, in the bottom sections (see Fig.'s 30-32). The joints could be repaired piecemeal as required, but as a long-term solution, it is advisable to replace them with properly engineered cloth joints. Some of the alternatives shown below have already been considered in earlier discussions with NLH.

Solution alternatives - Breeching

Note: Indicative Pricing has been provided in Appendix 2. This indicative pricing is intended to provide an indication of relative supply and erect costs for budgeting purposes, approximately ±30%, and in not intended as an offer to provide services. Should Newfoundland & Labrador Hydro wish to pursue an option, Alstom would then provide a Proposal for such scope based on conditions at that time.

The "Solution" reference for each option refers to the "Breeching Solution" as outlined in the Indicative Pricing Estimate in Appendix 2.

- A) Current ducts are in serviceable condition and remain in place:
 - Keep current duct arrangement, repair duct and lining as required (Breeching Solution A1); use cheaper insulation material to replace borosilicate blocks (e.g., Pennguard 55 vs. Pennguard 28)

<u>Pros</u>: no capital investment, no time lost to upgrading ducting; potential for reducing maintenance cost by changing insulation block material;

<u>Cons</u>: break-down of the insulation material and adhesive membrane will likely not subside, may become worse; prohibitive cost of repairs will remain; difficulties accessing the sites of corrosion damage and leaks under insulation and the outer protective coating will not change; cleaning ash and debris from the duct floor remains impaired; erosion wastage of lining may still be a problem

2) Keep current duct arrangement, but add 4" of external water repellent insulation and a watertight cladding (Breeching Solution A2): repair internal lining as required, and have the overall concept - materials and specs - reviewed for possible improvements - less expensive insulation blocks, increased concrete layer and block thickness, etc; protect external cladding against falling ice (catwalk grating, hood, etc., see B below) if that remains a genuine problem. The external surface should be cleaned of rust before installing the insulation..

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<u>Pros</u>: the external insulation will help prevent gas cooling even if lining damaged; potential for reducing maintenance cost by changing insulation block material; corrosion of the duct

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shell <u>due to gas cooling</u> through contact with the duct plate will be minimized or eliminated if external insulation is maintained; degradation of borosilicate lining less critical with external insulation added

<u>Cons</u>: added cost of external insulation and cladding c/w protection against damage; breakdown of the internal insulation material and adhesive membrane will likely not subside, may become worse; the internal liner will still have to be maintained, therefore prohibitive cost of repairs will remain; continuing difficulties accessing the sites for inspection; cleaning ash and debris from the duct floor remains impaired;

3) keep current duct, add 6" of external insulation and remove internal liner blocks and silicate concrete (Breeching Solution A3); protect external cladding against falling ice (catwalk grating, hood, etc., see B) below) if that remains a problem. The external surface should be cleaned from rust before installing the insulation.

<u>Pros</u>: the upgraded external insulation will provide adequate insulation to prevent gas cooling, assuming it is kept in good serviceable condition; reduced maintenance cost by comparison to current situation – no insulation blocks to replace; corrosion <u>due to gas cooling</u> will be minimized or eliminated if external insulation is maintained; improved access for duct inspection and cleaning

<u>Cons</u>: added cost of external insulation and cladding c/w protection against damage; added cost of internal liner removal; access for duct inspection somewhat impaired if remnants of internal liner remain (e.g., adhesive membrane)

A modified Option 2 above (<u>Breeching Solution A2</u>) would be a preferred long-term solution **if the breeching is to be left in place**, i.e., the external insulation 6" thick (as opposed to 4" in Option 2) with the internal lining left alone initially and removed only if the silicate block degradation continued unabated. This way, no upgrade of external insulation (to the 6" thickness) would have been required if the internal liner were removed, as in Option 3.

B) Replace the entire breeching:

- 1) original duct design, made of
 - a) (<u>Breeching Solution B1a</u>) ‡" mild carbon steel plate (G40.21 or equivalent) c/w 6" of external water repellent insulation c/w watertight high quality cladding and flashing
 - b) (Breeching Solution B1b) ‡" Corten or equivalent high temperature carbon steel c/w
 6" of external water repellent insulation c/w watertight high quality cladding and flashing

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- c) (<u>Breeching Solution B1c</u>) 3/16" stainless steel (e.g., 304, 316L, 904L, HASTELLOY C276) c/w 4" of external water repellent insulation c/w watertight high quality cladding and flashing
- d) (<u>Breeching Solution B1d</u>) 3/16" Avesta plate (2205) plate c/w 4" of external water repellent insulation c/w watertight high quality cladding and flashing

<u>Pros</u>: a) if properly designed and maintained, the insulation offers adequate protection against gas cooling; standard ducting material used; reduced maintenance cost compared to the current breeching; reduced load on supports and ducting plate compared to inner liner; good access for duct inspection; insulation not susceptible to cracking

- b) same as a) above, but offers some protection against corrosion if gas temperature drops below acid dew point (higher chrome content min. 0.7%)
- c) and d) same as a) above, but the materials are corrosion resistant and therefore not susceptible to corrosion problems if the gas temperature is not maintained; less insulation required; less plate material used

<u>Cons</u>: a) does not address the original problem of insulation being damaged by falling ice; will suffer corrosion problems if outlet gas temperature is not maintained above acid dew point

- b) does not address the original problem of insulation being damaged by falling ice; higher material cost:
- c) and d) do not address the original problem of insulation being damaged by falling ice; high material cost; design check required due to thinner plate
- 2) <u>original duct design, construction alternatives as per 1), with added protection</u> against damage caused by ice falling from stack and powerhouse, as shown below:
 - a) (<u>Protection Solution B2a</u>) light-weight (LW), 1½" catwalk grating on the top panels (over aluminium cladding) attached to stack and side panels
 - b) (<u>Protection Solution B2b</u>) U-shaped 7 ga. plate encasement slid over the top panels (possibly with ice-breaker ribs)
 - c) (<u>Protection Solution B2c</u>) 3/16" carbon steel hood over the duct, attached to the duct sidewalls
 - (<u>Protection Solution B2d</u>) extra heavy gage, ribbed aluminium or steel cladding on the top panels

<u>Pros</u>: same as 1) but addresses the original problem of insulation being damaged by falling ice; less maintenance required for the external insulation if prevented from being damaged,

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relatively simple design needed for the protection; option d) would not require a special design for added protection

<u>Cons</u>: same as 1) except the falling ice protection; added cost of material and design of the falling ice protection, danger of creating heat sinks where protection attached to the duct

3) 1/4" Corten or equivalent hi-temp carbon steel duct, internal insulation c/w stainless steel liner (Breeching Solution 3) - similar to HRSG construction (3" cerwool or mineral wool insulation bats, 304L or 316L stainless steel 10 ga liner held in place with studs), no external insulation but protection coating

<u>Pros</u>: works well in HRSG application; less prone to external corrosion because of better plate material; insulation stays in place, traditionally low maintenance once settled

<u>Cons</u>: access for inspection restricted; installation sensitive; high installation cost, condensation may by a problem on bottom panel

Other options could include alloy or stainless steel cladding applied directly on the duct plate or a layer of polymer coating inside combined with external insulation, but these options were already explored by NLH and found expensive to apply and maintain, and were rejected.

The preferred long-term solution for **replacing the breeching** would be Breeching Solution B1b, with the Protection Solution B2b. Hi-temp carbon steels such as Corten have been used in the past for back end (breeching) ductwork, even if the gas temperature did not require it, because of their improved resistance to corrosion compared to low carbon steels. An additional 1/8" corrosion allowance could be added to extend the life of the ducting.

Solution alternatives - Hot air duct expansion joints, Unit 3

- 1) Repair or replace sections as required (Expansion It Solution 1): the bellows could be weld repaired as required, or partially replaced, specifically the bottom part of the joints. Considering the service life and the overall condition of the joints, this should be only a short-term maintenance fix. It may however prove difficult to weld-repair the joints because of the general condition of the expansion joint material.
- 2) Install cloth seal over the metallic expansion joints (Expansion It Solution 2): this interim solution would replace repairing the ailing metallic joints. It would not have any effect on the function of the current joints, but would prevent leaks. Care must be taken to evaluate correctly the movements as not the cause failure of these joints as well.
- 3) Replace the expansion joints in kind (Expansion It Solution 3): this alternative would see the expansion joints replaced as originally designed and built. No engineering is required, but the probable shortcomings of the current design would be copied.

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- 4) Replace with metallic joints, but review the selection (Expansion It Solution 4): engineering review would be required to confirm or repudiate the current selection, and possibly come up with a better system to prevent the current failures.
- 5) Replace the expansion joints with cloth joints, properly engineered (Expansion It Solution 5): cloth expansion joints are widely used and are the preferred solution in most ducting systems. They do not exert reaction forces to the system supports, and would not be subject to fatigue-induced cracking.

From engineering and operation standpoint, Option 5 is the preferred solution.

POST MEETING FOLLOW-UP

A meeting was held at Holyrood site on March 5, 2009 to review the findings of the Study as issued in Revision 1 dated March 4, 2009.

Based on discussions during the review meeting, it is recommended that replacement of the breeching is preferred over repairing the existing materials. This is supported by the fact that the current breeching is approximately 20 years old, the original breeching on Units 1 & 2 lasted approximately 20 years, and the fact that a lifespan of 20 years is quite typical for breeching.

For reference purposes, it was decided to select two options (Modified A2, and B1b) along with extended ice protection (B2b) option for more detailed installation estimate. Include repair of support structure for the repair option (Modified A2) and replacement of support structure in the replacement option (B1b).

The existing support structure on Units 1 & 2 breeching requires some repair and should be replaced if the breeching is replaced. It was determined after the meeting that the pricing for the supports is not in the current estimate. Also, fairly extensive repairs would be required to the support structure. For pricing purposes, only a replacement is to be priced.

N&L Hydro - Holyrood G.S. Stack Breeching Assessment 40833010 December 18, 2008 Rev. 1 – March 4, 2009 Rev. 2 – August 28, 2009 Rev. 3 –March 25, 2010 Rev. 4 – July 2, 2010

Table 1: J. Adams, Breeching History Summary 2000-2008

Appendix 1 – Figures & Tables

Year	Unit 1	Unit 2	Unit 3
2008	West side no scaffold - difficult to assess pantleg. However appeared to be sections where liner has failed above and adjacent to expansion joint. 40 to 50 blocks estimated but could be worse than appears. Horizontal section good – about 10 blocks replaced. East side many holes - duct patched from outside at north side of bend. Refractory in bend also failed. 230 blocks replaced in bend area. Horizontal section good. Scaffold up to expansion joint only. Above expansion joint liner is questionable condition. Could be a significant repair required. Expansion joints have failed both sides.	The refractory floor on both sides now in poor condition and requires replacement. West side approx 15 blocks replaced. No scaffold installed. Three other locations about 4 blocks each looked loose but not replaced due to condensation/sweat problem. East side one 9 block section was replaced. Block also wet and apparently soft overhead and up the pantleg in sections. Expansion joint in poor condition on both sides.	Test patches of Pennguard 55 block and refractory both in good condition after one year. About 40 blocks replaced – scaffold was erected. Debris noted in expansion joint should be cleaned out. Looked OK from external inspection.
2007	Minor repairs only – about 40 blocks total. Cost about \$5k	East floor in poor condition – not replaced. About 90 blocks on each side replaced – all in horizontal section – no scaffold required. 3 holes patched in west side. Total cost about \$16k.	Blocks replaced overhead and at both side corners – about 200 sqft. 15 holes patched (welded inside – Devcon outside). Trial patch of Pennguard 55 and Smoothkote refractory installed. Total cost about \$25k
2006	C&E Refractories poured new floor east side and block both sides. Total about 760 sqft. 5 holes in west and 12 in east side patched from inside and sealed with Devcon outside. Expansion joint cover plates bad. Total cost about \$320k	East floor in poor condition – not replaced. Block good both sides.	About 40 blocks to replace overhead but not done – no scaffold. 15 blocks that were accessible were replaced. No cost captured.
2005	East floor bad. Block to replace overhead and north on east side not done. West small quantity of block replaced but more to do with scaffold. Cost about \$2k captured.	Mount Pearl Painting hired to replace refractory on west floor and block on both sides. Many holes found on both sides and repaired from outside. Total cost about \$290k.	Hole found in top near stack. Patched from outside. No scaffold installed – accessible block replaced as required. About 50 blocks replaced and 15 not accessible. Total about \$5k.
2004	East floor bad – not replaced. East side scaffolded and block replaced. Hole in expansion joint patched. Cover plates bad. West side small quantity of block replaced – no scaffold. Cost about 515k	Just a couple of blocks replaced	Block replaced overhead and at corners (higher than 2003). No holes found. Scaffold erected. Total cost about \$10k.
2003	East floor starting to fail. Few blocks to replace. Supposedly repaired by another contractor working on the stack	Approximately 350 sqft of block replaced mostly on east side. Scaffold erected. Through holes patched. Done by C&E Refractories. Cost about \$90k.	Holes found on both sides. Scaffold erected and holes repaired. Block replaced as required. Costs not captured.
2002	Damage repaired by C&E Refractories. This included replacement of the west floor refractory. Don't know cost.	No significant work	Very small quantity of block replaced with no scaffold. Scaffold recommended to replace block next year.
2001	No significant work	No significant work	No work done. Minor repairs recommended.
2000	Significant work done to replace block. 540 hours reported – estimated around \$35k	C&E Refractory replaced about 750 sqft of block. Don't know cost.	Minor repair to borosilicate block liner

Table 1: J. Adams, Breeching History Summary 2000-2008



Fig. 1: Original Breeching, floor in horizontal section - Unit 1 or 2



Fig. 2: Original Breeching, pantleg inlet - Unit 1 or 2



Fig. 3: Original Breeching, sloping section - Unit 1 or 2



Fig. 4: Original Breeching, bend section - Unit 1 or 2



Fig. 5: Original Breeching, entrance to horizontal section (at heater) - Unit 1 or 2

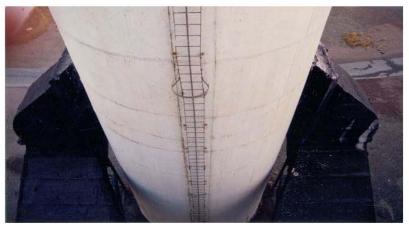


Fig. 6: Original Breeching, top view – Unit 1

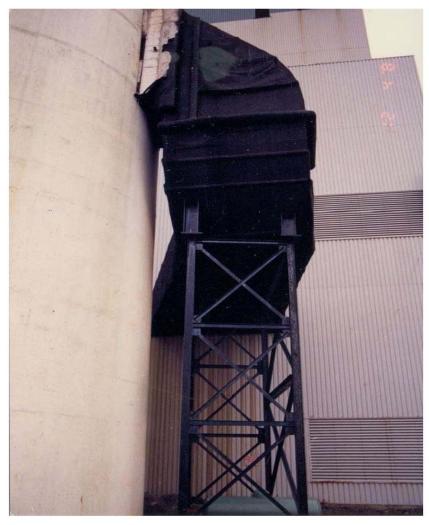


Fig. 7: Original Breeching, elevation view - Unit 1



Fig. 8: Unit 1 - Insulating block replacement

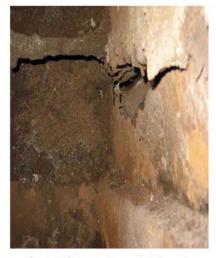


Fig. 9: Unit 1 - Duct corroded through



Fig. 10: Unit 1 - Sloped section as found



Fig. 11: Unit 1 - Sidewall and floor



Fig. 12: Unit 1 – Replaced blocks

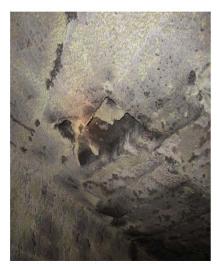


Fig. 13: Unit 1 – Missing block overhead



Fig.14: Unit 1 – Ash accumulated on the floor



Fig. 15: Unit 1 - Damaged expansion joint



Fig. 16: Unit 1 - External duct repairs



Fig. 17: Unit 1 - External duct repairs



Fig. 18: Unit 2 - Missing insulation blocks



Fig. 19: Unit 2 - Missing insulation blocks



Fig. 20: Unit 2 - Cracked cement floor



Fig. 21: Unit 2 - Cracked cement floor



Fig. 22: Unit 2 – External coating break down



Fig. 23: Unit 3 - Repairs 2007



Fig. 24: Unit 3 – Crotch repairs



Fig. 25: Unit 3 – Patched casing (from inside)



Fig. 26: Unit 3 – Top near the stack

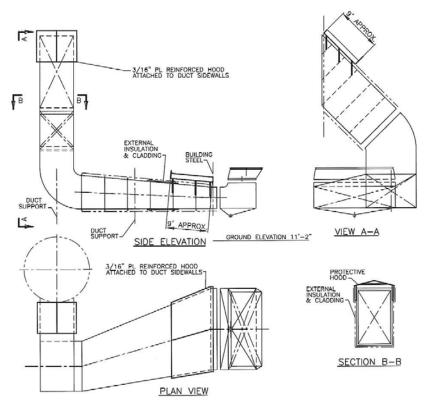


Fig. 27: Proposed cladding protection – protective hood

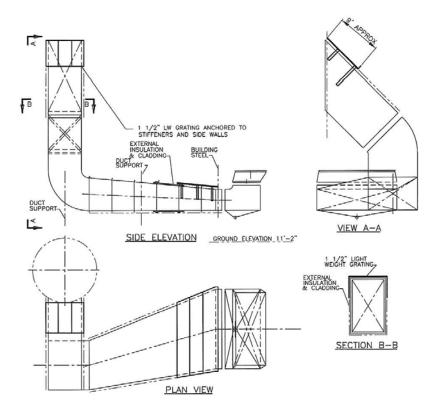


Fig. 28: Proposed cladding protection – catwalk grating

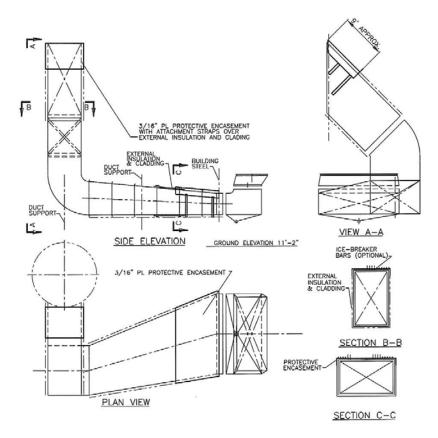


Fig. 29: Proposed cladding protection – 7ga. plate encasement



Fig. 30: Unit 3 – Expansion joint, hot air duct from air heater



Fig. 31: Unit 3 – Expansion joint, hot air duct from air heater



Fig. 32: Unit 3 - Expansion joint #4, hot air duct from air heater

Appendix 2 - Indicative Pricing

ALSTOM POW	er Service INDIC	ATIVE PRICING ESTIMATE		
CONTRACT #	40833010	ESTIMATE TYPE:	INDICATIVE	
CUSTOMER:	NLH	PROJECT TYPE:	SUPPLY & ERECT	
SITE:	Holyrood, NF	DATE:	19-Aug-2009	
PROP. DWG:	ne co	Rev 2	v 2 - 29/06/2010	
SCOPE:	Air Heater to Stack Breeching Study			

Breeching Solution Alternatives For U1, U2 & U3	S&E (Indicative Prices)	
Breeching Solution A2 Mod - Remove Rogue Insul. Blocks and Repair Casing As Reg'd. Add 6" New External Insulation U1,U2 & U3 - Based on removing 1610 ft ² of blocks. (Assumed) - Casing and expansion joints repairs are not included due to unknown condition. These repairs can be done during annual maintenance. - To be done at the same time as annual maintenance.	\$1,318,080	
Breeching Solution B1b - New 1/4" Corten Breeching with New Exp Jts and New 6" External Insulation U1, U2 & U3 - Corten Skin, mild steel stiffeners, primed - 6" mineral Fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding. - Scaffolding Included	\$7,678,456	

Ice Protection Solution Alternatives For U1 & U2	S&E (Indicative Prices)	
Protection Solution B2b - U-shaped 7 ga Plate Encasement Slide Over Top Panels, U1 & U2 Only:		
- Primed and top coat	\$214,252	
- C.S. material		

Breeching Support Structure Replacement For U1 & U2	S&E (Indicative Prices)	
Replace Breeching Support Structure for U1 & U2 Only:		
- SP-6 blast c/w primer and top coat		
- End frames are assembled as a unit		
- Welding CWB 47.1	\$153,661	
- Material G40.21 44W		
- To be installed at the same time with B1b breeching solution only. Additional cost is required with		
A2 breeching solution since the existing breeching is not removed.		

Notes:

- (1) Construction estimate on ice protection and expansion joint is based on being on site in conjunction with the maintenance work.
- (2) For Unit #3 (B&W), we have no drawings. For future firm price proposal, we are expecting NLH to provide the necessary drawings of the existing ducting for us to work from.
- (3) For Solution A2 Mod. Casing repair because the condition is not known, it should be done during annual maintenance.
- (4) This budget proposal gives a preliminary indication of the basis of which [services/deliveries] can be undertaken, and does not constitute an offer to carry out those [deliveries/services]. In particular, any prices, delivery times or performance figures mentioned are given without commitment at this stage. Nevertheless we trust the information provided is sufficiently detailed to enable you to assess the benefits which you can obtain by utilising our Company's services /deliveries, and we confirm our keen interest in working with you. To this end we look forward to discussing with you the content of this proposal and, when appropriate, submitting an offer to you.
- (5) Breeching support replacement pricing is applicable only with B1b breeching solution. Additional cost is required with A2 breeching solution since the existing breeching is not removed.

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Engineering Study - Final Report Holyrood G.S. - Stack Breeching Assessment Alstom Reference #40833010 December 18, 2008

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Final Report

to

Newfoundland & Labrador Hydro

of an

Engineering Study

on

Condition Assessment of Stack Breeching

at

Holyrood G.S.

Units #1, 2, & 3

Prepared by

Alstom Canada Inc. Ottawa, ON

Reference # 40833010

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This report was prepared by Pavel Kratina, P. Eng. and was reviewed by John McMillan, P.Eng.



EXECUTIVE SUMMARY

Environmental and operational conditions in Holyrood G.S. have precipitated severe corrosion of the original, externally insulated breeching that has necessitated intensive and costly maintenance. Initially, the corrosion of the ductwork was more prevalent in Units 1 and 2, since Unit 3 was built ten years later. In replacing the breeching at the time of the 1989 boiler upgrades, NLH has turned to an alternative design featuring internal borosilicate lining along with an outside protective coating, which carried a promise of low maintenance cost.

Although the changeover to internal insulation partially solved the corrosion predicament, it has created a worse problem of having to repair and replace the broken and dislodged glass insulation blocks; during winter operation, gas cooling below the dew point may be occurring at those locations causing corrosion of the duct shell. The cost of maintaining the internal liner in a serviceable condition is becoming prohibitive, and it seems to be far offsetting the benefits of eliminating the icefall damage of the breeching exterior. Less expensive and more reliable materials could probably replace the current insulating blocks and refractory, but the underlying concern – no access for inspection of the duct plate and potential for localized corrosion - would remain.

A more serious root cause of the internal corrosion may have been the operating conditions of the units that prevailed until the recent change to a more sulphur "friendly" fuel (1% max. limit). At the full-load operation and with no controls employed, the outlet gas temperatures would come very close to the sulphuric acid dew point of fuels containing 2.5% or more sulphur, and the situation would become worse at low-load operation. The steam coils, used to control the average cold end temperature (ACET) of the pre-heaters, did not have adequate capacity for winter operation until the boiler uprates in 1998 when they were upgraded.

It is conceivable that the initial corrosion and maintenance problems would not have been so severe under the current operating conditions, i.e., lower sulphur content and improved outlet gas temperature control, providing the external insulation was protected from the elements and well maintained.

A number of options is provided with varying capital costs and associated anticipated maintenance requirements as shown in the "SUMMARY AND RECOMMENDATIONS" section. Also included is an overview of the condition of the Unit 3 expansion joints and suggested options to deal with the problems.

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INTRODUCTION AND PROBLEM DEFINITION

Units 1 and 2 at the Newfoundland and Labrador Hydro Holyrood G.S. are pressurized units of Alstom (formerly CE) design from 1968; Unit 3 is a B&W boiler, constructed in 1979. Units 1 and 2 were uprated from 150 to 175 MW in 1989, and part of the upgrade was a replacement of the breeching section between the air pre-heater and the stack.

The original breeching was a typical back end duct design constructed of 1/4" carbon steel and insulated externally. From the information available it appears that the cladding was continually damaged by ice falling from the powerhouse and stacks, allowing moisture to penetrate in insulation, which led to insulation break down and severe corrosion of the carbon steel ducting. The cost of repairing/replacing the corroded duct sections was deemed to be too high and a decision was made by the plant management to replace the breeching.

A NLH internal study opted for a design that provided for internal insulation of borosilicate blocks and a protective coating on the breeching exterior. The promise of the new system was a much-reduced maintenance cost by comparison to the original ducting. Replacement of the breeching of the two Alstom units was completed in late 1990. Since there is no specific information available one can only speculate that it was done at the same time as Units 1 and 2.

Early into the operation (1991), the new ducts developed problems such as erosion wastage and cracking of the insulation and the concrete layer. Later, problems with the liner began to mount – the insulation blocks would break and fall out allowing the gas to penetrate to the duct plate, cool and cause localized corrosion of the duct plate. As the records show, the internal liner requires frequent repairs, and the cost of keeping the insulation blocks in good order has proven to be considerably higher then anticipated. One of the reasons for the internal liner degrading may be the specified service temperature limit of the adhesive membrane of about 200 °F that is easily exceeded if in contact with the flue gas (through cracks initially), which in turn may explain dislodged silicate blocks.

To make the situation worse, the exact sites of the corrosion damage are difficult to find under the insulation layers and the protective coating outside until the plate is corroded through. Cleaning the duct floors has become difficult with the floor concrete layer broken or otherwise damaged.

Alstom was commissioned to evaluate the current situation, reflect on the latest practices in the industry, and propose alternatives to minimize the breeching corrosion problems and high maintenance cost.

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CONDITIONS LEADING TO DUCT REPLACEMENT

The decision to replace the breeching was made in 1987-88, and concerned mainly units 1 and 2. The move was driven by corrosion related maintenance problems and associated maintenance cost. Unit 3 ducting, which is of a different layout, was eventually replaced as well although it was only 10 years old at the time and presumably had not experienced the same degree of deterioration. The underlining problem seemed to have been a severe corrosion condition created by formation of acidic condensate due to flue gas temperatures dropping below the acid dew point. The sub-cooled gas temperatures may have been a result of boiler operation and/or a contact with poorly insulated ducting.

It appears the condition of the external insulation contributed significantly or may have even been instrumental to the ductwork deterioration. As it happened, insulating materials on the two older units were not identical: Unit 1 was insulated with 2-1/2" of calcium silicate rigid insulation with a 1/8" flintcote 110-26 mastic applied over the blocks and reinforced with fibreglass mesh set in the mastic; Unit 2 was covered with soft bat exterior insulation and protective cladding. It is not known if there were differences in the degree of deterioration and maintenance between the two ducts.

Based on the information available (plant personnel recollection and a 1990 technical paper presented at CEA workshop), the problems with the original breeching stemmed from damaged external insulation leading to a severe corrosion of the duct plate. Moisture would penetrate into the insulation through damaged outer protection (mastic or cladding) – presumably damaged by ice falling from the stack and powerhouse (Fig. 6-7), rending the insulation ineffective. In addition, the wet insulation on sidewalls likely sagged, creating pockets of no or very little insulating material. It is believed that the degraded condition of the insulation caused considerable corrosion of ducting from outside. To further exacerbate the situation, a lack of insulating allowed the gas in contact with the duct plate to cool below the acid dew point causing in turn widespread internal corrosion (Fig.'s 1-5). Deterioration of expansion joints was an added irritant, which needed to be addressed.

In 1987 the condition of breeching was such that replacement was deemed necessary. An in-house study produced four replacement alternatives:

- 1) modified existing design (modifications referred to expansion joints)
- 2) borosilicate lining inside and corrosion resistant coating on the exterior
- sheets of corrosion resistant alloy material welded to the carbon steel ducting plate c/w external insulation
- 4) liquid fluorocarbon coating inside and insulation outside.

Based on cost analysis, the plant management favoured to second option mainly because of the promise of dependable service and low maintenance cost. The breeching ducting was replaced in 1989-1990 with ducts insulated inside with borosilicate (glass) insulation blocks and additional layer of silicate concrete on the floor. The new breeching went into operation at the end of 1990.

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CONDITION ASSESSMENT OF CURRENT BREECHING

Shortly after start up, the new breeching developed erosion and cracking problems requiring costly repairs, which later escalated as the concrete floors began breaking up and the insulation blocks falling out. Following is an overview of the problem history of the current breeching, based on information made available (see also Fig.'s 8-26):

Past history of problems

Inspection of breeching in 1991- brief summary:

(Ref.: Internal inspection report, Wayne Rice, Nov. 1991)

- installation of the new breeching in Unit 1 was completed in the fall of 1990
- the unit operated from Dec 1990 to April 1991; subsequent inspection of the ducting uncovered erosion wastage of the lining in the upper half of the elbow – the material loss amounted to1/4" to 1/2" over a 4-month period
- test blocks were selected to monitor the erosion rate; second measurement in October 1991 showed loss of another 1/16" to 3/16"
- the problem was linked to the fans capacity increase required for the boiler uprate, delivering higher air volume, which in turn increased the gas velocities to 50 fps from the previous 43 fps.
 For comparison, the supplier (Autochem) affirmed the material suitability for up to 120 fps flow
- Unit 2 was first inspected in the fall of 1990 and no erosion was found. The unit operated
 erosion free for one year with the original impeller until the fan was upgraded during the 1991
 outage (possibly April or May). An inspection in October 1991 uncovered similar lining loss as in
 Unit 1
- erosion affected approximately 3% off the total surface area of each duct in question
- repair cost for both units was quoted at \$55,000 by a contractor on site
- some cracks in the lining were found and repaired
- external protective coating started to show signs of rust discoloration

Operating period 1992-2000

No inspection and maintenance records available for review

Summary of breeching repair work 2000-2008:

(Ref.: Breeching history summary, J. Adams, Alstom)

Unit 1:

After eleven years in operation, extensive repairs to the insulation blocks were required. There was no significant work done in 2001, but repairs were required in the following years. In 2006, a new floor was poured by C&E Refractories. Another major insulation block replacement was carried out in 2008.

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Unit 2:

In 2000, approximately 750 ${\rm ft}^2$ of insulation was replaced. Some insulation block replacement was done in the years 2003-2005. The floor has deteriorated significantly, but to date no major work was done to correct the situation.

Unit 3:

Very little repair work was carried out until 2002. After that, insulation blocks were replaced and holes patched as required. In 2007 a new material was used for replacements, Pennguard 55 (as opposed to Pennguard 28), on trial basis. Inspection in 2008 found the Pennguard blocks in very good condition.

Current breeching condition - inspection summary

(Ref.: 2008 Inspection Report, J. Adams, Alstom Canada)

Unit 1:

West breeching

A large quantity of ash was found on top of the duct floor, but the refractory was intact. The horizontal section appeared to be in good condition - there were no holes found and no evidence of leaks. The sidewall insulation blocks were in excellent to good condition. The ceiling was good overall, but there were a few small isolated sections requiring repair - about 10 blocks were replaced. All bracing was found in good condition.

The pantleg (inclined) section had a few blocks fallen off from the overhead panel between the expansion (EJ) joint and the stack, and up to 6-10 blocks near the EJ were damaged or fallen out. A few blocks were loose and others in questionable condition on the sidewalls. The refractory at the upward bend was in acceptable condition.

East breeching

Ash has accumulated on the floor, but the refractory appeared in good condition. No major damage was found in the horizontal section, only a few isolated small sections overhead were slightly damaged needing repair. Above the up-bend, about 60 blocks had fallen off exposing the mesh. Ash and debris has accumulated between the refractory and the casing. Initially two through holes were spotted, but 12 holes were found when the loose blocks were removed and the casing cleaned.

The expansion joint has deteriorated considerably: cover plates were hanging loose, mostly separated from the sides. Behind the cover plates, the inner layers of the fabric element (insulation layers) and the inside of what appeared to be the outer belt could be seen.

The condition of the liner above the expansion joint was difficult to ascertain because no scaffolding was erected for access. However, there appeared to be loose blocks overhead and on the sides that should be replaced. This could amount to a significant repair work. Loose blocks in area of EJ were replaced, holes in breeching were patched from outside and rods were welded to the inside of the duct shell to secure the mesh for refractory, and the EJ cover plates were repaired.

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A hole was found in the bottom corner of the expansion joint and repaired. The ladder inside the breeching is severely corroded and should be removed completely. A total of about 230 blocks were installed in the east breeching.

External breeching inspection

A great degree deterioration of the expansion joints is obvious – failed corners, evidence of leaks. A more detailed inspection is needed, but that would require removal of the cover plates. Corrosion was visible under the coating.

Unit 2:

West breeching

There were a number of blocks to be replaced on the south and north walls under the air heater. The breeching floor was cracked near the hopper and lifting up. It is quite thin – only about 1‡" to 2". This floor was done in 2005, and may have to be replaced again in the near future.

Overall, the internal lining was in acceptable condition. There were isolated small areas requiring attention. The pantleg area appeared to be in good condition except for a section of relatively new blocks on the north wall that seemed to be separating from the duct. There was no access for a closer look – scaffolding was not erected. Very little ash was found on the duct floor. One brace in the horizontal section had separated from the duct on the bottom.

Approximately 15 blocks were replaced. Three other small locations with loose blocks were identified but could not be stripped due to the slime deposit on all surfaces (condensation). Two of these were in the horizontal section while the other was in the pantleg. Without scaffold it was difficult to better assess the pantleg condition. However, each location appeared to require between 4 and 6 block replacements.

East breeching

The floor was in poor condition, but the rest of the block liner was sound with only a 9-block section replaced. However, the blocks appeared wet and soft overhead at the beginning of the up-bend. No leaks were found.

External breeching inspection

On the east side, the expansion joint had a leak at the bottom flange. The cover plate does not cover the entire flange to provide adequate protection from the environment. Also there are many locations on top of the cover where water is allowed to pool. The fabric element behind the cover plate appeared to be intact, but it would be necessary to remove the cover plate for a proper assessment.

On the west side, the protective coating broke down in small, localized areas and at a brace attachment showing corrosion. The expansion joint element has failed along the top, and a leak was found in the flange at the bottom. Again, water was pooling on top of the cover plate. Relatively minor rust

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discoloration was noted on the coating of the horizontal section. Also, a patch on top of the flue, welded from the inside, had not been sealed from outside.

Unit 3:

Internal breeching

Test patches of Pennguard 55 insulation material, installed in 2007, do not exhibit any deterioration or damage. Another new material, Smoothkote refractory, may also be a viable option, as the test patch remained in good condition after one year of operation. The Pennguard 55 block differs very little from the normally used Pennguard 28, and is about 30% cheaper. However, the currently used material may have been in equally good condition after one year of operation, and more time is required to draw a conclusion regarding possible use in the future.

Overall, the block liner is in acceptable condition. The blocks, replaced previous year, show no appreciable damage. However, there were new sites identified where the lining has degraded: the inspection identified about 40 silicate blocks requiring replacement.

It was noted that ash has accumulated in the expansion joint near the stack and this was causing the cover plates to be pushed outward. It was recommended that the plates be removed temporarily to allow the ash to be removed. Not much ash was found in the breeching.

External breeching inspection

The breeching appears in good condition from the outside. There were no indications of leaks in the corner areas or on top where they have been found in recent years. On the west side, a hole could be seen that had been patched from the inside, but not sealed from the outside, which allows moisture to pool inside the cavity and cause external corrosion. Also, the top of the breeching near the stack should be re-painted. The crotch area looked good.

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UNIT OPERATION CONSIDERATIONS

Operation of the boiler and back end equipment is believed to have contributed significantly to creating conditions leading to deterioration of the original breeching as well as of the breeching installed as part of units 1 and 2 upgrade. The back end system, as designed, relies on steam coil air heaters (SCAH) to control the gas temperature leaving the Ljungstrom air pre-heater. The general recommendation is that the flue gas temperature be at least 28°C (50°F) above the sulphuric acid dew point of a fuel.

Although the target sulphur content in the fuel has always been 2.2% according to Alstom personnel on site, the Holyrood records typically refer to 2.5% sulphur content (an analysis of a 1987 bunker C oil sample showed as much as 2.8% sulphur content) for which the acid dew point was calculated to be 148°C (298°F), commanding a "safe" temperature of the gas of at least 177°C (350°F). Fluctuations in sulphur content is echoed in the increase or decrease of the safe temperatures needed to avoid acid formation in the duct. The current limit on sulphur content in the fuel stands at 1%, which corresponds to 138°C (280°F) and 166 °C (330°F) dew point and safe outlet gas temperatures respectively.

Without SCAH intervention, the acid dew point of the flue gas would come close to the gas design outlet temperature of approximately 150°C (302°F) for the original MCR (150 MW) and approximately 155°C (311°F) for the uprated load condition (175 MW). The temperature would drop below the dew point at low loads in off peak operating periods, possibly falling to 115-120°C. The boilers seldom operate at full load; typical loads may vary between 70 and 140 MW, but could operate as low as 50 MW (30% MCR), which means that gas temperatures would be below the dew point for a large portion of the unit operating time. As an example, in 2007 the averaged output of Unit 1 was 70 MW (40 %MCR), Unit 2 put out 110 MW (63 %MCR) and Unit 3 put out 89 MW (69 %MCR).

The steam coils have always been used in Holyrood striving to keep the average cold end temperature (ACET) of the air pre-heater at a target temperature of approximately 107°C (235°F) with a corresponding gas outlet temperature of 164°C (327°F). This would not have been a safe gas temperature for the pre-2006 fuel (needed 177°C), but would be acceptable for the new fuel composition criterion. By comparison, the target ACET for 1.0% sulphur oil is 105°C (221°F).

It was recognized in the early years of the units' operating life that the SCAH's did not have adequate capacity to support the air pre-heater requirements in winter operation with the cold air drawn from the outside, which in turn caused the outlet gas temperatures be much lower than the design. The remedy was to draw the combustion air from inside the powerhouse at the expense of creating another set of problems – because of the considerable vacuum created by the fan intake, air from outside the building would enter from all available openings and cause frequent freeze-ups throughout the plant, and opening of doors was difficult causing the doors slam shut endangering the plant personnel (Re: 1990 CEA paper). The SCAH's have been upgraded following the uprate in 1989 - a second bank was added effectively doubling their capacity. Also, a "warm air make-up system" has since been added that helps feed the combustion air into the plant in a controlled fashion that helps to avoid the freeze-up problems.

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SUMMARY AND RECOMMENDATIONS

In the utility boiler industry, it is a recognized fact that breeching ducting has limited life and may need replacement periodically, either completely or partially. Although a twenty-year life span of ducting is not unusual, controlling or preventing the adverse conditions leading to early deterioration, both inside and outside, can extend it.

Most breeching systems employed by the utilities surveyed are of carbon steel plate construction with adequate external insulation, and only in extreme cases or in some old utilities internal insulation liners are employed. Externally insulated ducts are generally much easier to inspect, maintain and clean. Alstom does have a standard design for internal lining, typically consisting of 4" calcium silicate blocks with expanded metal mesh and 3/4" layer of Super 3000 (Alstom hi-temp refractory) on top, but the design is rarely used being maintenance intensive. Internal insulation or corrosion resistant steel liners are used in pulp and paper industry and by HRSG's. From the operation perspective, there is no advantage to insulating ducts inside rather then externally.

The chronic corrosion of the original breeching in Holyrood appears to have been rooted in deteriorated external insulation, and in operating conditions, such as low-load operation, that drove the gas outlet temperatures below the sulphuric acid dew point.

The new breeching, fitted with internal borosilicate lining, was expected to alleviate both the corrosion problems and the high maintenance cost, but failed to do either. Not only did the internal and external corrosion problems continue, although at a reduced rate, but the corroded sites became difficult to inspect and access for repairs, and the bulk of the maintenance has shifted to replacing and repairing the internal liner blocks. The projected annual maintenance cost burgeoned from the expected \$8K per duct (extracted from the 1988 internal cost analysis) to a sizable multiple of that at times (e.g., in 2003, replacement of 350 sq.ft. of the silicate block liner in Unit 2 cost \$90K). For comparison, the projected cost of maintaining a breeching as per the original design was \$21K per year per duct.

To have a real chance of succeeding in minimizing the corrosion problem, any solution alternative selected has to embrace continuous gas temperature control at all loads. That means the ACET should be subordinate to maintaining the gas outlet temperature at 166°C (330°F) or higher at all times to avoid formation of sulphuric acid, assuming the upper limit of sulphur in the fuel (1%) is adhered to. External corrosion problems have to be addressed in parallel with controlling the internal conditions.

A prerequisite to adopting any of the proposed alternatives is a complete assessment of the soundness of the ducting shell, which should include strategic removal of external protective coating (e.g., at locations of discoloration) and measuring the plate thickness. The results of such evaluation will dictate the direction for the solutions sought, i.e., A) the existing ducting (plate and stiffening) is in a reasonably sound condition and may require only partial plate replacement along with the insulation upgrade, and B) the duct shell has for the most part no or very little life left and should be replaced.

Considering the fact that the acid dew point has been lowered by virtue of a lower maximum allowed sulphur content in the fuel, the conditions for acid corrosion would have been somewhat mitigated

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already, which should reflect in lower duct maintenance in the future. However, due to the length of the service life (almost twenty years) and extended exposure to the past prevailing conditions, deterioration of the current liner may continue at the same pace or worse, if some upgrades are not implemented. The low service temperature of the adhesive membrane is likely to remain a contributing factor to the insulation block failures.

The breeching expansion joints are in a poor condition and need a major overhaul as an interim solution, but a replacement in kind should be in the planning.

A separate issue to be dealt with is the deteriorating condition of the seven metallic expansion joints one omega and six bellow joints on the hot air outlet duct from the air pre-heater. These are the original components and have been in operation for almost 30 years. Although air duct expansion joints are not exposed to as harsh environment as the gas touched components, time and service demands eventually took their toll of they all appear heavily rusted and are cracking, likely due to fatigue, in the bottom sections (see Fig.'s 30-32). The joints could be repaired piecemeal as required, but as a long-term solution, it is advisable to replace them with properly engineered cloth joints. Some of the alternatives shown below have already been considered in earlier discussions with NLH.

Solution alternatives - breeching

- A) Current ducts are in serviceable condition and remain in place:
 - keep current duct arrangement, repair duct and lining as required, use cheaper insulation material to replace borosilicate blocks (e.g., Pennguard 55 vs. Pennguard 28)

<u>Pros:</u> no capital investment, no time lost to upgrading ducting; potential for reducing maintenance cost by changing insulation block material;

- <u>Cons</u>: break-down of the insulation material and adhesive membrane will likely not subside, may become worse; prohibitive cost of repairs will remain; difficulties accessing the sites of corrosion damage and leaks under insulation and the outer protective coating will not change; cleaning ash and debris from the duct floor remains impaired; erosion wastage of lining may still be a problem
- 2) keep current duct arrangement, but add 4" of external water repellent insulation and a watertight cladding; repair internal lining as required, and have the overall concept materials and specs reviewed for possible improvements less expensive insulation blocks, increased concrete layer and block thickness, etc; protect external cladding against falling ice (catwalk grating, hood, etc., see B below) if that remains a genuine problem. The external surface should be cleaned of rust before installing the insulation..

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<u>Pros</u>: the external insulation will help prevent gas cooling even if lining damaged; potential for reducing maintenance cost by changing insulation block material; corrosion of the duct shell <u>due to gas cooling</u> through contact with the duct plate will be minimized or eliminated if

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external insulation is maintained; degradation of borosilicate lining less critical with external insulation added

<u>Cons</u>: added cost of external insulation and cladding c/w protection against damage; breakdown of the internal insulation material and adhesive membrane will likely not subside, may become worse; the internal liner will still have to be maintained, therefore prohibitive cost of repairs will remain; continuing difficulties accessing the sites for inspection; cleaning ash and debris from the duct floor remains impaired;

3) keep current duct, add 6" of external insulation and remove internal liner blocks and silicate concrete; protect external cladding against falling ice (catwalk grating, hood, etc., see B) below) if that remains a problem. The external surface should be cleaned from rust before installing the insulation.

<u>Pros</u>: the upgraded external insulation will provide adequate insulation to prevent gas cooling, assuming it is kept in good serviceable condition; reduced maintenance cost by comparison to current situation – no insulation blocks to replace; corrosion <u>due to gas cooling</u> will be minimized or eliminated if external insulation is maintained; improved access for duct inspection and cleaning

<u>Cons</u>: added cost of external insulation and cladding c/w protection against damage; added cost of internal liner removal; access for duct inspection somewhat impaired if remnants of internal liner remain (e.g., adhesive membrane)

A modified option 2 would be a preferred long-term solution, i.e., the external insulation 6" thick with the internal lining left alone initially and removed only if the silicate block degradation continued unabated. This way, no upgrade of external insulation (to 6" thickness) would have been required if the internal liner were removed, as in option 3.

B) Replace the entire breeching:

- 1) original duct design, made of
 - a) ‡" mild carbon steel plate (G40.21 or equivalent) c/w 6" of external water repellent insulation c/w watertight high quality cladding and flashing
 - b) ‡" Corten or equivalent high temperature carbon steel c/w 6" of external water repellent insulation c/w watertight high quality cladding and flashing
 - c) 3/16" stainless steel (e.g., 304, 316L, 904L, HASTELLOY C276) c/w 4" of external water repellent insulation c/w watertight high quality cladding and flashing
 - d) 3/16" Avesta plate (2205) plate c/w 4" of external water repellent insulation c/w watertight high quality cladding and flashing

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<u>Pros</u>: a) if properly designed and maintained, the insulation offers adequate protection against gas cooling; standard ducting material used; reduced maintenance cost compared to the current breeching; reduced load on supports and ducting plate compared to inner liner; good access for duct inspection; insulation not susceptible to cracking

b) same as a) above, but offers some protection against corrosion if gas temperature drops below acid dew point (higher chrome content – min. 0.7%)

c) and d) same as a) above, but the materials are corrosion resistant and therefore not susceptible to corrosion problems if the gas temperature is not maintained; less insulation required; less plate material used

<u>Cons</u>: a) does not address the original problem of insulation being damaged by falling ice; will suffer corrosion problems if outlet gas temperature is not maintained above acid dew point

- b) does not address the original problem of insulation being damaged by falling ice; higher material cost:
- c) and d) do not address the original problem of insulation being damaged by falling ice; high material cost; design check required due to thinner plate
- 2) <u>original duct design, construction alternatives as per 1), added protection against damage</u> caused by ice falling from stack and powerhouse, as shown below:
 - a) light-weight (LW), 1‡" catwalk grating on the top panels (over aluminium cladding) attached to stack and side panels
 - U-shaped 7 ga. plate encasement slid over the top panels (possibly with ice-breaker ribs)
 - c) 3/16" carbon steel hood over the duct, attached to the duct sidewalls
 - d) extra heavy gage, ribbed aluminium or steel cladding on the top panels

<u>Pros</u>: same as 1) but addresses the original problem of insulation being damaged by falling ice; less maintenance required for the external insulation if prevented from being damaged, relatively simple design needed for the protection; option d) would not require a special design for added protection

<u>Cons</u>: same as 1) except the falling ice protection; added cost of material and design of the falling ice protection, danger of creating heat sinks where protection attached to the duct

3) 1/4" Corten or equivalent hi-temp carbon steel duct, internal insulation c/w stainless steel liner similar to HRSG construction (3" cerwool or mineral wool insulation bats, 304L or 316L stainless steel 10 ga liner held in place with studs), no external insulation but protection coating

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<u>Pros</u>: works well in HRSG application; less prone to external corrosion because of better plate material; insulation stays in place, traditionally low maintenance once settled

<u>Cons</u>: access for inspection restricted; installation sensitive; high installation cost, condensation may by a problem on bottom panel

Other options could include alloy or stainless steel cladding applied directly on the duct plate or a layer of polymer coating inside combined with external insulation, but these options were already explored by NLH and found expensive to apply and maintain, and were rejected.

The preferred long-term solution would be option 2 with the 1(b) construction alternative. Hi-temp carbon steels such as Corten have been used in the past for back end (breeching) ductwork, even if the gas temperature did not require it, because of their improved resistance to corrosion compared to low carbon steels. An additional 1/8" corrosion allowance could be added to extended the life of the ducting.

Solution alternatives - hot air duct expansion joints, Unit 3

- Repair or replace sections as required: the bellows could be weld repaired as required, or
 partially replaced, specifically the bottom part of the joints. Considering the service life and the
 overall condition of the joints, this should be only an short-term maintenance fix. It may
 however prove difficult to weld-repair the joints because of the general condition of the
 expansion joint material.
- 2) <u>Install cloth seal over the metallic expansion joints</u>: this <u>interim</u> solution would replace repairing the ailing metallic joints. It would not have any effect on the function of the current joints, but would prevent leaks. Care must be taken to evaluate correctly the movements as not the cause failure of these joints as well.
- 3) Replace the expansion joints in kind: this alternative would see the expansion joints replaced as originally designed and built. No engineering is required, but the probable shortcomings of the current design would be copied.
- 4) Replace with metallic joints, but review the selection: engineering review would be required to confirm or repudiate the current selection, and possibly come up with a better system to prevent the current failures.
- 5) Replace the expansion joints with cloth joints, properly engineered: cloth expansion joints are widely used and are the preferred solution in most ducting systems. They do not exert reaction forces to the system supports, and would not be subject to fatigue-induced cracking.

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From engineering and operation standpoint, option 5 is the preferred solution.

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FIGURES AND TABLES

Year	Unit 1	Unit 2	Unit 3
2008	West side no scaffold - difficult to assess pantleg. However appeared to be sections where liner has failed above and adjacent to expansion joint. 40 to 50 blocks estimated but could be worse than appears. Horizontal section good - about 10 blocks replaced. East side many holes - duct patched from outside at north side of bend. Refractory in bend also failed. 230 blocks replaced in bend area. Horizontal section good. Scaffold up to expansion joint only. Above expansion joint liner is questionable condition. Could be a significant repair required. Expansion joints have failed both sides.	The refractory floor on both sides now in poor condition and requires replacement. West side approx 15 blocks replaced. No scaffold installed. Three other locations about 4 blocks each looked loose but not replaced due to condensation/sweat problem. East side one 9 block section was replaced. Block also wet and apparently soft overhead and up the pantleg in sections. Expansion joint in poor condition on both sides.	Test patches of Pennguard 55 block and refractory both in good condition after one year. About 40 blocks replaced – scaffold was erected. Debris noted in expansion joint should be cleaned out. Looked OK from external inspection.
2007	Minor repairs only – about 40 blocks total. Cost about \$5k	East floor in poor condition – not replaced. About 90 blocks on each side replaced – all in horizontal section – no scaffold required. 3 holes patched in west side. Total cost about \$16k.	Blocks replaced overhead and at both side corners – about 200 sqft. 15 holes patched (welded inside – Devcon outside). Trial patch of Pennguard 55 and Smoothkote refractory installed. Total cost about \$25k
2006	C&E Refractories poured new floor east side and block both sides. Total about 760 sqft. 5 holes in west and 12 in east side patched from inside and sealed with Devcon outside. Expansion joint cover plates bad. Total cost about \$320k	East floor in poor condition – not replaced. Block good both sides.	About 40 blocks to replace overhead but not done – no scaffold. 15 blocks that were accessible were replaced. No cost captured.
2005	East floor bad. Block to replace overhead and north on east side not done. West small quantity of block replaced but more to do with scaffold. Cost about \$2k captured.	Mount Pearl Painting hired to replace refractory on west floor and block on both sides. Many holes found on both sides and repaired from outside. Total cost about \$290k.	Hole found in top near stack. Patched from outside. No scaffold installed – accessible block replaced as required. About 50 blocks replaced and 15 not accessible. Total about SSk.
2004	East floor bad – not replaced. East side scaffolded and block replaced. Hole in expansion joint patched. Cover plates bad. West side small quantity of block replaced – no scaffold. Cost about \$15k	Just a couple of blocks replaced	Block replaced overhead and at corners (higher than 2003). No holes found. Scaffold erected. Total cost about \$10k.
2003	East floor starting to fail. Few blocks to replace. Supposedly repaired by another contractor working on the stack	Approximately 350 sqft of block replaced mostly on east side. Scaffold erected. Through holes patched. Done by C&E Refractories. Cost about \$90k.	Holes found on both sides. Scaffold erected and holes repaired. Block replaced as required. Costs not captured.
2002	Damage repaired by C&E Refractories. This included replacement of the west floor refractory. Don't know cost.	No significant work	Very small quantity of block replaced with no scaffold. Scaffold recommended to replace block next year.
2001	No significant work	No significant work	No work done. Minor repairs recommended.
2000	Significant work done to replace block. 540 hours reported – estimated around \$35k	C&E Refractory replaced about 750 sqft of block. Don't know cost.	Minor repair to borosilicate block liner

Table 1: J. Adams, Breeching History Summary 2000-2008



Fig. 1: Original Breeching, floor in horizontal section – Unit 1 or 2



Fig. 2: Original Breeching, pantleg inlet - Unit 1 or 2



Fig. 3: Original Breeching, sloping section – Unit 1 or 2



Fig. 4: Original Breeching, bend section - Unit 1 or 2



Fig. 5: Original Breeching, entrance to horizontal section (at heater) – Unit 1 or 2



Fig. 6: Original Breeching, top view – Unit 1



Fig. 7: Original Breeching, elevation view - Unit 1



Fig. 8: Unit 1 – Insulating block replacement

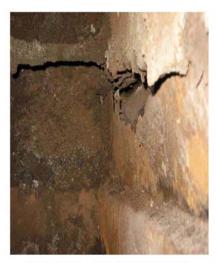


Fig. 9: Unit 1 - Duct corroded through



Fig. 10: Unit 1 - Sloped section as found



Fig. 11: Unit 1 - Sidewall and floor



Fig. 12: Unit 1 – Replaced blocks

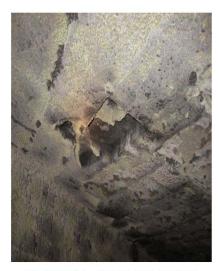


Fig. 13: Unit 1 – Missing block overhead



Fig.14: Unit 1 - Ash accumulated on the floor



Fig. 15: Unit 1 - Damaged expansion joint



Fig. 16: Unit 1 – External duct repairs



Fig. 17: Unit 1 – External duct repairs



Fig. 18: Unit 2 - Missing insulation blocks



Fig. 19: Unit 2 - Missing insulation blocks



Fig. 20: Unit 2 – Cracked cement floor



Fig. 21: Unit 2 - Cracked cement floor



Fig. 22: Unit 2 – External coating break down



Fig. 23: Unit 3 - Repairs 2007



Fig. 24: Unit 3 – Crotch repairs



Fig. 25: Unit 3 – Patched casing (from inside)



Fig. 26: Unit 3 – Top near the stack

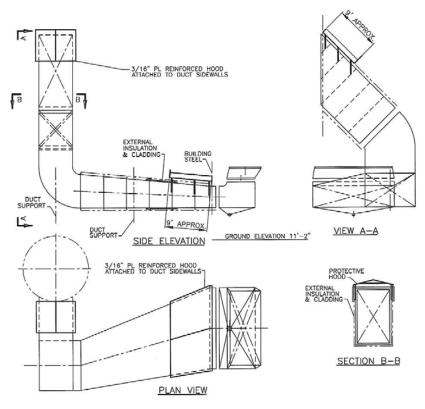


Fig. 27: Proposed cladding protection – protective hood

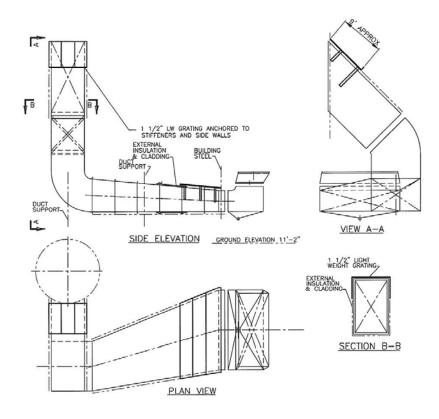


Fig. 28: Proposed cladding protection – catwalk grating

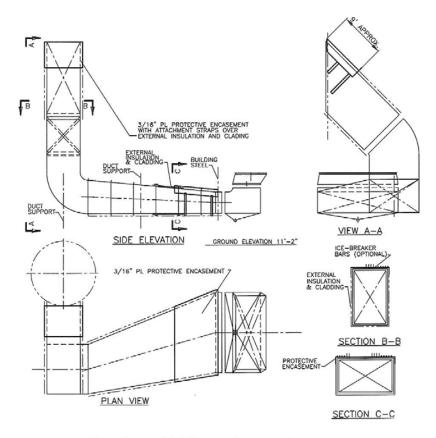


Fig. 29: Proposed cladding protection – 7ga. plate encasement



Fig. 30: Unit 3 – Expansion joint, hot air duct from air heater



Fig. 31: Unit 3 – Expansion joint, hot air duct from air heater



Fig. 32: Unit 3 - Expansion joint #4, hot air duct from air heater

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Engineering Study - Final Report Holyrood G.S. - Stack Breeching Assessment Alstom Reference #40833010 December 18, 2008 Rev. 1 - March 4, 2009

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Final Report

to

Newfoundland & Labrador Hydro

of an

Engineering Study

on

Condition Assessment of Stack Breeching

at

Holyrood G.S.

Units #1, 2, & 3

Prepared by

Alstom Canada Inc. Ottawa, ON

Reference # 40833010

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This report was prepared by Pavel Kratina, P. Eng. and was reviewed by John McMillan, P.Eng.



EXECUTIVE SUMMARY

Environmental and operational conditions in Holyrood G.S. have precipitated severe corrosion of the original, externally insulated breeching that has necessitated intensive and costly maintenance. Initially, the corrosion of the ductwork was more prevalent in Units 1 and 2, since Unit 3 was built ten years later. In replacing the breeching at the time of the 1989 boiler upgrades, Newfoundland & Labrador Hydro has turned to an alternative design featuring internal borosilicate lining along with an outside protective coating, which carried a promise of low maintenance cost.

Although the changeover to internal insulation partially solved the corrosion predicament, it has created a worse problem of having to repair and replace the broken and dislodged glass insulation blocks; during winter operation, gas cooling below the dew point may be occurring at those locations causing corrosion of the duct shell. The cost of maintaining the internal liner in a serviceable condition is becoming prohibitive, and it seems to be far offsetting the benefits of eliminating the icefall damage of the breeching exterior. Less expensive and more reliable materials could probably replace the current insulating blocks and refractory, but the underlying concern – no access for inspection of the duct plate and potential for localized corrosion - would remain.

A more serious root cause of the internal corrosion may have been the operating conditions of the units that prevailed until the recent change to a more sulphur "friendly" fuel (1% max. limit). At the full-load operation and with no controls employed, the outlet gas temperatures would come very close to the sulphuric acid dew point of fuels containing 2.5% or more sulphur, and the situation would become worse at low-load operation. The steam coils, used to control the average cold end temperature (ACET) of the pre-heaters, did not have adequate capacity for winter operation until the boiler uprates in 1998 when they were upgraded.

It is conceivable that the initial corrosion and maintenance problems would not have been so severe under the current operating conditions, i.e., lower sulphur content and improved outlet gas temperature control, providing the external insulation was protected from the elements and well maintained.

A number of options are provided with varying capital costs and associated anticipated maintenance requirements as shown in the "SUMMARY AND RECOMMENDATIONS" section. Also included is an overview of the condition of the Unit 3 expansion joints and suggested options to deal with the problems.

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INTRODUCTION AND PROBLEM DEFINITION

Units 1 and 2 at the Newfoundland and Labrador Hydro (NLH) Holyrood G.S. are pressurized units of Alstom (formerly CE) design from 1968; Unit 3 is a B&W boiler, constructed in 1979. Units 1 and 2 were up-rated from 150 to 175 MW in 1989, and part of the upgrade was a replacement of the breeching section between the air pre-heater and the stack.

The original breeching was a typical back end duct design constructed of 1/4" carbon steel and insulated externally. From the information available it appears that the cladding was continually damaged by ice falling from the powerhouse and stacks, allowing moisture to penetrate in insulation, which led to insulation break down and severe corrosion of the carbon steel ducting. The cost of repairing/replacing the corroded duct sections was deemed to be too high and a decision was made by the plant management to replace the breeching.

A NLH internal study opted for a design that provided for internal insulation of borosilicate blocks and a protective coating on the breeching exterior. The promise of the new system was a much-reduced maintenance cost by comparison to the original ducting. Replacement of the breeching of the two Alstom units was completed in late 1990. Since there is no specific information available one can only speculate that it was done at the same time as Units 1 and 2.

Early into the operation (1991), the new ducts developed problems such as erosion wastage and cracking of the insulation and the concrete layer. Later, problems with the liner began to mount – the insulation blocks would break and fall out allowing the gas to penetrate to the duct plate, cool and cause localized corrosion of the duct plate. As the records show, the internal liner requires frequent repairs, and the cost of keeping the insulation blocks in good order has proven to be considerably higher then anticipated. One of the reasons for the internal liner degrading may be the specified service temperature limit of the adhesive membrane of about 200°F that is easily exceeded if in contact with the flue gas (through cracks initially), which in turn may explain dislodged silicate blocks.

To make the situation worse, the exact sites of the corrosion damage are difficult to find under the insulation layers and the protective coating outside until the plate is corroded through. Cleaning the duct floors has become difficult with the floor concrete layer broken or otherwise damaged.

Alstom was commissioned to evaluate the current situation, reflect on the latest practices in the industry, and propose alternatives to minimize the breeching corrosion problems and high maintenance cost.

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CONDITIONS LEADING TO DUCT REPLACEMENT

The decision to replace the breeching was made in 1987-88, and concerned mainly units 1 and 2. The move was driven by corrosion related maintenance problems and associated maintenance cost. Unit 3 ducting, which is of a different layout, was eventually replaced as well although it was only 10 years old at the time and presumably had not experienced the same degree of deterioration. The underlining problem seemed to have been a severe corrosion condition created by formation of acidic condensate due to flue gas temperatures dropping below the acid dew point. The sub-cooled gas temperatures may have been a result of boiler operation and/or a contact with poorly insulated ducting.

It appears the condition of the external insulation contributed significantly or may have even been instrumental to the ductwork deterioration. As it happened, insulating materials on the two older units were not identical: Unit 1 was insulated with 2-1/2" of calcium silicate rigid insulation with a 1/8" flintcote 110-26 mastic applied over the blocks and reinforced with fibreglass mesh set in the mastic; Unit 2 was covered with soft bat exterior insulation and protective cladding. It is not known if there were differences in the degree of deterioration and maintenance between the two ducts.

Based on the information available (plant personnel recollection and a 1990 technical paper presented at CEA workshop), the problems with the original breeching stemmed from damaged external insulation leading to a severe corrosion of the duct plate. Moisture would penetrate into the insulation through damaged outer protection (mastic or cladding) – presumably damaged by ice falling from the stack and powerhouse (Fig. 6-7), rending the insulation ineffective. In addition, the wet insulation on sidewalls likely sagged, creating pockets of no or very little insulating material. It is believed that the degraded condition of the insulation caused considerable corrosion of ducting from outside. To further exacerbate the situation, a lack of insulating allowed the gas in contact with the duct plate to cool below the acid dew point causing in turn widespread internal corrosion (Fig's 1-5). Deterioration of expansion joints was an added irritant, which needed to be addressed.

In 1987 the condition of breeching was such that replacement was deemed necessary. An in-house study produced four replacement alternatives:

- 1) Modified existing design (modifications referred to expansion joints)
- 2) Borosilicate lining inside and corrosion resistant coating on the exterior
- Sheets of corrosion resistant alloy material welded to the carbon steel ducting plate c/w external insulation
- 4) Liquid fluorocarbon coating inside and insulation outside.

Based on cost analysis, the plant management favoured to second option mainly because of the promise of dependable service and low maintenance cost. The breeching ducting was replaced in 1989-1990 with ducts insulated inside with borosilicate (glass) insulation blocks and additional layer of silicate concrete on the floor. The new breeching went into operation at the end of 1990.

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CONDITION ASSESSMENT OF CURRENT BREECHING

Shortly after start up, the new breeching developed erosion and cracking problems requiring costly repairs, which later escalated as the concrete floors began breaking up and the insulation blocks falling out. Following is an overview of the problem history of the current breeching, based on information made available (see also Fig's 8-26):

Past history of problems

Inspection of breeching in 1991- brief summary:

(Ref.: Internal inspection report, Wayne Rice, Nov. 1991)

- Installation of the new breeching in Unit 1 was completed in the fall of 1990
- The unit operated from Dec 1990 to April 1991; subsequent inspection of the ducting uncovered erosion wastage of the lining in the upper half of the elbow the material loss amounted to 1/4" to 1/2" over a 4-month period
- Test blocks were selected to monitor the erosion rate; second measurement in October 1991 showed loss of another 1/16" to 3/16"
- The problem was linked to the fans capacity increase required for the boiler uprate, delivering higher air volume, which in turn increased the gas velocities to 50 fps from the previous 43 fps.
 For comparison, the supplier (Autochem) affirmed the material suitability for up to 120 fps flow
- Unit 2 was first inspected in the fall of 1990 and no erosion was found. The unit operated
 erosion free for one year with the original impeller until the fan was upgraded during the 1991
 outage (possibly April or May). An inspection in October 1991 uncovered similar lining loss as in
 Unit 1
- Erosion affected approximately 3% off the total surface area of each duct in question
- Repair cost for both units was quoted at \$55,000 by a contractor on site
- Some cracks in the lining were found and repaired
- External protective coating started to show signs of rust discoloration

Operating period 1992-2000

No inspection and maintenance records available for review

Summary of breeching repair work 2000-2008:

(Ref.: Breeching history summary, J. Adams, Alstom)

Unit 1:

After eleven years in operation, extensive repairs to the insulation blocks were required. There was no significant work done in 2001, but repairs were required in the following years. In 2006, a new floor was poured by C&E Refractories. Another major insulation block replacement was carried out in 2008.

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Unit 2:

In 2000, approximately 750 ${\rm ft}^2$ of insulation was replaced. Some insulation block replacement was done in the years 2003-2005. The floor has deteriorated significantly, but to date no major work was done to correct the situation.

Unit 3:

Very little repair work was carried out until 2002. After that, insulation blocks were replaced and holes patched as required. In 2007 a new material was used for replacements, Pennguard 55 (as opposed to Pennguard 28), on trial basis. Inspection in 2008 found the Pennguard blocks in very good condition.

Current breeching condition - inspection summary

(Ref.: 2008 Inspection Report, J. Adams, Alstom Canada)

Unit 1:

West breeching

A large quantity of ash was found on top of the duct floor, but the refractory was intact. The horizontal section appeared to be in good condition - there were no holes found and no evidence of leaks. The sidewall insulation blocks were in excellent to good condition. The ceiling was good overall, but there were a few small isolated sections requiring repair - about 10 blocks were replaced. All bracing was found in good condition.

The pantleg (inclined) section had a few blocks fallen off from the overhead panel between the expansion (EJ) joint and the stack, and up to 6-10 blocks near the EJ were damaged or fallen out. A few blocks were loose and others in questionable condition on the sidewalls. The refractory at the upward bend was in acceptable condition.

East breeching

Ash has accumulated on the floor, but the refractory appeared in good condition. No major damage was found in the horizontal section, only a few isolated small sections overhead were slightly damaged needing repair. Above the up-bend, about 60 blocks had fallen off exposing the mesh. Ash and debris has accumulated between the refractory and the casing. Initially two through holes were spotted, but 12 holes were found when the loose blocks were removed and the casing cleaned.

The expansion joint has deteriorated considerably: cover plates were hanging loose, mostly separated from the sides. Behind the cover plates, the inner layers of the fabric element (insulation layers) and the inside of what appeared to be the outer belt could be seen.

The condition of the liner above the expansion joint was difficult to ascertain because no scaffolding was erected for access. However, there appeared to be loose blocks overhead and on the sides that should be replaced. This could amount to a significant repair work. Loose blocks in area of EJ were replaced, holes in breeching were patched from outside and rods were welded to the inside of the duct shell to secure the mesh for refractory, and the EJ cover plates were repaired.

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A hole was found in the bottom corner of the expansion joint and repaired. The ladder inside the breeching is severely corroded and should be removed completely. A total of about 230 blocks were installed in the east breeching.

External breeching inspection

A great degree deterioration of the expansion joints is obvious – failed corners, evidence of leaks. A more detailed inspection is needed, but that would require removal of the cover plates. Corrosion was visible under the coating.

Unit 2:

West breeching

There were a number of blocks to be replaced on the south and north walls under the air heater. The breeching floor was cracked near the hopper and lifting up. It is quite thin – only about 1‡" to 2". This floor was done in 2005, and may have to be replaced again in the near future.

Overall, the internal lining was in acceptable condition. There were isolated small areas requiring attention. The pantleg area appeared to be in good condition except for a section of relatively new blocks on the north wall that seemed to be separating from the duct. There was no access for a closer look – scaffolding was not erected. Very little ash was found on the duct floor. One brace in the horizontal section had separated from the duct on the bottom.

Approximately 15 blocks were replaced. Three other small locations with loose blocks were identified but could not be stripped due to the slime deposit on all surfaces (condensation). Two of these were in the horizontal section while the other was in the pantleg. Without scaffold it was difficult to better assess the pantleg condition. However, each location appeared to require between 4 and 6 block replacements.

East breeching

The floor was in poor condition, but the rest of the block liner was sound with only a 9-block section replaced. However, the blocks appeared wet and soft overhead at the beginning of the up-bend. No leaks were found.

External breeching inspection

On the east side, the expansion joint had a leak at the bottom flange. The cover plate does not cover the entire flange to provide adequate protection from the environment. Also there are many locations on top of the cover where water is allowed to pool. The fabric element behind the cover plate appeared to be intact, but it would be necessary to remove the cover plate for a proper assessment.

On the west side, the protective coating broke down in small, localized areas and at a brace attachment showing corrosion. The expansion joint element has failed along the top, and a leak was found in the flange at the bottom. Again, water was pooling on top of the cover plate. Relatively minor rust

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discoloration was noted on the coating of the horizontal section. Also, a patch on top of the flue, welded from the inside, had not been sealed from outside.

Unit 3:

Internal breeching

Test patches of Pennguard 55 insulation material, installed in 2007, do not exhibit any deterioration or damage. Another new material, Smoothkote refractory, may also be a viable option, as the test patch remained in good condition after one year of operation. The Pennguard 55 block differs very little from the normally used Pennguard 28, and is about 30% cheaper. However, the currently used material may have been in equally good condition after one year of operation, and more time is required to draw a conclusion regarding possible use in the future.

Overall, the block liner is in acceptable condition. The blocks, replaced previous year, show no appreciable damage. However, there were new sites identified where the lining has degraded: the inspection identified about 40 silicate blocks requiring replacement.

It was noted that ash has accumulated in the expansion joint near the stack and this was causing the cover plates to be pushed outward. It was recommended that the plates be removed temporarily to allow the ash to be removed. Not much ash was found in the breeching.

External breeching inspection

The breeching appears in good condition from the outside. There were no indications of leaks in the corner areas or on top where they have been found in recent years. On the west side, a hole could be seen that had been patched from the inside, but not sealed from the outside, which allows moisture to pool inside the cavity and cause external corrosion. Also, the top of the breeching near the stack should be re-painted. The crotch area looked good.



UNIT OPERATION CONSIDERATIONS

Operation of the boiler and back end equipment is believed to have contributed significantly to creating conditions leading to deterioration of the original breeching as well as of the breeching installed as part of units 1 and 2 upgrade. The back end system, as designed, relies on steam coil air heaters (SCAH) to control the gas temperature leaving the Ljungstrom air pre-heater. The general recommendation is that the flue gas temperature be at least 28°C (50°F) above the sulphuric acid dew point of a fuel.

Although the target sulphur content in the fuel has always been 2.2% according to Alstom personnel on site, the Holyrood records typically refer to 2.5% sulphur content (an analysis of a 1987 bunker C oil sample showed as much as 2.8% sulphur content) for which the acid dew point was calculated to be 148°C (298°F), commanding a "safe" temperature of the gas of at least 177°C (350°F). Fluctuations in sulphur content is echoed in the increase or decrease of the safe temperatures needed to avoid acid formation in the duct. The current limit on sulphur content in the fuel stands at 1%, which corresponds to 138°C (280°F) and 166°C (330°F) dew point and safe outlet gas temperatures respectively.

Without SCAH intervention, the acid dew point of the flue gas would come close to the gas design outlet temperature of approximately 150°C (302°F) for the original MCR (150 MW) and approximately 155°C (311°F) for the uprated load condition (175 MW). The temperature would drop below the dew point at low loads in off peak operating periods, possibly falling to 115-120°C. The boilers seldom operate at full load; typical loads may vary between 70 and 140 MW, but could operate as low as 50 MW (30% MCR), which means that gas temperatures would be below the dew point for a large portion of the unit operating time. As an example, in 2007 the averaged output of Unit 1 was 70 MW (40 %MCR), Unit 2 put out 110 MW (63 %MCR) and Unit 3 put out 89 MW (69 %MCR).

The steam coils have always been used in Holyrood striving to keep the average cold end temperature (ACET) of the air pre-heater at a target temperature of approximately 107°C (235°F) with a corresponding gas outlet temperature of 164°C (327°F). This would not have been a safe gas temperature for the pre-2006 fuel (needed 177°C), but would be acceptable for the new fuel composition criterion. By comparison, the target ACET for 1.0% sulphur oil is 105°C (221°F).

It was recognized in the early years of the units' operating life that the SCAH's did not have adequate capacity to support the air pre-heater requirements in winter operation with the cold air drawn from the outside, which in turn caused the outlet gas temperatures be much lower than the design. The remedy was to draw the combustion air from inside the powerhouse at the expense of creating another set of problems – because of the considerable vacuum created by the fan intake, air from outside the building would enter from all available openings and cause frequent freeze-ups throughout the plant, and opening of doors was difficult causing the doors slam shut endangering the plant personnel (Re: 1990 CEA paper). The SCAH's have been upgraded following the uprate in 1989 - a second bank was added effectively doubling their capacity. Also, a "warm air make-up system" has since been added that helps feed the combustion air into the plant in a controlled fashion that helps to avoid the freeze-up problems.

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SUMMARY AND RECOMMENDATIONS

In the utility boiler industry, it is a recognized fact that breeching ducting has a limited life and may need replacement periodically, either completely or partially. Although a twenty-year life span of ducting is not unusual, controlling or preventing the adverse conditions leading to early deterioration, both inside and outside, can extend it.

Most breeching systems employed by the utilities surveyed are of carbon steel plate construction with adequate external insulation, and only in extreme cases or in some old utilities internal insulation liners are employed. Externally insulated ducts are generally much easier to inspect, maintain and clean. Alstom does have a standard design for internal lining, typically consisting of 4" calcium silicate blocks with expanded metal mesh and 3/4" layer of Super 3000 (Alstom hi-temp refractory) on top, but the design is rarely used being maintenance intensive. Internal insulation or corrosion resistant steel liners are used in pulp and paper industry and by HRSG's. From the operation perspective, there is no advantage to insulating ducts inside rather then externally.

The chronic corrosion of the original breeching in Holyrood appears to have been rooted in deteriorated external insulation, and in operating conditions, such as low-load operation, that drove the gas outlet temperatures below the sulphuric acid dew point.

The new breeching, fitted with internal borosilicate lining, was expected to alleviate both the corrosion problems and the high maintenance cost, but failed to do either. Not only did the internal and external corrosion problems continue, although at a reduced rate, but the corroded sites became difficult to inspect and access for repairs, and the bulk of the maintenance has shifted to replacing and repairing the internal liner blocks. The projected annual maintenance cost burgeoned from the expected \$8K per duct (extracted from the 1988 internal cost analysis) to a sizable multiple of that at times (e.g., in 2003, replacement of 350 sq.ft. of the silicate block liner in Unit 2 cost \$90K). For comparison, the projected cost of maintaining a breeching as per the original design was \$21K per year per duct.

To have a real chance of succeeding in minimizing the corrosion problem, any solution alternative selected has to embrace continuous gas temperature control at all loads. That means the ACET should be subordinate to maintaining the gas outlet temperature at 166°C (330°F) or higher at all times to avoid formation of sulphuric acid, assuming the upper limit of sulphur in the fuel (1%) is adhered to. External corrosion problems have to be addressed in parallel with controlling the internal conditions.

A prerequisite to adopting any of the proposed alternatives is a complete assessment of the soundness of the ducting shell, which should include strategic removal of external protective coating (e.g., at locations of discoloration) and measuring the plate thickness. The results of such evaluation will dictate the direction for the solutions sought, i.e., A) the existing ducting (plate and stiffening) is in a reasonably sound condition and may require only partial plate replacement along with the insulation upgrade, and B) the duct shell has for the most part no or very little life left and should be replaced.

Considering the fact that the acid dew point has been lowered by virtue of a lower maximum allowed sulphur content in the fuel, the conditions for acid corrosion would have been somewhat mitigated

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already, which should reflect in lower duct maintenance in the future. However, due to the length of the service life (almost twenty years) and extended exposure to the past prevailing conditions, deterioration of the current liner may continue at the same pace or worse, if some upgrades are not implemented. The low service temperature of the adhesive membrane is likely to remain a contributing factor to the insulation block failures.

The breeching expansion joints are in a poor condition and need a major overhaul as an interim solution, but a replacement in kind should be in the planning.

A separate issue to be dealt with is the deteriorating condition of the seven metallic expansion joints one omega and six bellow joints on the hot air outlet duct from the air pre-heater. These are the original components and have been in operation for almost 30 years. Although air duct expansion joints are not exposed to as harsh environment as the gas touched components, time and service demands eventually took their toll of they all appear heavily rusted and are cracking, likely due to fatigue, in the bottom sections (see Fig.'s 30-32). The joints could be repaired piecemeal as required, but as a long-term solution, it is advisable to replace them with properly engineered cloth joints. Some of the alternatives shown below have already been considered in earlier discussions with NLH.

Solution alternatives - Breeching

Note: Indicative Pricing has been provided in Appendix 2. This indicative pricing is intended to provide an indication of relative supply and erect costs for budgeting purposes, approximately ±30%, and in not intended as an offer to provide services. Should Newfoundland & Labrador Hydro wish to pursue an option, Alstom would then provide a Proposal for such scope based on conditions at that time.

The "Solution" reference for each option refers to the "Breeching Solution" as outlined in the Indicative Pricing Estimate in Appendix 2.

- A) Current ducts are in serviceable condition and remain in place:
 - Keep current duct arrangement, repair duct and lining as required (Breeching Solution A1); use cheaper insulation material to replace borosilicate blocks (e.g., Pennguard 55 vs. Pennguard 28)
 - <u>Pros</u>: no capital investment, no time lost to upgrading ducting; potential for reducing maintenance cost by changing insulation block material;
 - <u>Cons</u>: break-down of the insulation material and adhesive membrane will likely not subside, may become worse; prohibitive cost of repairs will remain; difficulties accessing the sites of corrosion damage and leaks under insulation and the outer protective coating will not change; cleaning ash and debris from the duct floor remains impaired; erosion wastage of lining may still be a problem
 - 2) Keep current duct arrangement, but add 4" of external water repellent insulation and a watertight cladding (Breeching Solution A2): repair internal lining as required, and have the overall concept materials and specs reviewed for possible improvements less expensive insulation blocks, increased concrete layer and block thickness, etc; protect external cladding

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against falling ice (catwalk grating, hood, etc., see B below) if that remains a genuine problem. The external surface should be cleaned of rust before installing the insulation..

<u>Pros</u>: the external insulation will help prevent gas cooling even if lining damaged; potential for reducing maintenance cost by changing insulation block material; corrosion of the duct shell <u>due to gas cooling</u> through contact with the duct plate will be minimized or eliminated if external insulation is maintained; degradation of borosilicate lining less critical with external insulation added

<u>Cons</u>: added cost of external insulation and cladding c/w protection against damage; breakdown of the internal insulation material and adhesive membrane will likely not subside, may become worse; the internal liner will still have to be maintained, therefore prohibitive cost of repairs will remain; continuing difficulties accessing the sites for inspection; cleaning ash and debris from the duct floor remains impaired;

3) keep current duct, add 6" of external insulation and remove internal liner blocks and silicate concrete (Breeching Solution A3); protect external cladding against falling ice (catwalk grating, hood, etc., see B) below) if that remains a problem. The external surface should be cleaned from rust before installing the insulation.

<u>Pros</u>: the upgraded external insulation will provide adequate insulation to prevent gas cooling, assuming it is kept in good serviceable condition; reduced maintenance cost by comparison to current situation – no insulation blocks to replace; corrosion <u>due to gas cooling</u> will be minimized or eliminated if external insulation is maintained; improved access for duct inspection and cleaning

<u>Cons</u>: added cost of external insulation and cladding c/w protection against damage; added cost of internal liner removal; access for duct inspection somewhat impaired if remnants of internal liner remain (e.g., adhesive membrane)

A modified Option 2 above (<u>Breeching Solution A2</u>) would be a preferred long-term solution **if the breeching is to be left in place**, i.e., the external insulation 6" thick (as opposed to 4" in Option 2) with the internal lining left alone initially and removed only if the silicate block degradation continued unabated. This way, no upgrade of external insulation (to the 6" thickness) would have been required if the internal liner were removed, as in Option 3.

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- B) Replace the entire breeching:
 - 1) original duct design, made of
 - a) (<u>Breeching Solution B1a</u>) ‡" mild carbon steel plate (G40.21 or equivalent) c/w 6" of external water repellent insulation c/w watertight high quality cladding and flashing

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- b) (<u>Breeching Solution B1b</u>) ‡" Corten or equivalent high temperature carbon steel c/w
 6" of external water repellent insulation c/w watertight high quality cladding and flashing
- c) (<u>Breeching Solution B1c</u>) 3/16" stainless steel (e.g., 304, 316L, 904L, HASTELLOY C276) c/w 4" of external water repellent insulation c/w watertight high quality cladding and flashing
- d) (Breeching Solution B1d) 3/16" Avesta plate (2205) plate c/w 4" of external water repellent insulation c/w watertight high quality cladding and flashing

<u>Pros</u>: a) if properly designed and maintained, the insulation offers adequate protection against gas cooling; standard ducting material used; reduced maintenance cost compared to the current breeching; reduced load on supports and ducting plate compared to inner liner; good access for duct inspection; insulation not susceptible to cracking

- b) same as a) above, but offers some protection against corrosion if gas temperature drops below acid dew point (higher chrome content min. 0.7%)
- c) and d) same as a) above, but the materials are corrosion resistant and therefore not susceptible to corrosion problems if the gas temperature is not maintained; less insulation required; less plate material used

<u>Cons</u>: a) does not address the original problem of insulation being damaged by falling ice; will suffer corrosion problems if outlet gas temperature is not maintained above acid dew point

- b) does not address the original problem of insulation being damaged by falling ice; higher material cost;
- c) and d) do not address the original problem of insulation being damaged by falling ice; high material cost; design check required due to thinner plate
- original duct design, construction alternatives as per 1), with added protection against damage caused by ice falling from stack and powerhouse, as shown below:
 - a) (<u>Protection Solution B2a</u>) light-weight (LW), 1½" catwalk grating on the top panels (over aluminium cladding) attached to stack and side panels
 - b) (<u>Protection Solution B2b</u>) U-shaped 7 ga. plate encasement slid over the top panels (possibly with ice-breaker ribs)
 - c) (Protection Solution B2c) 3/16" carbon steel hood over the duct, attached to the duct sidewalls
 - d) (<u>Protection Solution B2d</u>) extra heavy gage, ribbed aluminium or steel cladding on the top panels

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<u>Pros</u>: same as 1) but addresses the original problem of insulation being damaged by falling ice; less maintenance required for the external insulation if prevented from being damaged, relatively simple design needed for the protection; option d) would not require a special design for added protection

<u>Cons</u>: same as 1) except the falling ice protection; added cost of material and design of the falling ice protection, danger of creating heat sinks where protection attached to the duct

3) 1/4" Corten or equivalent hi-temp carbon steel duct, internal insulation c/w stainless steel liner (Breeching Solution 3) - similar to HRSG construction (3" cerwool or mineral wool insulation bats, 304L or 316L stainless steel 10 ga liner held in place with studs), no external insulation but protection coating

<u>Pros</u>: works well in HRSG application; less prone to external corrosion because of better plate material; insulation stays in place, traditionally low maintenance once settled

<u>Cons</u>: access for inspection restricted; installation sensitive; high installation cost, condensation may by a problem on bottom panel

Other options could include alloy or stainless steel cladding applied directly on the duct plate or a layer of polymer coating inside combined with external insulation, but these options were already explored by NLH and found expensive to apply and maintain, and were rejected.

The preferred long-term solution for **replacing the breeching** would be Breeching Solution B1b, with the Protection Solution B2b. Hi-temp carbon steels such as Corten have been used in the past for back end (breeching) ductwork, even if the gas temperature did not require it, because of their improved resistance to corrosion compared to low carbon steels. An additional 1/8" corrosion allowance could be added to extend the life of the ducting.

Solution alternatives - Hot air duct expansion joints, Unit 3

- 1) Repair or replace sections as required (Expansion It Solution 1): the bellows could be weld repaired as required, or partially replaced, specifically the bottom part of the joints. Considering the service life and the overall condition of the joints, this should be only an short-term maintenance fix. It may however prove difficult to weld-repair the joints because of the general condition of the expansion joint material.
- 2) Install cloth seal over the metallic expansion joints (Expansion It Solution 2): this interim solution would replace repairing the ailing metallic joints. It would not have any effect on the function of the current joints, but would prevent leaks. Care must be taken to evaluate correctly the movements as not the cause failure of these joints as well.

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- 3) Replace the expansion joints in kind (Expansion It Solution 3): this alternative would see the expansion joints replaced as originally designed and built. No engineering is required, but the probable shortcomings of the current design would be copied.
- 4) Replace with metallic joints, but review the selection (Expansion It Solution 4): engineering review would be required to confirm or repudiate the current selection, and possibly come up with a better system to prevent the current failures.
- 5) Replace the expansion joints with cloth joints, properly engineered (Expansion It Solution 5): cloth expansion joints are widely used and are the preferred solution in most ducting systems. They do not exert reaction forces to the system supports, and would not be subject to fatigue-induced cracking.

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From engineering and operation standpoint, Option 5 is the preferred solution.

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Year	Unit 1	Unit 2	Unit 3	
2008	West side no scaffold - difficult to assess pantleg. However appeared to be sections where liner has failed above and adjacent to expansion joint. 40 to 50 blocks estimated but could be worse than appears. Horizontal section good – about 10 blocks replaced. East side many holes - duct patched from outside at north side of bend. Refractory in bend also failed. 230 blocks replaced in bend area. Horizontal section good. Scaffold up to expansion joint only. Above expansion joint liner is questionable condition. Could be a significant repair required. Expansion joints have failed both sides.	The refractory floor on both sides now in poor condition and requires replacement. West side approx 15 blocks replaced. No scaffold installed. Three other locations about 4 blocks each looked loose but not replaced due to condensation/sweat problem. East side one 9 block section was replaced. Block also wet and apparently soft overhead and up the pantleg in sections. Expansion joint in poor condition on both sides.	Test patches of Pennguard 55 block and refractory both in good condition after one year. About 40 blocks replaced – scaffold was erected. Debris noted in expansion joint should be cleaned out. Looked OK from external inspection.	
2007	Minor repairs only – about 40 blocks total. Cost about \$5k	East floor in poor condition – not replaced. About 90 blocks on each side replaced – all in horizontal section – no scaffold required. 3 holes patched in west side. Total cost about \$16k.	Blocks replaced overhead and at both side corners – about 200 sqft. 15 holes patched (welded inside – Devcon outside). Trial patch of Pennguard 55 and Smoothkote refractory installed. Total cost about \$25k	
2006	C&E Refractories poured new floor east side and block both sides. Total about 760 sqft. 5 holes in west and 12 in east side patched from inside and sealed with Devcon outside. Expansion joint cover plates bad. Total cost about \$320k	East floor in poor condition – not replaced. Block good both sides.	About 40 blocks to replace overhead but not done – no scaffold. 15 blocks that were accessible were replaced. No cost captured.	
2005	East floor bad. Block to replace overhead and north on east side not done. West small quantity of block replaced but more to do with scaffold. Cost about \$2k captured.	Mount Pearl Painting hired to replace refractory on west floor and block on both sides. Many holes found on both sides and repaired from outside. Total cost about \$290k.	Hole found in top near stack. Patched from outside. No scaffold installed – accessible block replaced as required. About 50 blocks replaced and 15 not accessible. Total about \$5k.	
2004	East floor bad – not replaced. East side scaffolded and block replaced. Hole in expansion joint patched. Cover plates bad. West side small quantity of block replaced – no scaffold. Cost about \$15k	Just a couple of blocks replaced	Block replaced overhead and at corners (higher than 2003). No holes found. Scaffold erected. Total cost about \$10k.	
2003	East floor starting to fail. Few blocks to replace. Supposedly repaired by another contractor working on the stack	Approximately 350 sqft of block replaced mostly on east side. Scaffold erected. Through holes patched. Done by C&E Refractories. Cost about \$90k.	Holes found on both sides. Scaffold erected and holes repaired. Block replaced as required. Costs not captured.	
2002	Damage repaired by C&E Refractories. This included replacement of the west floor refractory. Don't know cost.	No significant work	Very small quantity of block replaced with no scaffold. Scaffold recommended to replace block next year.	
2001	No significant work	No significant work	No work done. Minor repairs recommended.	
2000	Significant work done to replace block. 540 hours reported – estimated around \$35k	C&E Refractory replaced about 750 sqft of block. Don't know cost.	Minor repair to borosilicate block liner	

Table 1: J. Adams, Breeching History Summary 2000-2008



Fig. 1: Original Breeching, floor in horizontal section - Unit 1 or 2



Fig. 2: Original Breeching, pantleg inlet - Unit 1 or 2



Fig. 3: Original Breeching, sloping section - Unit 1 or 2



Fig. 4: Original Breeching, bend section - Unit 1 or 2



Fig. 5: Original Breeching, entrance to horizontal section (at heater) - Unit 1 or 2



Fig. 6: Original Breeching, top view – Unit 1

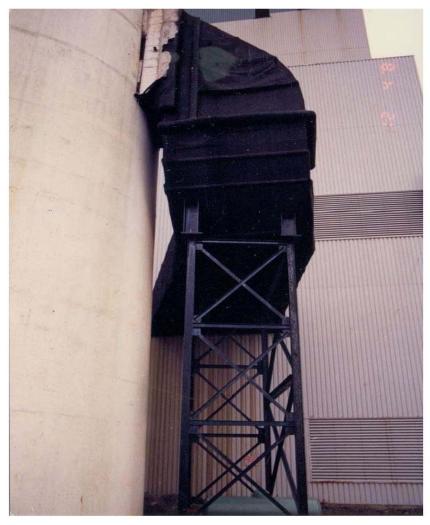


Fig. 7: Original Breeching, elevation view - Unit 1



Fig. 8: Unit 1 - Insulating block replacement



Fig. 9: Unit 1 - Duct corroded through



Fig. 10: Unit 1 - Sloped section as found



Fig. 11: Unit 1 - Sidewall and floor



Fig. 12: Unit 1 – Replaced blocks



Fig. 13: Unit 1 – Missing block overhead



Fig.14: Unit 1 – Ash accumulated on the floor



Fig. 15: Unit 1 - Damaged expansion joint



Fig. 16: Unit 1 - External duct repairs



Fig. 17: Unit 1 - External duct repairs



Fig. 18: Unit 2 - Missing insulation blocks



Fig. 19: Unit 2 - Missing insulation blocks



Fig. 20: Unit 2 - Cracked cement floor



Fig. 21: Unit 2 - Cracked cement floor



Fig. 22: Unit 2 – External coating break down



Fig. 23: Unit 3 - Repairs 2007



Fig. 24: Unit 3 – Crotch repairs



Fig. 25: Unit 3 – Patched casing (from inside)



Fig. 26: Unit 3 – Top near the stack

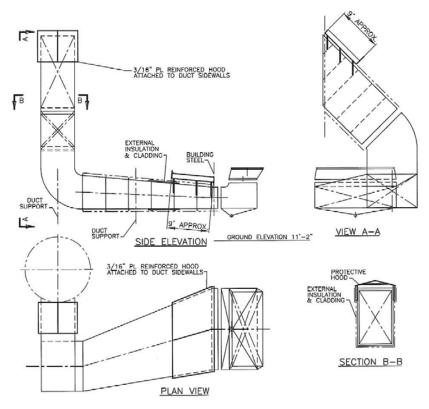


Fig. 27: Proposed cladding protection – protective hood

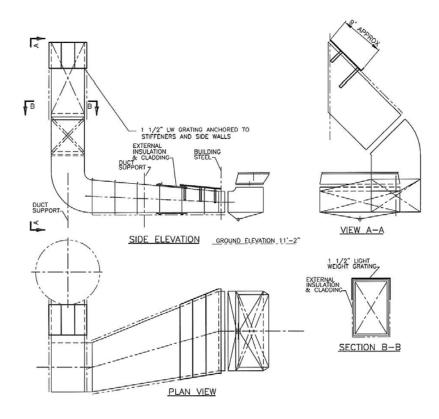


Fig. 28: Proposed cladding protection – catwalk grating

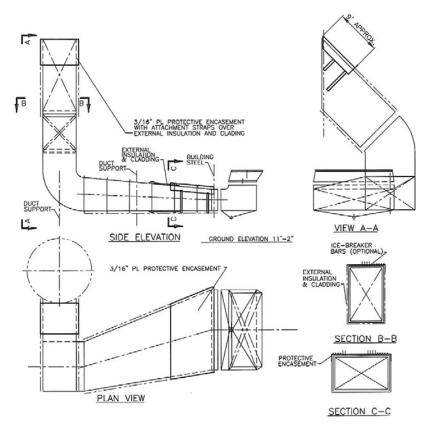


Fig. 29: Proposed cladding protection – 7ga. plate encasement



Fig. 30: Unit 3 – Expansion joint, hot air duct from air heater



Fig. 31: Unit 3 – Expansion joint, hot air duct from air heater



Fig. 32: Unit 3 - Expansion joint #4, hot air duct from air heater

Appendix 2 - Indicative Pricing

	ver Service		
CONTRACT #	40833010	ESTIMATE TYPE:	INDICATIVE
CUSTOMER:	NLH	PROJECT TYPE:	SUPPLY & EREC
SITE: PROP. DWG:	Holyrood, NF	DATE:	9-Feb-2009
SCOPE:	Air Heater to Stack Breeching S	Study	
3001 E.	All Heater to Stack Dreeting	July	
Breeching Soluti	on Alternatives For U1, U2	& U3	S&E (Indicative Prices)
Based on repairing	on joints repairs are not included	due to unknown condition. These repairs can	\$370,000
Insulation U1,U2 a - Based on repairing	k U3 1610 ft² of blocks. on joints repairs are not included	ing As Reg'd. Add 4" New External due to unknown condition. These repairs can	\$1,488,000
Insulation U1, U2 a - Tear-out of all block	& U3 ks. on joints repairs are not included	due to unknown condition. These repairs can	\$1,528,000
Insulation U1, U2 - All mild steel skin a	& U3 nd stiffeners, primed ard and finish with 0.040" box rib	with New Exp Jts and New 6" External aluminium jacket for water tight cladding.	\$7,607,000
Insulation U1, U2 - Corten Skin, mild s	& U3 teel stiffeners, primed ard and finish with 0.040" box rib	g with New Exp Jts and New 6" External o aluminium jacket for water tight cladding.	\$7,624,000
Insulation U1, U2 - 304 S.S. Skin, mild	& U3 steel stiffeners, MS primed ard and finish with 0.040" box rib	ning with New Exp Jts and New 4" External or aluminium jacket for water tight cladding.	\$7,932,000
External Insulation. - Avesta (2205) Skin	- U1, U2 & U3 , mild steel stiffeners, MS primed ard and finish with 0.040" box rib	reeching with New Exp Jts and New 4" o aluminium jacket for water tight cladding.	8,178,000

ALSTOM POW	ver Service	INDICATIVE PRICING ESTIMATE	
CONTRACT #	40833010	ESTIMATE TYPE:	INDICATIVE
CUSTOMER:	NLH	PROJECT TYPE:	
SITE:	Holyrood, NF	DATE:	9-Feb-2009
PROP. DWG: SCOPE:	Air Heater to Stack Breeching Stud	у	
Breeching Solution 3	3 - New 1/4" Corten Breeching with	New Exp Jts and New 3" Internal	
	teel stiffeners, primed		\$8,540,000
and the second s	d finish with 10 gauge S.S. liner.		50-050 81
- Scaffolding Include			
Ice Protection Sc	S&E (Indicative Prices)		
Protection Solution E	\$178,000		
Protection Solution E	\$186,000		
Protection Solution E	\$189,000		
Protection Solution E Only	22d - Extra Heavy Gage, Ribbed Al or	Steel Cladding on Top Panels, U1 & U2	No suitable material for this application
Expansion Joint Solution Alternatives For U3			S&E (Indicative Prices)
Expansion Jt Solution	1 - Replace and Repair Sections as	Required - U3 Only	Do on time and & Material because the condition is not known.
Expansion Jt Solution	\$88,000		
Expansion Jt Solution	\$97,000		
Expansion Jt Solution	n Metallic New Design - U3 Only	\$98,000	
		Control of the Contro	\$100,000

Notes:

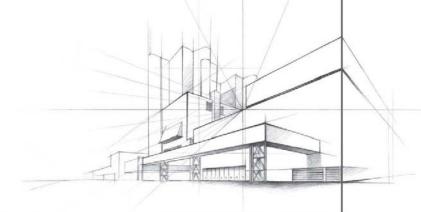
- (1) Construction estimate on ice protection and expansion joint is based on being on site in conjunction with the maintenance work.
- (2) For Unit #3 (B&W), we have no drawings. For future firm price proposal, we are expecting NLH to provide the necessary drawings of the existing ducting for us to work from.
- (3) For Casing repair because the condition is not known, it should be done during annual maintenance.
- (4) For U3 expansion joint repair, it should be done on time and & material because the condition is not known
- (5) This budget proposal gives a preliminary indication of the basis of which [services/deliveries] can be undertaken, and does not constitute an offer to carry out those [deliveries/services]. In particular, any prices, delivery times or performance figures mentioned are given without commitment at this stage. Nevertheless we trust the information provided is sufficiently detailed to enable you to assess the benefits which you can obtain by utilising our Company's services /deliveries, and we confirm our keen interest in working with you. To this end we look forward to discussing with you the content of this proposal and, when appropriate, submitting an offer to you.

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Engineering Study – Final Report Holyrood G.S. – Stack Breeching Assessment Alstom Reference #40833010 December 18, 2008 Rev. 1 – March 4, 2009 Rev. 2 – August 28, 2009

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Final Report

to

Newfoundland & Labrador Hydro

of an

Engineering Study

on

Condition Assessment of Stack Breeching at Holyrood G.S. Units #1, 2, & 3

Prepared by

Alstom Canada Inc. Ottawa, ON

Reference # 40833010

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23108012 FOUNDE OF ONT HED REV. 2 - June 2009-08-28

POFESSION

J.D. KEARNS

This report was prepared by Pavel Kratina, P. Eng. and was reviewed by John McMillan, P.Eng. Revisions 1 & 2 were edited by Jim Kearns, P. Eng.



EXECUTIVE SUMMARY

Environmental and operational conditions in Holyrood G.S. have precipitated severe corrosion of the original, externally insulated breeching that has necessitated intensive and costly maintenance. Initially, the corrosion of the ductwork was more prevalent in Units 1 and 2, since Unit 3 was built ten years later. In replacing the breeching at the time of the 1989 boiler upgrades, Newfoundland & Labrador Hydro has turned to an alternative design featuring internal borosilicate lining along with an outside protective coating, which carried a promise of low maintenance cost.

Although the changeover to internal insulation partially solved the corrosion predicament, it has created a worse problem of having to repair and replace the broken and dislodged glass insulation blocks; during winter operation, gas cooling below the dew point may be occurring at those locations causing corrosion of the duct shell. The cost of maintaining the internal liner in a serviceable condition is becoming prohibitive, and it seems to be far offsetting the benefits of eliminating the icefall damage of the breeching exterior. Less expensive and more reliable materials could probably replace the current insulating blocks and refractory, but the underlying concern – no access for inspection of the duct plate and potential for localized corrosion - would remain.

A more serious root cause of the internal corrosion may have been the operating conditions of the units that prevailed until the recent change to a more sulphur "friendly" fuel (1% max. limit). At the full-load operation and with no controls employed, the outlet gas temperatures would come very close to the sulphuric acid dew point of fuels containing 2.5% or more sulphur, and the situation would become worse at low-load operation. The steam coils, used to control the average cold end temperature (ACET) of the pre-heaters, did not have adequate capacity for winter operation until the boiler uprates in 1998 when they were upgraded.

It is conceivable that the initial corrosion and maintenance problems would not have been so severe under the current operating conditions, i.e., lower sulphur content and improved outlet gas temperature control, providing the external insulation was protected from the elements and well maintained.

A number of options are provided with varying capital costs and associated anticipated maintenance requirements as shown in the "SUMMARY AND RECOMMENDATIONS" section. Also included is an overview of the condition of the Unit 3 expansion joints and suggested options to deal with the problems.

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INTRODUCTION AND PROBLEM DEFINITION

Units 1 and 2 at the Newfoundland and Labrador Hydro (NLH) Holyrood G.S. are pressurized units of Alstom (formerly CE) design from 1968; Unit 3 is a B&W boiler, constructed in 1979. Units 1 and 2 were up-rated from 150 to 175 MW in 1989, and part of the upgrade was a replacement of the breeching section between the air pre-heater and the stack.

The original breeching was a typical back end duct design constructed of 1/4" carbon steel and insulated externally. From the information available it appears that the cladding was continually damaged by ice falling from the powerhouse and stacks, allowing moisture to penetrate in insulation, which led to insulation break down and severe corrosion of the carbon steel ducting. The cost of repairing/replacing the corroded duct sections was deemed to be too high and a decision was made by the plant management to replace the breeching.

A NLH internal study opted for a design that provided for internal insulation of borosilicate blocks and a protective coating on the breeching exterior. The promise of the new system was a much-reduced maintenance cost by comparison to the original ducting. Replacement of the breeching of the two Alstom units was completed in late 1990. Since there is no specific information available one can only speculate that it was done at the same time as Units 1 and 2.

Early into the operation (1991), the new ducts developed problems such as erosion wastage and cracking of the insulation and the concrete layer. Later, problems with the liner began to mount – the insulation blocks would break and fall out allowing the gas to penetrate to the duct plate, cool and cause localized corrosion of the duct plate. As the records show, the internal liner requires frequent repairs, and the cost of keeping the insulation blocks in good order has proven to be considerably higher then anticipated. One of the reasons for the internal liner degrading may be the specified service temperature limit of the adhesive membrane of about 200°F that is easily exceeded if in contact with the flue gas (through cracks initially), which in turn may explain dislodged silicate blocks.

To make the situation worse, the exact sites of the corrosion damage are difficult to find under the insulation layers and the protective coating outside until the plate is corroded through. Cleaning the duct floors has become difficult with the floor concrete layer broken or otherwise damaged.

Alstom was commissioned to evaluate the current situation, reflect on the latest practices in the industry, and propose alternatives to minimize the breeching corrosion problems and high maintenance cost.

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CONDITIONS LEADING TO DUCT REPLACEMENT

The decision to replace the breeching was made in 1987-88, and concerned mainly units 1 and 2. The move was driven by corrosion related maintenance problems and associated maintenance cost. Unit 3 ducting, which is of a different layout, was eventually replaced as well although it was only 10 years old at the time and presumably had not experienced the same degree of deterioration. The underlining problem seemed to have been a severe corrosion condition created by formation of acidic condensate due to flue gas temperatures dropping below the acid dew point. The sub-cooled gas temperatures may have been a result of boiler operation and/or a contact with poorly insulated ducting.

It appears the condition of the external insulation contributed significantly or may have even been instrumental to the ductwork deterioration. As it happened, insulating materials on the two older units were not identical: Unit 1 was insulated with 2-1/2" of calcium silicate rigid insulation with a 1/8" flintcote 110-26 mastic applied over the blocks and reinforced with fibreglass mesh set in the mastic; Unit 2 was covered with soft bat exterior insulation and protective cladding. It is not known if there were differences in the degree of deterioration and maintenance between the two ducts.

Based on the information available (plant personnel recollection and a 1990 technical paper presented at CEA workshop), the problems with the original breeching stemmed from damaged external insulation leading to a severe corrosion of the duct plate. Moisture would penetrate into the insulation through damaged outer protection (mastic or cladding) – presumably damaged by ice falling from the stack and powerhouse (Fig. 6-7), rending the insulation ineffective. In addition, the wet insulation on sidewalls likely sagged, creating pockets of no or very little insulating material. It is believed that the degraded condition of the insulation caused considerable corrosion of ducting from outside. To further exacerbate the situation, a lack of insulating allowed the gas in contact with the duct plate to cool below the acid dew point causing in turn widespread internal corrosion (Fig's 1-5). Deterioration of expansion joints was an added irritant, which needed to be addressed.

In 1987 the condition of breeching was such that replacement was deemed necessary. An in-house study produced four replacement alternatives:

- 1) Modified existing design (modifications referred to expansion joints)
- 2) Borosilicate lining inside and corrosion resistant coating on the exterior
- Sheets of corrosion resistant alloy material welded to the carbon steel ducting plate c/w external insulation
- 4) Liquid fluorocarbon coating inside and insulation outside.

Based on cost analysis, the plant management favoured to second option mainly because of the promise of dependable service and low maintenance cost. The breeching ducting was replaced in 1989-1990 with ducts insulated inside with borosilicate (glass) insulation blocks and additional layer of silicate concrete on the floor. The new breeching went into operation at the end of 1990.

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CONDITION ASSESSMENT OF CURRENT BREECHING

Shortly after start up, the new breeching developed erosion and cracking problems requiring costly repairs, which later escalated as the concrete floors began breaking up and the insulation blocks falling out. Following is an overview of the problem history of the current breeching, based on information made available (see also Fig's 8-26):

Past history of problems

Inspection of breeching in 1991- brief summary:

(Ref.: Internal inspection report, Wayne Rice, Nov. 1991)

- Installation of the new breeching in Unit 1 was completed in the fall of 1990
- The unit operated from Dec 1990 to April 1991; subsequent inspection of the ducting uncovered erosion wastage of the lining in the upper half of the elbow the material loss amounted to 1/4" to 1/2" over a 4-month period
- Test blocks were selected to monitor the erosion rate; second measurement in October 1991 showed loss of another 1/16" to 3/16"
- The problem was linked to the fans capacity increase required for the boiler uprate, delivering higher air volume, which in turn increased the gas velocities to 50 fps from the previous 43 fps.
 For comparison, the supplier (Autochem) affirmed the material suitability for up to 120 fps flow
- Unit 2 was first inspected in the fall of 1990 and no erosion was found. The unit operated
 erosion free for one year with the original impeller until the fan was upgraded during the 1991
 outage (possibly April or May). An inspection in October 1991 uncovered similar lining loss as in
 Unit 1
- Erosion affected approximately 3% off the total surface area of each duct in question
- Repair cost for both units was quoted at \$55,000 by a contractor on site
- Some cracks in the lining were found and repaired
- External protective coating started to show signs of rust discoloration

Operating period 1992-2000

No inspection and maintenance records available for review

Summary of breeching repair work 2000-2008:

(Ref.: Breeching history summary, J. Adams, Alstom)

Unit 1:

After eleven years in operation, extensive repairs to the insulation blocks were required. There was no significant work done in 2001, but repairs were required in the following years. In 2006, a new floor was poured by C&E Refractories. Another major insulation block replacement was carried out in 2008.

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Unit 2:

In 2000, approximately 750 ${\rm ft}^2$ of insulation was replaced. Some insulation block replacement was done in the years 2003-2005. The floor has deteriorated significantly, but to date no major work was done to correct the situation.

Unit 3:

Very little repair work was carried out until 2002. After that, insulation blocks were replaced and holes patched as required. In 2007 a new material was used for replacements, Pennguard 55 (as opposed to Pennguard 28), on trial basis. Inspection in 2008 found the Pennguard blocks in very good condition.

Current breeching condition - inspection summary

(Ref.: 2008 Inspection Report, J. Adams, Alstom Canada)

Unit 1:

West breeching

A large quantity of ash was found on top of the duct floor, but the refractory was intact. The horizontal section appeared to be in good condition - there were no holes found and no evidence of leaks. The sidewall insulation blocks were in excellent to good condition. The ceiling was good overall, but there were a few small isolated sections requiring repair - about 10 blocks were replaced. All bracing was found in good condition.

The pantleg (inclined) section had a few blocks fallen off from the overhead panel between the expansion (EJ) joint and the stack, and up to 6-10 blocks near the EJ were damaged or fallen out. A few blocks were loose and others in questionable condition on the sidewalls. The refractory at the upward bend was in acceptable condition.

East breeching

Ash has accumulated on the floor, but the refractory appeared in good condition. No major damage was found in the horizontal section, only a few isolated small sections overhead were slightly damaged needing repair. Above the up-bend, about 60 blocks had fallen off exposing the mesh. Ash and debris has accumulated between the refractory and the casing. Initially two through holes were spotted, but 12 holes were found when the loose blocks were removed and the casing cleaned.

The expansion joint has deteriorated considerably: cover plates were hanging loose, mostly separated from the sides. Behind the cover plates, the inner layers of the fabric element (insulation layers) and the inside of what appeared to be the outer belt could be seen.

The condition of the liner above the expansion joint was difficult to ascertain because no scaffolding was erected for access. However, there appeared to be loose blocks overhead and on the sides that should be replaced. This could amount to a significant repair work. Loose blocks in area of EJ were replaced, holes in breeching were patched from outside and rods were welded to the inside of the duct shell to secure the mesh for refractory, and the EJ cover plates were repaired.

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A hole was found in the bottom corner of the expansion joint and repaired. The ladder inside the breeching is severely corroded and should be removed completely. A total of about 230 blocks were installed in the east breeching.

External breeching inspection

A great degree deterioration of the expansion joints is obvious – failed corners, evidence of leaks. A more detailed inspection is needed, but that would require removal of the cover plates. Corrosion was visible under the coating.

Unit 2:

West breeching

There were a number of blocks to be replaced on the south and north walls under the air heater. The breeching floor was cracked near the hopper and lifting up. It is quite thin – only about 11" to 2". This floor was done in 2005, and may have to be replaced again in the near future.

Overall, the internal lining was in acceptable condition. There were isolated small areas requiring attention. The pantleg area appeared to be in good condition except for a section of relatively new blocks on the north wall that seemed to be separating from the duct. There was no access for a closer look – scaffolding was not erected. Very little ash was found on the duct floor. One brace in the horizontal section had separated from the duct on the bottom.

Approximately 15 blocks were replaced. Three other small locations with loose blocks were identified but could not be stripped due to the slime deposit on all surfaces (condensation). Two of these were in the horizontal section while the other was in the pantleg. Without scaffold it was difficult to better assess the pantleg condition. However, each location appeared to require between 4 and 6 block replacements.

East breeching

The floor was in poor condition, but the rest of the block liner was sound with only a 9-block section replaced. However, the blocks appeared wet and soft overhead at the beginning of the up-bend. No leaks were found.

External breeching inspection

On the east side, the expansion joint had a leak at the bottom flange. The cover plate does not cover the entire flange to provide adequate protection from the environment. Also there are many locations on top of the cover where water is allowed to pool. The fabric element behind the cover plate appeared to be intact, but it would be necessary to remove the cover plate for a proper assessment.

On the west side, the protective coating broke down in small, localized areas and at a brace attachment showing corrosion. The expansion joint element has failed along the top, and a leak was found in the flange at the bottom. Again, water was pooling on top of the cover plate. Relatively minor rust

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discoloration was noted on the coating of the horizontal section. Also, a patch on top of the flue, welded from the inside, had not been sealed from outside.

Unit 3:

Internal breeching

Test patches of Pennguard 55 insulation material, installed in 2007, do not exhibit any deterioration or damage. Another new material, Smoothkote refractory, may also be a viable option, as the test patch remained in good condition after one year of operation. The Pennguard 55 block differs very little from the normally used Pennguard 28, and is about 30% cheaper. However, the currently used material may have been in equally good condition after one year of operation, and more time is required to draw a conclusion regarding possible use in the future.

Overall, the block liner is in acceptable condition. The blocks, replaced previous year, show no appreciable damage. However, there were new sites identified where the lining has degraded: the inspection identified about 40 silicate blocks requiring replacement.

It was noted that ash has accumulated in the expansion joint near the stack and this was causing the cover plates to be pushed outward. It was recommended that the plates be removed temporarily to allow the ash to be removed. Not much ash was found in the breeching.

External breeching inspection

The breeching appears in good condition from the outside. There were no indications of leaks in the corner areas or on top where they have been found in recent years. On the west side, a hole could be seen that had been patched from the inside, but not sealed from the outside, which allows moisture to pool inside the cavity and cause external corrosion. Also, the top of the breeching near the stack should be re-painted. The crotch area looked good.



UNIT OPERATION CONSIDERATIONS

Operation of the boiler and back end equipment is believed to have contributed significantly to creating conditions leading to deterioration of the original breeching as well as of the breeching installed as part of units 1 and 2 upgrade. The back end system, as designed, relies on steam coil air heaters (SCAH) to control the gas temperature leaving the Ljungstrom air pre-heater. The general recommendation is that the flue gas temperature be at least 28°C (50°F) above the sulphuric acid dew point of a fuel.

Although the target sulphur content in the fuel has always been 2.2% according to Alstom personnel on site, the Holyrood records typically refer to 2.5% sulphur content (an analysis of a 1987 bunker C oil sample showed as much as 2.8% sulphur content) for which the acid dew point was calculated to be 148°C (298°F), commanding a "safe" temperature of the gas of at least 177°C (350°F). Fluctuations in sulphur content is echoed in the increase or decrease of the safe temperatures needed to avoid acid formation in the duct. The current limit on sulphur content in the fuel stands at 1%, which corresponds to 138°C (280°F) and 166°C (330°F) dew point and safe outlet gas temperatures respectively.

Without SCAH intervention, the acid dew point of the flue gas would come close to the gas design outlet temperature of approximately 150°C (302°F) for the original MCR (150 MW) and approximately 155°C (311°F) for the uprated load condition (175 MW). The temperature would drop below the dew point at low loads in off peak operating periods, possibly falling to 115-120°C. The boilers seldom operate at full load; typical loads may vary between 70 and 140 MW, but could operate as low as 50 MW (30% MCR), which means that gas temperatures would be below the dew point for a large portion of the unit operating time. As an example, in 2007 the averaged output of Unit 1 was 70 MW (40 %MCR), Unit 2 put out 110 MW (63 %MCR) and Unit 3 put out 89 MW (69 %MCR).

The steam coils have always been used in Holyrood striving to keep the average cold end temperature (ACET) of the air pre-heater at a target temperature of approximately 107°C (235°F) with a corresponding gas outlet temperature of 164°C (327°F). This would not have been a safe gas temperature for the pre-2006 fuel (needed 177°C), but would be acceptable for the new fuel composition criterion. By comparison, the target ACET for 1.0% sulphur oil is 105°C (221°F).

It was recognized in the early years of the units' operating life that the SCAH's did not have adequate capacity to support the air pre-heater requirements in winter operation with the cold air drawn from the outside, which in turn caused the outlet gas temperatures be much lower than the design. The remedy was to draw the combustion air from inside the powerhouse at the expense of creating another set of problems – because of the considerable vacuum created by the fan intake, air from outside the building would enter from all available openings and cause frequent freeze-ups throughout the plant, and opening of doors was difficult causing the doors slam shut endangering the plant personnel (Re: 1990 CEA paper). The SCAH's have been upgraded following the uprate in 1989 - a second bank was added effectively doubling their capacity. Also, a "warm air make-up system" has since been added that helps feed the combustion air into the plant in a controlled fashion that helps to avoid the freeze-up problems.

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SUMMARY AND RECOMMENDATIONS

In the utility boiler industry, it is a recognized fact that breeching ducting has a limited life and may need replacement periodically, either completely or partially. Although a twenty-year life span of ducting is not unusual, controlling or preventing the adverse conditions leading to early deterioration, both inside and outside, can extend it.

Most breeching systems employed by the utilities surveyed are of carbon steel plate construction with adequate external insulation, and only in extreme cases or in some old utilities internal insulation liners are employed. Externally insulated ducts are generally much easier to inspect, maintain and clean. Alstom does have a standard design for internal lining, typically consisting of 4" calcium silicate blocks with expanded metal mesh and 3/4" layer of Super 3000 (Alstom hi-temp refractory) on top, but the design is rarely used being maintenance intensive. Internal insulation or corrosion resistant steel liners are used in pulp and paper industry and by HRSG's. From the operation perspective, there is no advantage to insulating ducts inside rather then externally.

The chronic corrosion of the original breeching in Holyrood appears to have been rooted in deteriorated external insulation, and in operating conditions, such as low-load operation, that drove the gas outlet temperatures below the sulphuric acid dew point.

The new breeching, fitted with internal borosilicate lining, was expected to alleviate both the corrosion problems and the high maintenance cost, but failed to do either. Not only did the internal and external corrosion problems continue, although at a reduced rate, but the corroded sites became difficult to inspect and access for repairs, and the bulk of the maintenance has shifted to replacing and repairing the internal liner blocks. The projected annual maintenance cost burgeoned from the expected \$8K per duct (extracted from the 1988 internal cost analysis) to a sizable multiple of that at times (e.g., in 2003, replacement of 350 sq.ft. of the silicate block liner in Unit 2 cost \$90K). For comparison, the projected cost of maintaining a breeching as per the original design was \$21K per year per duct.

To have a real chance of succeeding in minimizing the corrosion problem, any solution alternative selected has to embrace continuous gas temperature control at all loads. That means the ACET should be subordinate to maintaining the gas outlet temperature at 166°C (330°F) or higher at all times to avoid formation of sulphuric acid, assuming the upper limit of sulphur in the fuel (1%) is adhered to. External corrosion problems have to be addressed in parallel with controlling the internal conditions.

A prerequisite to adopting any of the proposed alternatives is a complete assessment of the soundness of the ducting shell, which should include strategic removal of external protective coating (e.g., at locations of discoloration) and measuring the plate thickness. The results of such evaluation will dictate the direction for the solutions sought, i.e., A) the existing ducting (plate and stiffening) is in a reasonably sound condition and may require only partial plate replacement along with the insulation upgrade, and B) the duct shell has for the most part no or very little life left and should be replaced.

Considering the fact that the acid dew point has been lowered by virtue of a lower maximum allowed sulphur content in the fuel, the conditions for acid corrosion would have been somewhat mitigated

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already, which should reflect in lower duct maintenance in the future. However, due to the length of the service life (almost twenty years) and extended exposure to the past prevailing conditions, deterioration of the current liner may continue at the same pace or worse, if some upgrades are not implemented. The low service temperature of the adhesive membrane is likely to remain a contributing factor to the insulation block failures.

The breeching expansion joints are in a poor condition and need a major overhaul as an interim solution, but a replacement in kind should be in the planning.

A separate issue to be dealt with is the deteriorating condition of the seven metallic expansion joints—all bellows type joints—on the hot air outlet duct from the air pre-heater. These are the original components and have been in operation for almost 30 years. Although air duct expansion joints are not exposed to as harsh environment as the gas touched components, time and service demands eventually took their toll—they all appear heavily rusted and are cracking, likely due to fatigue, in the bottom sections (see Fig.'s 30-32). The joints could be repaired piecemeal as required, but as a long-term solution, it is advisable to replace them with properly engineered cloth joints. Some of the alternatives shown below have already been considered in earlier discussions with NLH.

Solution alternatives - Breeching

Note: Indicative Pricing has been provided in Appendix 2. This indicative pricing is intended to provide an indication of relative supply and erect costs for budgeting purposes, approximately ±30%, and in not intended as an offer to provide services. Should Newfoundland & Labrador Hydro wish to pursue an option, Alstom would then provide a Proposal for such scope based on conditions at that time.

The "Solution" reference for each option refers to the "Breeching Solution" as outlined in the Indicative Pricing Estimate in Appendix 2.

- A) Current ducts are in serviceable condition and remain in place:
 - Keep current duct arrangement, repair duct and lining as required (Breeching Solution A1); use cheaper insulation material to replace borosilicate blocks (e.g., Pennguard 55 vs. Pennguard 28)
 - <u>Pros</u>: no capital investment, no time lost to upgrading ducting; potential for reducing maintenance cost by changing insulation block material;
 - <u>Cons</u>: break-down of the insulation material and adhesive membrane will likely not subside, may become worse; prohibitive cost of repairs will remain; difficulties accessing the sites of corrosion damage and leaks under insulation and the outer protective coating will not change; cleaning ash and debris from the duct floor remains impaired; erosion wastage of lining may still be a problem
 - 2) Keep current duct arrangement, but add 4" of external water repellent insulation and a watertight cladding (Breeching Solution A2): repair internal lining as required, and have the overall concept materials and specs reviewed for possible improvements less expensive insulation blocks, increased concrete layer and block thickness, etc; protect external cladding

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against falling ice (catwalk grating, hood, etc., see B below) if that remains a genuine problem. The external surface should be cleaned of rust before installing the insulation..

<u>Pros</u>: the external insulation will help prevent gas cooling even if lining damaged; potential for reducing maintenance cost by changing insulation block material; corrosion of the duct shell <u>due to gas cooling</u> through contact with the duct plate will be minimized or eliminated if external insulation is maintained; degradation of borosilicate lining less critical with external insulation added

<u>Cons</u>: added cost of external insulation and cladding c/w protection against damage; breakdown of the internal insulation material and adhesive membrane will likely not subside, may become worse; the internal liner will still have to be maintained, therefore prohibitive cost of repairs will remain; continuing difficulties accessing the sites for inspection; cleaning ash and debris from the duct floor remains impaired;

3) keep current duct, add 6" of external insulation and remove internal liner blocks and silicate concrete (Breeching Solution A3); protect external cladding against falling ice (catwalk grating, hood, etc., see B) below) if that remains a problem. The external surface should be cleaned from rust before installing the insulation.

<u>Pros</u>: the upgraded external insulation will provide adequate insulation to prevent gas cooling, assuming it is kept in good serviceable condition; reduced maintenance cost by comparison to current situation – no insulation blocks to replace; corrosion <u>due to gas cooling</u> will be minimized or eliminated if external insulation is maintained; improved access for duct inspection and cleaning

<u>Cons</u>: added cost of external insulation and cladding c/w protection against damage; added cost of internal liner removal; access for duct inspection somewhat impaired if remnants of internal liner remain (e.g., adhesive membrane)

A modified Option 2 above (<u>Breeching Solution A2</u>) would be a preferred long-term solution **if the breeching is to be left in place**, i.e., the external insulation 6" thick (as opposed to 4" in Option 2) with the internal lining left alone initially and removed only if the silicate block degradation continued unabated. This way, no upgrade of external insulation (to the 6" thickness) would have been required if the internal liner were removed, as in Option 3.

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- B) Replace the entire breeching:
 - 1) original duct design, made of
 - a) (<u>Breeching Solution B1a</u>) ‡" mild carbon steel plate (G40.21 or equivalent) c/w 6" of external water repellent insulation c/w watertight high quality cladding and flashing

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- b) (<u>Breeching Solution B1b</u>) ‡" Corten or equivalent high temperature carbon steel c/w
 6" of external water repellent insulation c/w watertight high quality cladding and flashing
- c) (<u>Breeching Solution B1c</u>) 3/16" stainless steel (e.g., 304, 316L, 904L, HASTELLOY C276) c/w 4" of external water repellent insulation c/w watertight high quality cladding and flashing
- d) (<u>Breeching Solution B1d</u>) 3/16" Avesta plate (2205) plate c/w 4" of external water repellent insulation c/w watertight high quality cladding and flashing

<u>Pros</u>: a) if properly designed and maintained, the insulation offers adequate protection against gas cooling; standard ducting material used; reduced maintenance cost compared to the current breeching; reduced load on supports and ducting plate compared to inner liner; good access for duct inspection; insulation not susceptible to cracking

- b) same as a) above, but offers some protection against corrosion if gas temperature drops below acid dew point (higher chrome content min. 0.7%)
- c) and d) same as a) above, but the materials are corrosion resistant and therefore not susceptible to corrosion problems if the gas temperature is not maintained; less insulation required; less plate material used

<u>Cons</u>: a) does not address the original problem of insulation being damaged by falling ice; will suffer corrosion problems if outlet gas temperature is not maintained above acid dew point

- b) does not address the original problem of insulation being damaged by falling ice; higher material cost;
- c) and d) do not address the original problem of insulation being damaged by falling ice; high material cost; design check required due to thinner plate
- original duct design, construction alternatives as per 1), with added protection against damage caused by ice falling from stack and powerhouse, as shown below:
 - a) (<u>Protection Solution B2a</u>) light-weight (LW), 1½" catwalk grating on the top panels (over aluminium cladding) attached to stack and side panels
 - b) (<u>Protection Solution B2b</u>) U-shaped 7 ga. plate encasement slid over the top panels (possibly with ice-breaker ribs)
 - c) (<u>Protection Solution B2c</u>) 3/16" carbon steel hood over the duct, attached to the duct sidewalls
 - d) (<u>Protection Solution B2d</u>) extra heavy gage, ribbed aluminium or steel cladding on the top panels

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<u>Pros</u>: same as 1) but addresses the original problem of insulation being damaged by falling ice; less maintenance required for the external insulation if prevented from being damaged, relatively simple design needed for the protection; option d) would not require a special design for added protection

<u>Cons</u>: same as 1) except the falling ice protection; added cost of material and design of the falling ice protection, danger of creating heat sinks where protection attached to the duct

3) 1/4" Corten or equivalent hi-temp carbon steel duct, internal insulation c/w stainless steel liner (Breeching Solution 3) - similar to HRSG construction (3" cerwool or mineral wool insulation bats, 304L or 316L stainless steel 10 ga liner held in place with studs), no external insulation but protection coating

<u>Pros</u>: works well in HRSG application; less prone to external corrosion because of better plate material; insulation stays in place, traditionally low maintenance once settled

<u>Cons</u>: access for inspection restricted; installation sensitive; high installation cost, condensation may by a problem on bottom panel

Other options could include alloy or stainless steel cladding applied directly on the duct plate or a layer of polymer coating inside combined with external insulation, but these options were already explored by NLH and found expensive to apply and maintain, and were rejected.

The preferred long-term solution for **replacing the breeching** would be Breeching Solution B1b, with the Protection Solution B2b. Hi-temp carbon steels such as Corten have been used in the past for back end (breeching) ductwork, even if the gas temperature did not require it, because of their improved resistance to corrosion compared to low carbon steels. An additional 1/8" corrosion allowance could be added to extend the life of the ducting.

Solution alternatives - Hot air duct expansion joints, Unit 3

- 1) Repair or replace sections as required (Expansion It Solution 1): the bellows could be weld repaired as required, or partially replaced, specifically the bottom part of the joints. Considering the service life and the overall condition of the joints, this should be only a short-term maintenance fix. It may however prove difficult to weld-repair the joints because of the general condition of the expansion joint material.
- 2) Install cloth seal over the metallic expansion joints (Expansion It Solution 2): this interim solution would replace repairing the ailing metallic joints. It would not have any effect on the function of the current joints, but would prevent leaks. Care must be taken to evaluate correctly the movements as not the cause failure of these joints as well.

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- 3) Replace the expansion joints in kind (Expansion It Solution 3): this alternative would see the expansion joints replaced as originally designed and built. No engineering is required, but the probable shortcomings of the current design would be copied.
- 4) Replace with metallic joints, but review the selection (Expansion It Solution 4): engineering review would be required to confirm or repudiate the current selection, and possibly come up with a better system to prevent the current failures.
- 5) Replace the expansion joints with cloth joints, properly engineered (Expansion It Solution 5): cloth expansion joints are widely used and are the preferred solution in most ducting systems. They do not exert reaction forces to the system supports, and would not be subject to fatigue-induced cracking.

From engineering and operation standpoint, Option 5 is the preferred solution.

POST MEETING FOLLOW-UP

A meeting was held at Holyrood site on March 5, 2009 to review the findings of the Study as issued in Revision 1 dated March 4, 2009.

Based on discussions during the review meeting, it is recommended that replacement of the breeching is preferred over repairing the existing materials. This is supported by the fact that the current breeching is approximately 20 years old, the original breeching on Units 1 & 2 lasted approximately 20 years, and the fact that a lifespan of 20 years is quite typical for breeching.

For reference purposes, it was decided to select two options (Modified A2, and B1b) along with extended ice protection (B2b) option for more detailed installation estimate. Include repair of support structure for the repair option (Modified A2) and replacement of support structure in the replacement option (B1b).

The existing support structure on Units 1 & 2 breeching requires some repair and should be replaced if the breeching is replaced. It was determined after the meeting that the pricing for the supports is not in the current estimate. Also, fairly extensive repairs would be required to the support structure. For pricing purposes, only a replacement is to be priced.

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Table 1: J. Adams, Breeching History Summary 2000-2008

Appendix 1 – Figures & Tables

Year	Unit 1	Unit 2	Unit 3
2008	West side no scaffold - difficult to assess pantleg. However appeared to be sections where liner has failed above and adjacent to expansion joint. 40 to 50 blocks estimated but could be worse than appears. Horizontal section good – about 10 blocks replaced. East side many holes - duct patched from outside at north side of bend. Refractory in bend also failed. 230 blocks replaced in bend area. Horizontal section good. Scaffold up to expansion joint only. Above expansion joint liner is questionable condition. Could be a significant repair required. Expansion joints have failed both sides.	The refractory floor on both sides now in poor condition and requires replacement. West side approx 15 blocks replaced. No scaffold installed. Three other locations about 4 blocks each looked loose but not replaced due to condensation/sweat problem. East side one 9 block section was replaced. Block also wet and apparently soft overhead and up the pantleg in sections. Expansion joint in poor condition on both sides.	Test patches of Pennguard 55 block and refractory both in good condition after one year. About 40 blocks replaced – scaffold was erected. Debris noted in expansion joint should be cleaned out. Looked OK from external inspection.
2007	Minor repairs only – about 40 blocks total. Cost about \$5k	East floor in poor condition – not replaced. About 90 blocks on each side replaced – all in horizontal section – no scaffold required. 3 holes patched in west side. Total cost about \$16k.	Blocks replaced overhead and at both side corners – about 200 sqft. 15 holes patched (welded inside – Devcon outside). Trial patch of Pennguard 55 and Smoothkote refractory installed. Total cost about \$25k
2006	C&E Refractories poured new floor east side and block both sides. Total about 760 sqft. 5 holes in west and 12 in east side patched from inside and sealed with Devcon outside. Expansion joint cover plates bad. Total cost about \$320k	East floor in poor condition – not replaced. Block good both sides.	About 40 blocks to replace overhead but not done – no scaffold. 15 blocks that were accessible were replaced. No cost captured.
2005	East floor bad. Block to replace overhead and north on east side not done. West small quantity of block replaced but more to do with scaffold. Cost about \$2k captured.	Mount Pearl Painting hired to replace refractory on west floor and block on both sides. Many holes found on both sides and repaired from outside. Total cost about \$290k.	Hole found in top near stack. Patched from outside. No scaffold installed – accessible block replaced as required. About 50 blocks replaced and 15 not accessible. Total about \$5k.
2004	East floor bad – not replaced. East side scaffolded and block replaced. Hole in expansion joint patched. Cover plates bad. West side small quantity of block replaced – no scaffold. Cost about 515k	Just a couple of blocks replaced	Block replaced overhead and at corners (higher than 2003). No holes found. Scaffold erected. Total cost about \$10k.
2003	East floor starting to fail. Few blocks to replace. Supposedly repaired by another contractor working on the stack	Approximately 350 sqft of block replaced mostly on east side. Scaffold erected. Through holes patched. Done by C&E Refractories. Cost about \$90k.	Holes found on both sides. Scaffold erected and holes repaired. Block replaced as required. Costs not captured.
2002	Damage repaired by C&E Refractories. This included replacement of the west floor refractory. Don't know cost.	No significant work	Very small quantity of block replaced with no scaffold. Scaffold recommended to replace block next year.
2001	No significant work	No significant work	No work done. Minor repairs recommended.
2000	Significant work done to replace block. 540 hours reported – estimated around \$35k	C&E Refractory replaced about 750 sqft of block. Don't know cost.	Minor repair to borosilicate block liner

Table 1: J. Adams, Breeching History Summary 2000-2008



Fig. 1: Original Breeching, floor in horizontal section - Unit 1 or 2



Fig. 2: Original Breeching, pantleg inlet - Unit 1 or 2



Fig. 3: Original Breeching, sloping section - Unit 1 or 2



Fig. 4: Original Breeching, bend section - Unit 1 or 2



Fig. 5: Original Breeching, entrance to horizontal section (at heater) - Unit 1 or 2



Fig. 6: Original Breeching, top view – Unit 1

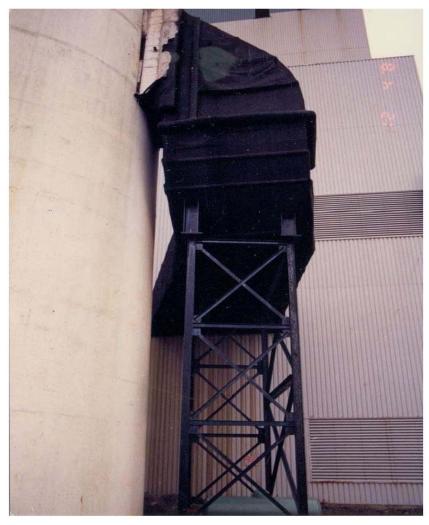


Fig. 7: Original Breeching, elevation view - Unit 1



Fig. 8: Unit 1 - Insulating block replacement



Fig. 9: Unit 1 - Duct corroded through



Fig. 10: Unit 1 - Sloped section as found



Fig. 11: Unit 1 - Sidewall and floor



Fig. 12: Unit 1 – Replaced blocks



Fig. 13: Unit 1 – Missing block overhead



Fig.14: Unit 1 – Ash accumulated on the floor



Fig. 15: Unit 1 - Damaged expansion joint



Fig. 16: Unit 1 - External duct repairs



Fig. 17: Unit 1 - External duct repairs



Fig. 18: Unit 2 - Missing insulation blocks



Fig. 19: Unit 2 - Missing insulation blocks



Fig. 20: Unit 2 - Cracked cement floor



Fig. 21: Unit 2 - Cracked cement floor



Fig. 22: Unit 2 – External coating break down



Fig. 23: Unit 3 - Repairs 2007



Fig. 24: Unit 3 – Crotch repairs



Fig. 25: Unit 3 – Patched casing (from inside)



Fig. 26: Unit 3 - Top near the stack

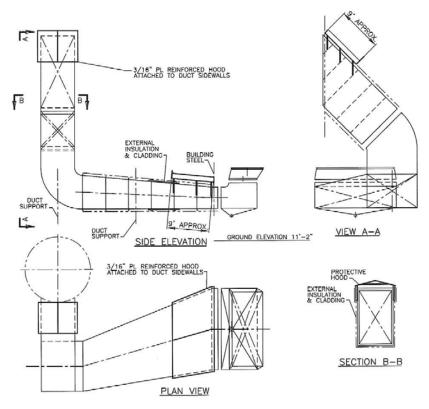


Fig. 27: Proposed cladding protection – protective hood

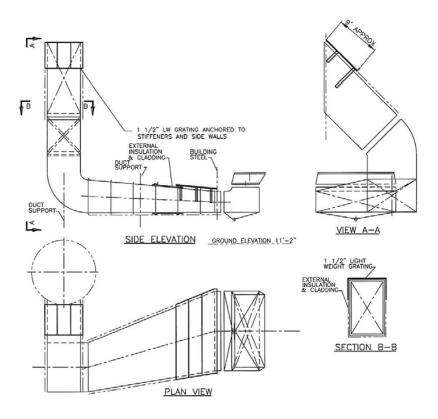


Fig. 28: Proposed cladding protection – catwalk grating

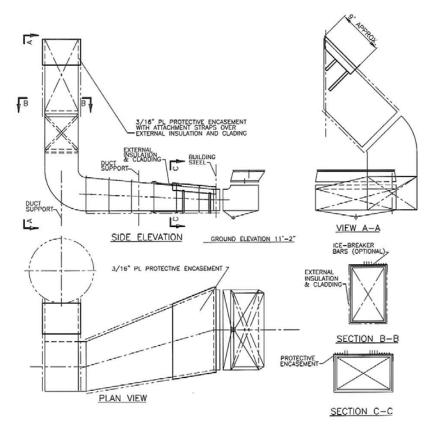


Fig. 29: Proposed cladding protection – 7ga. plate encasement



Fig. 30: Unit 3 – Expansion joint, hot air duct from air heater



Fig. 31: Unit 3 – Expansion joint, hot air duct from air heater



Fig. 32: Unit 3 - Expansion joint #4, hot air duct from air heater

Appendix 2 - Indicative Pricing

ALSTOM POW	rer Service INI	DICATIVE PRICING ESTIMATE	
CONTRACT #	40833010	ESTIMATE TYPE:	INDICATIVE
CUSTOMER:	NLH	PROJECT TYPE:	SUPPLY & ERECT
SITE:	Holyrood, NF	DATE:	19-Aug-2009
PROP. DWG:			
SCOPE:	Air Heater to Stack Breeching Study		

Breeching Solution Alternatives For U1, U2 & U3	S&E (Indicative Prices)	
Breeching Solution A2 - Repair Insul. Blocks and Casing As Reg'd. Add 4" New External Insulation U1,U2 & U3 - Based on repairing 1610 ft? of blocks. - Casing and expansion joints repairs are not included due to unknown condition. These repairs can be done during annual maintenance. - To be done at the same time as annual maintenance.	\$1,504,806	
Breeching Solution B1b - New 1/4" Corten Breeching with New Exp Jts and New 6" External Insulation U1, U2 & U3 - Corten Skin, mild steel stiffeners, primed - 6" mineral Fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding. - Scaffolding Included	\$7,678,456	

Ice Protection Solution Alternatives For U1 & U2	S&E (Indicative Prices)	
Protection Solution B2b - U-shaped 7 ga Plate Encasement Slide Over Top Panels, U1 & U2 Only:		
- Primed and top coat	\$214,252	
- C.S. material		

Breeching Support Structure Replacement For U1 & U2	S&E (Indicative Prices)	
Replace Breeching Support Structure for U1 & U2 Only:		
- SP-6 blast c/w primer and top coat		
- End frames are assembled as a unit		
- Welding CWB 47.1	\$153,661	
- Material G40.21 44W		
- To be installed at the same time with B1b breeching solution only. Additional cost is required with		
A2 breeching solution since the existing breeching is not removed.		

Notes:

- (1) Construction estimate on ice protection and expansion joint is based on being on site in conjunction with the maintenance work.
- (2) For Unit #3 (B&W), we have no drawings. For future firm price proposal, we are expecting NLH to provide the necessary drawings of the existing ducting for us to work from.
- (3) For Solution A2 Casing repair because the condition is not known, it should be done during annual maintenance.
- (4) This budget proposal gives a preliminary indication of the basis of which [services/deliveries] can be undertaken, and does not constitute an offer to carry out those [deliveries/services]. In particular, any prices, delivery times or performance figures mentioned are given without commitment at this stage. Nevertheless we trust the information provided is sufficiently detailed to enable you to assess the benefits which you can obtain by utilising our Company's services /deliveries, and we confirm our keen interest in working with you. To this end we look forward to discussing with you the content of this proposal and, when appropriate, submitting an offer to you.
- (5) Breeching support replacement pricing is applicable only with B1b breeching solution. Additional cost is required with A2 breeching solution since the existing breeching is not removed.

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Final Report

to

Newfoundland & Labrador Hydro

of an

Engineering Study

on

Condition Assessment of Stack Breeching at Holyrood G.S. Units #1, 2, & 3

Prepared by

Alstom Canada Inc. Ottawa, ON

Reference # 40833010

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This report was prepared by Pavel Kratina, P. Eng. and was reviewed by John McMillan, P.Eng. Revisions 1 & 2 were edited by Jim Kearns, P. Eng.



EXECUTIVE SUMMARY

Environmental and operational conditions in Holyrood G.S. have precipitated severe corrosion of the original, externally insulated breeching that has necessitated intensive and costly maintenance. Initially, the corrosion of the ductwork was more prevalent in Units 1 and 2, since Unit 3 was built ten years later. In replacing the breeching at the time of the 1989 boiler upgrades, Newfoundland & Labrador Hydro has turned to an alternative design featuring internal borosilicate lining along with an outside protective coating, which carried a promise of low maintenance cost.

Although the changeover to internal insulation partially solved the corrosion predicament, it has created a worse problem of having to repair and replace the broken and dislodged glass insulation blocks; during winter operation, gas cooling below the dew point may be occurring at those locations causing corrosion of the duct shell. The cost of maintaining the internal liner in a serviceable condition is becoming prohibitive, and it seems to be far offsetting the benefits of eliminating the icefall damage of the breeching exterior. Less expensive and more reliable materials could probably replace the current insulating blocks and refractory, but the underlying concern – no access for inspection of the duct plate and potential for localized corrosion - would remain.

A more serious root cause of the internal corrosion may have been the operating conditions of the units that prevailed until the recent change to a more sulphur "friendly" fuel (1% max. limit). At the full-load operation and with no controls employed, the outlet gas temperatures would come very close to the sulphuric acid dew point of fuels containing 2.5% or more sulphur, and the situation would become worse at low-load operation. The steam coils, used to control the average cold end temperature (ACET) of the pre-heaters, did not have adequate capacity for winter operation until the boiler uprates in 1998 when they were upgraded.

It is conceivable that the initial corrosion and maintenance problems would not have been so severe under the current operating conditions, i.e., lower sulphur content and improved outlet gas temperature control, providing the external insulation was protected from the elements and well maintained.

A number of options are provided with varying capital costs and associated anticipated maintenance requirements as shown in the "SUMMARY AND RECOMMENDATIONS" section. Also included is an overview of the condition of the Unit 3 expansion joints and suggested options to deal with the problems.

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INTRODUCTION AND PROBLEM DEFINITION

Units 1 and 2 at the Newfoundland and Labrador Hydro (NLH) Holyrood G.S. are pressurized units of Alstom (formerly CE) design from 1968; Unit 3 is a B&W boiler, constructed in 1979. Units 1 and 2 were up-rated from 150 to 175 MW in 1989, and part of the upgrade was a replacement of the breeching section between the air pre-heater and the stack.

The original breeching was a typical back end duct design constructed of 1/4" carbon steel and insulated externally. From the information available it appears that the cladding was continually damaged by ice falling from the powerhouse and stacks, allowing moisture to penetrate in insulation, which led to insulation break down and severe corrosion of the carbon steel ducting. The cost of repairing/replacing the corroded duct sections was deemed to be too high and a decision was made by the plant management to replace the breeching.

A NLH internal study opted for a design that provided for internal insulation of borosilicate blocks and a protective coating on the breeching exterior. The promise of the new system was a much-reduced maintenance cost by comparison to the original ducting. Replacement of the breeching of the two Alstom units was completed in late 1990. Since there is no specific information available one can only speculate that it was done at the same time as Units 1 and 2.

Early into the operation (1991), the new ducts developed problems such as erosion wastage and cracking of the insulation and the concrete layer. Later, problems with the liner began to mount – the insulation blocks would break and fall out allowing the gas to penetrate to the duct plate, cool and cause localized corrosion of the duct plate. As the records show, the internal liner requires frequent repairs, and the cost of keeping the insulation blocks in good order has proven to be considerably higher then anticipated. One of the reasons for the internal liner degrading may be the specified service temperature limit of the adhesive membrane of about 200°F that is easily exceeded if in contact with the flue gas (through cracks initially), which in turn may explain dislodged silicate blocks.

To make the situation worse, the exact sites of the corrosion damage are difficult to find under the insulation layers and the protective coating outside until the plate is corroded through. Cleaning the duct floors has become difficult with the floor concrete layer broken or otherwise damaged.

Alstom was commissioned to evaluate the current situation, reflect on the latest practices in the industry, and propose alternatives to minimize the breeching corrosion problems and high maintenance cost.

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CONDITIONS LEADING TO DUCT REPLACEMENT

The decision to replace the breeching was made in 1987-88, and concerned mainly units 1 and 2. The move was driven by corrosion related maintenance problems and associated maintenance cost. Unit 3 ducting, which is of a different layout, was eventually replaced as well although it was only 10 years old at the time and presumably had not experienced the same degree of deterioration. The underlining problem seemed to have been a severe corrosion condition created by formation of acidic condensate due to flue gas temperatures dropping below the acid dew point. The sub-cooled gas temperatures may have been a result of boiler operation and/or a contact with poorly insulated ducting.

It appears the condition of the external insulation contributed significantly or may have even been instrumental to the ductwork deterioration. As it happened, insulating materials on the two older units were not identical: Unit 1 was insulated with 2-1/2" of calcium silicate rigid insulation with a 1/8" flintcote 110-26 mastic applied over the blocks and reinforced with fibreglass mesh set in the mastic; Unit 2 was covered with soft bat exterior insulation and protective cladding. It is not known if there were differences in the degree of deterioration and maintenance between the two ducts.

Based on the information available (plant personnel recollection and a 1990 technical paper presented at CEA workshop), the problems with the original breeching stemmed from damaged external insulation leading to a severe corrosion of the duct plate. Moisture would penetrate into the insulation through damaged outer protection (mastic or cladding) – presumably damaged by ice falling from the stack and powerhouse (Fig. 6-7), rending the insulation ineffective. In addition, the wet insulation on sidewalls likely sagged, creating pockets of no or very little insulating material. It is believed that the degraded condition of the insulation caused considerable corrosion of ducting from outside. To further exacerbate the situation, a lack of insulating allowed the gas in contact with the duct plate to cool below the acid dew point causing in turn widespread internal corrosion (Fig's 1-5). Deterioration of expansion joints was an added irritant, which needed to be addressed.

In 1987 the condition of breeching was such that replacement was deemed necessary. An in-house study produced four replacement alternatives:

- 1) Modified existing design (modifications referred to expansion joints)
- 2) Borosilicate lining inside and corrosion resistant coating on the exterior
- Sheets of corrosion resistant alloy material welded to the carbon steel ducting plate c/w external insulation
- 4) Liquid fluorocarbon coating inside and insulation outside.

Based on cost analysis, the plant management favoured to second option mainly because of the promise of dependable service and low maintenance cost. The breeching ducting was replaced in 1989-1990 with ducts insulated inside with borosilicate (glass) insulation blocks and additional layer of silicate concrete on the floor. The new breeching went into operation at the end of 1990.

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CONDITION ASSESSMENT OF CURRENT BREECHING

Shortly after start up, the new breeching developed erosion and cracking problems requiring costly repairs, which later escalated as the concrete floors began breaking up and the insulation blocks falling out. Following is an overview of the problem history of the current breeching, based on information made available (see also Fig's 8-26):

Past history of problems

Inspection of breeching in 1991- brief summary:

(Ref.: Internal inspection report, Wayne Rice, Nov. 1991)

- Installation of the new breeching in Unit 1 was completed in the fall of 1990
- The unit operated from Dec 1990 to April 1991; subsequent inspection of the ducting uncovered erosion wastage of the lining in the upper half of the elbow – the material loss amounted to 1/4" to 1/2" over a 4-month period
- Test blocks were selected to monitor the erosion rate; second measurement in October 1991 showed loss of another 1/16" to 3/16"
- The problem was linked to the fans capacity increase required for the boiler uprate, delivering higher air volume, which in turn increased the gas velocities to 50 fps from the previous 43 fps.
 For comparison, the supplier (Autochem) affirmed the material suitability for up to 120 fps flow
- Unit 2 was first inspected in the fall of 1990 and no erosion was found. The unit operated
 erosion free for one year with the original impeller until the fan was upgraded during the 1991
 outage (possibly April or May). An inspection in October 1991 uncovered similar lining loss as in
 Unit 1
- Erosion affected approximately 3% off the total surface area of each duct in question
- Repair cost for both units was quoted at \$55,000 by a contractor on site
- Some cracks in the lining were found and repaired
- External protective coating started to show signs of rust discoloration

Operating period 1992-2000

No inspection and maintenance records available for review

Summary of breeching repair work 2000-2008:

(Ref.: Breeching history summary, J. Adams, Alstom)

Unit 1:

After eleven years in operation, extensive repairs to the insulation blocks were required. There was no significant work done in 2001, but repairs were required in the following years. In 2006, a new floor was poured by C&E Refractories. Another major insulation block replacement was carried out in 2008.

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Unit 2:

In 2000, approximately 750 ${\rm ft}^2$ of insulation was replaced. Some insulation block replacement was done in the years 2003-2005. The floor has deteriorated significantly, but to date no major work was done to correct the situation.

Unit 3:

Very little repair work was carried out until 2002. After that, insulation blocks were replaced and holes patched as required. In 2007 a new material was used for replacements, Pennguard 55 (as opposed to Pennguard 28), on trial basis. Inspection in 2008 found the Pennguard blocks in very good condition.

Current breeching condition - inspection summary

(Ref.: 2008 Inspection Report, J. Adams, Alstom Canada)

Unit 1:

West breeching

A large quantity of ash was found on top of the duct floor, but the refractory was intact. The horizontal section appeared to be in good condition - there were no holes found and no evidence of leaks. The sidewall insulation blocks were in excellent to good condition. The ceiling was good overall, but there were a few small isolated sections requiring repair - about 10 blocks were replaced. All bracing was found in good condition.

The pantleg (inclined) section had a few blocks fallen off from the overhead panel between the expansion (EJ) joint and the stack, and up to 6-10 blocks near the EJ were damaged or fallen out. A few blocks were loose and others in questionable condition on the sidewalls. The refractory at the upward bend was in acceptable condition.

East breeching

Ash has accumulated on the floor, but the refractory appeared in good condition. No major damage was found in the horizontal section, only a few isolated small sections overhead were slightly damaged needing repair. Above the up-bend, about 60 blocks had fallen off exposing the mesh. Ash and debris has accumulated between the refractory and the casing. Initially two through holes were spotted, but 12 holes were found when the loose blocks were removed and the casing cleaned.

The expansion joint has deteriorated considerably: cover plates were hanging loose, mostly separated from the sides. Behind the cover plates, the inner layers of the fabric element (insulation layers) and the inside of what appeared to be the outer belt could be seen.

The condition of the liner above the expansion joint was difficult to ascertain because no scaffolding was erected for access. However, there appeared to be loose blocks overhead and on the sides that should be replaced. This could amount to a significant repair work. Loose blocks in area of EJ were replaced, holes in breeching were patched from outside and rods were welded to the inside of the duct shell to secure the mesh for refractory, and the EJ cover plates were repaired.

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A hole was found in the bottom corner of the expansion joint and repaired. The ladder inside the breeching is severely corroded and should be removed completely. A total of about 230 blocks were installed in the east breeching.

External breeching inspection

A great degree deterioration of the expansion joints is obvious – failed corners, evidence of leaks. A more detailed inspection is needed, but that would require removal of the cover plates. Corrosion was visible under the coating.

Unit 2:

West breeching

There were a number of blocks to be replaced on the south and north walls under the air heater. The breeching floor was cracked near the hopper and lifting up. It is quite thin – only about 11" to 2". This floor was done in 2005, and may have to be replaced again in the near future.

Overall, the internal lining was in acceptable condition. There were isolated small areas requiring attention. The pantleg area appeared to be in good condition except for a section of relatively new blocks on the north wall that seemed to be separating from the duct. There was no access for a closer look – scaffolding was not erected. Very little ash was found on the duct floor. One brace in the horizontal section had separated from the duct on the bottom.

Approximately 15 blocks were replaced. Three other small locations with loose blocks were identified but could not be stripped due to the slime deposit on all surfaces (condensation). Two of these were in the horizontal section while the other was in the pantleg. Without scaffold it was difficult to better assess the pantleg condition. However, each location appeared to require between 4 and 6 block replacements.

East breeching

The floor was in poor condition, but the rest of the block liner was sound with only a 9-block section replaced. However, the blocks appeared wet and soft overhead at the beginning of the up-bend. No leaks were found.

External breeching inspection

On the east side, the expansion joint had a leak at the bottom flange. The cover plate does not cover the entire flange to provide adequate protection from the environment. Also there are many locations on top of the cover where water is allowed to pool. The fabric element behind the cover plate appeared to be intact, but it would be necessary to remove the cover plate for a proper assessment.

On the west side, the protective coating broke down in small, localized areas and at a brace attachment showing corrosion. The expansion joint element has failed along the top, and a leak was found in the flange at the bottom. Again, water was pooling on top of the cover plate. Relatively minor rust

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discoloration was noted on the coating of the horizontal section. Also, a patch on top of the flue, welded from the inside, had not been sealed from outside.

Unit 3:

Internal breeching

Test patches of Pennguard 55 insulation material, installed in 2007, do not exhibit any deterioration or damage. Another new material, Smoothkote refractory, may also be a viable option, as the test patch remained in good condition after one year of operation. The Pennguard 55 block differs very little from the normally used Pennguard 28, and is about 30% cheaper. However, the currently used material may have been in equally good condition after one year of operation, and more time is required to draw a conclusion regarding possible use in the future.

Overall, the block liner is in acceptable condition. The blocks, replaced previous year, show no appreciable damage. However, there were new sites identified where the lining has degraded: the inspection identified about 40 silicate blocks requiring replacement.

It was noted that ash has accumulated in the expansion joint near the stack and this was causing the cover plates to be pushed outward. It was recommended that the plates be removed temporarily to allow the ash to be removed. Not much ash was found in the breeching.

External breeching inspection

The breeching appears in good condition from the outside. There were no indications of leaks in the corner areas or on top where they have been found in recent years. On the west side, a hole could be seen that had been patched from the inside, but not sealed from the outside, which allows moisture to pool inside the cavity and cause external corrosion. Also, the top of the breeching near the stack should be re-painted. The crotch area looked good.



UNIT OPERATION CONSIDERATIONS

Operation of the boiler and back end equipment is believed to have contributed significantly to creating conditions leading to deterioration of the original breeching as well as of the breeching installed as part of units 1 and 2 upgrade. The back end system, as designed, relies on steam coil air heaters (SCAH) to control the gas temperature leaving the Ljungstrom air pre-heater. The general recommendation is that the flue gas temperature be at least 28°C (50°F) above the sulphuric acid dew point of a fuel.

Although the target sulphur content in the fuel has always been 2.2% according to Alstom personnel on site, the Holyrood records typically refer to 2.5% sulphur content (an analysis of a 1987 bunker C oil sample showed as much as 2.8% sulphur content) for which the acid dew point was calculated to be 148°C (298°F), commanding a "safe" temperature of the gas of at least 177°C (350°F). Fluctuations in sulphur content is echoed in the increase or decrease of the safe temperatures needed to avoid acid formation in the duct. The current limit on sulphur content in the fuel stands at 1%, which corresponds to 138°C (280°F) and 166°C (330°F) dew point and safe outlet gas temperatures respectively.

Without SCAH intervention, the acid dew point of the flue gas would come close to the gas design outlet temperature of approximately 150°C (302°F) for the original MCR (150 MW) and approximately 155°C (311°F) for the uprated load condition (175 MW). The temperature would drop below the dew point at low loads in off peak operating periods, possibly falling to 115-120°C. The boilers seldom operate at full load; typical loads may vary between 70 and 140 MW, but could operate as low as 50 MW (30% MCR), which means that gas temperatures would be below the dew point for a large portion of the unit operating time. As an example, in 2007 the averaged output of Unit 1 was 70 MW (40 %MCR), Unit 2 put out 110 MW (63 %MCR) and Unit 3 put out 89 MW (69 %MCR).

The steam coils have always been used in Holyrood striving to keep the average cold end temperature (ACET) of the air pre-heater at a target temperature of approximately 107°C (235°F) with a corresponding gas outlet temperature of 164°C (327°F). This would not have been a safe gas temperature for the pre-2006 fuel (needed 177°C), but would be acceptable for the new fuel composition criterion. By comparison, the target ACET for 1.0% sulphur oil is 105°C (221°F).

It was recognized in the early years of the units' operating life that the SCAH's did not have adequate capacity to support the air pre-heater requirements in winter operation with the cold air drawn from the outside, which in turn caused the outlet gas temperatures be much lower than the design. The remedy was to draw the combustion air from inside the powerhouse at the expense of creating another set of problems – because of the considerable vacuum created by the fan intake, air from outside the building would enter from all available openings and cause frequent freeze-ups throughout the plant, and opening of doors was difficult causing the doors slam shut endangering the plant personnel (Re: 1990 CEA paper). The SCAH's have been upgraded following the uprate in 1989 - a second bank was added effectively doubling their capacity. Also, a "warm air make-up system" has since been added that helps feed the combustion air into the plant in a controlled fashion that helps to avoid the freeze-up problems.

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SUMMARY AND RECOMMENDATIONS

In the utility boiler industry, it is a recognized fact that breeching ducting has a limited life and may need replacement periodically, either completely or partially. Although a twenty-year life span of ducting is not unusual, controlling or preventing the adverse conditions leading to early deterioration, both inside and outside, can extend it.

Most breeching systems employed by the utilities surveyed are of carbon steel plate construction with adequate external insulation, and only in extreme cases or in some old utilities internal insulation liners are employed. Externally insulated ducts are generally much easier to inspect, maintain and clean. Alstom does have a standard design for internal lining, typically consisting of 4" calcium silicate blocks with expanded metal mesh and 3/4" layer of Super 3000 (Alstom hi-temp refractory) on top, but the design is rarely used being maintenance intensive. Internal insulation or corrosion resistant steel liners are used in pulp and paper industry and by HRSG's. From the operation perspective, there is no advantage to insulating ducts inside rather then externally.

The chronic corrosion of the original breeching in Holyrood appears to have been rooted in deteriorated external insulation, and in operating conditions, such as low-load operation, that drove the gas outlet temperatures below the sulphuric acid dew point.

The new breeching, fitted with internal borosilicate lining, was expected to alleviate both the corrosion problems and the high maintenance cost, but failed to do either. Not only did the internal and external corrosion problems continue, although at a reduced rate, but the corroded sites became difficult to inspect and access for repairs, and the bulk of the maintenance has shifted to replacing and repairing the internal liner blocks. The projected annual maintenance cost burgeoned from the expected \$8K per duct (extracted from the 1988 internal cost analysis) to a sizable multiple of that at times (e.g., in 2003, replacement of 350 sq.ft. of the silicate block liner in Unit 2 cost \$90K). For comparison, the projected cost of maintaining a breeching as per the original design was \$21K per year per duct.

To have a real chance of succeeding in minimizing the corrosion problem, any solution alternative selected has to embrace continuous gas temperature control at all loads. That means the ACET should be subordinate to maintaining the gas outlet temperature at 166°C (330°F) or higher at all times to avoid formation of sulphuric acid, assuming the upper limit of sulphur in the fuel (1%) is adhered to. External corrosion problems have to be addressed in parallel with controlling the internal conditions.

Considering the fact that the acid dew point has been lowered by virtue of a lower maximum allowed sulphur content in the fuel, the conditions for acid corrosion would have been somewhat mitigated already, which should reflect in lower duct maintenance in the future. However, due to the length of the service life (almost twenty years) and extended exposure to the past prevailing conditions, deterioration of the current liner may continue at the same pace or worse, if some upgrades are not implemented. The low service temperature of the adhesive membrane is likely to remain a contributing factor to the insulation block failures.

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The breeching expansion joints are in a poor condition and need a major overhaul as an interim solution, but a replacement in kind should be in the planning.

A separate issue to be dealt with is the deteriorating condition of the seven metallic expansion joints – all bellows type joints – on the hot air outlet duct from the air pre-heater. These are the original components and have been in operation for almost 30 years. Although air duct expansion joints are not exposed to as harsh environment as the gas touched components, time and service demands eventually took their toll - they all appear heavily rusted and are cracking, likely due to fatigue, in the bottom sections (see Fig.'s 30-32). The joints could be repaired piecemeal as required, but as a long-term solution, it is advisable to replace them with properly engineered cloth joints. Some of the alternatives shown below have already been considered in earlier discussions with NLH.

Solution alternatives - Breeching

Note: Indicative Pricing has been provided in Appendix 2. This indicative pricing is intended to provide an indication of relative supply and erect costs for budgeting purposes, approximately ±30%, and in not intended as an offer to provide services. Should Newfoundland & Labrador Hydro wish to pursue an option, Alstom would then provide a Proposal for such scope based on conditions at that time.

The "Solution" reference for each option refers to the "Breeching Solution" as outlined in the Indicative Pricing Estimate in Appendix 2.

- A) Current ducts are in serviceable condition and remain in place:
 - Keep current duct arrangement, repair duct and lining as required (Breeching Solution A1); use cheaper insulation material to replace borosilicate blocks (e.g., Pennguard 55 vs. Pennguard 28)

<u>Pros</u>: no capital investment, no time lost to upgrading ducting; potential for reducing maintenance cost by changing insulation block material;

<u>Cons</u>: break-down of the insulation material and adhesive membrane will likely not subside, may become worse; prohibitive cost of repairs will remain; difficulties accessing the sites of corrosion damage and leaks under insulation and the outer protective coating will not change; cleaning ash and debris from the duct floor remains impaired; erosion wastage of lining may still be a problem

2) Keep current duct arrangement, but add 4" of external water repellent insulation and a watertight cladding (Breeching Solution A2): repair internal lining as required, and have the overall concept - materials and specs - reviewed for possible improvements - less expensive insulation blocks, increased concrete layer and block thickness, etc; protect external cladding against falling ice (catwalk grating, hood, etc., see B below) if that remains a genuine problem. The external surface should be cleaned of rust before installing the insulation..

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<u>Pros</u>: the external insulation will help prevent gas cooling even if lining damaged; potential for reducing maintenance cost by changing insulation block material; corrosion of the duct shell <u>due to gas cooling</u> through contact with the duct plate will be minimized or eliminated if

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external insulation is maintained; degradation of borosilicate lining less critical with external insulation added

<u>Cons</u>: added cost of external insulation and cladding c/w protection against damage; breakdown of the internal insulation material and adhesive membrane will likely not subside, may become worse; the internal liner will still have to be maintained, therefore prohibitive cost of repairs will remain; continuing difficulties accessing the sites for inspection; cleaning ash and debris from the duct floor remains impaired;

3) keep current duct, add 6" of external insulation and remove internal liner blocks and silicate concrete (Breeching Solution A3); protect external cladding against falling ice (catwalk grating, hood, etc., see B) below) if that remains a problem. The external surface should be cleaned from rust before installing the insulation.

<u>Pros</u>: the upgraded external insulation will provide adequate insulation to prevent gas cooling, assuming it is kept in good serviceable condition; reduced maintenance cost by comparison to current situation – no insulation blocks to replace; corrosion <u>due to gas cooling</u> will be minimized or eliminated if external insulation is maintained; improved access for duct inspection and cleaning

<u>Cons</u>: added cost of external insulation and cladding c/w protection against damage; added cost of internal liner removal; access for duct inspection somewhat impaired if remnants of internal liner remain (e.g., adhesive membrane)

A modified Option 2 above (<u>Breeching Solution A2</u>) would be a preferred long-term solution **if the breeching is to be left in place**, i.e., the external insulation 6" thick (as opposed to 4" in Option 2) with the internal lining left alone initially and removed only if the silicate block degradation continued unabated. This way, no upgrade of external insulation (to the 6" thickness) would have been required if the internal liner were removed, as in Option 3.

B) Replace the entire breeching:

- 1) original duct design, made of
 - a) (<u>Breeching Solution B1a</u>) ‡" mild carbon steel plate (G40.21 or equivalent) c/w 6" of external water repellent insulation c/w watertight high quality cladding and flashing
 - b) (<u>Breeching Solution B1b</u>) ‡" Corten or equivalent high temperature carbon steel c/w
 6" of external water repellent insulation c/w watertight high quality cladding and flashing
 - c) (<u>Breeching Solution B1c</u>) 3/16" stainless steel (e.g., 304, 316L, 904L, HASTELLOY C276) c/w 4" of external water repellent insulation c/w watertight high quality cladding and flashing

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 d) (<u>Breeching Solution B1d</u>) - 3/16" Avesta plate (2205) plate c/w 4" of external water repellent insulation c/w watertight high quality cladding and flashing

<u>Pros</u>: a) if properly designed and maintained, the insulation offers adequate protection against gas cooling; standard ducting material used; reduced maintenance cost compared to the current breeching; reduced load on supports and ducting plate compared to inner liner; good access for duct inspection; insulation not susceptible to cracking

b) same as a) above, but offers some protection against corrosion if gas temperature drops below acid dew point (higher chrome content – min. 0.7%)

c) and d) same as a) above, but the materials are corrosion resistant and therefore not susceptible to corrosion problems if the gas temperature is not maintained; less insulation required; less plate material used

<u>Cons</u>: a) does not address the original problem of insulation being damaged by falling ice; will suffer corrosion problems if outlet gas temperature is not maintained above acid dew point

b) does not address the original problem of insulation being damaged by falling ice; higher material cost;

c) and d) do not address the original problem of insulation being damaged by falling ice; high material cost; design check required due to thinner plate

- original duct design, construction alternatives as per 1), with added protection against damage caused by ice falling from stack and powerhouse, as shown below:
 - a) (<u>Protection Solution B2a</u>) light-weight (LW), 1‡" catwalk grating on the top panels (over aluminium cladding) attached to stack and side panels
 - (<u>Protection Solution B2b</u>) U-shaped 7 ga. plate encasement slid over the top panels (possibly with ice-breaker ribs)
 - c) (<u>Protection Solution B2c</u>) 3/16" carbon steel hood over the duct, attached to the duct sidewalls
 - d) (<u>Protection Solution B2d</u>) extra heavy gage, ribbed aluminium or steel cladding on the top panels

<u>Pros</u>: same as 1) but addresses the original problem of insulation being damaged by falling ice; less maintenance required for the external insulation if prevented from being damaged, relatively simple design needed for the protection; option d) would not require a special design for added protection

<u>Cons</u>: same as 1) except the falling ice protection; added cost of material and design of the falling ice protection, danger of creating heat sinks where protection attached to the duct

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3) 1/4" Corten or equivalent hi-temp carbon steel duct, internal insulation c/w stainless steel liner (Breeching Solution 3) - similar to HRSG construction (3" cerwool or mineral wool insulation bats, 304L or 316L stainless steel 10 ga liner held in place with studs), no external insulation but protection coating

<u>Pros</u>: works well in HRSG application; less prone to external corrosion because of better plate material; insulation stays in place, traditionally low maintenance once settled

<u>Cons</u>: access for inspection restricted; installation sensitive; high installation cost, condensation may by a problem on bottom panel

Other options could include alloy or stainless steel cladding applied directly on the duct plate or a layer of polymer coating inside combined with external insulation, but these options were already explored by NLH and found expensive to apply and maintain, and were rejected.

The preferred long-term solution for **replacing the breeching** would be Breeching Solution B1b, with the Protection Solution B2b. Hi-temp carbon steels such as Corten have been used in the past for back end (breeching) ductwork, even if the gas temperature did not require it, because of their improved resistance to corrosion compared to low carbon steels. An additional 1/8" corrosion allowance could be added to extend the life of the ducting.

Solution alternatives - Hot air duct expansion joints, Unit 3

- 1) Repair or replace sections as required (Expansion It Solution 1): the bellows could be weld repaired as required, or partially replaced, specifically the bottom part of the joints. Considering the service life and the overall condition of the joints, this should be only a short-term maintenance fix. It may however prove difficult to weld-repair the joints because of the general condition of the expansion joint material.
- 2) Install cloth seal over the metallic expansion joints (Expansion It Solution 2): this interim solution would replace repairing the ailing metallic joints. It would not have any effect on the function of the current joints, but would prevent leaks. Care must be taken to evaluate correctly the movements as not the cause failure of these joints as well.
- 3) Replace the expansion joints in kind (Expansion It Solution 3): this alternative would see the expansion joints replaced as originally designed and built. No engineering is required, but the probable shortcomings of the current design would be copied.
- 4) Replace with metallic joints, but review the selection (Expansion It Solution 4): engineering review would be required to confirm or repudiate the current selection, and possibly come up with a better system to prevent the current failures.

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N&L Hydro – Holyrood G.S. Stack Breeching Assessment 40833010 December 18, 2008 Rev. 1 – March 4, 2009 Rev. 2 – August 28, 2009 Rev. 3 –March 25, 2010



5) Replace the expansion joints with cloth joints, properly engineered (Expansion It Solution 5): cloth expansion joints are widely used and are the preferred solution in most ducting systems. They do not exert reaction forces to the system supports, and would not be subject to fatigue-induced cracking.

From engineering and operation standpoint, Option 5 is the preferred solution.

POST MEETING FOLLOW-UP

A meeting was held at Holyrood site on March 5, 2009 to review the findings of the Study as issued in Revision 1 dated March 4, 2009.

Based on discussions during the review meeting, it is recommended that replacement of the breeching is preferred over repairing the existing materials. This is supported by the fact that the current breeching is approximately 20 years old, the original breeching on Units 1 & 2 lasted approximately 20 years, and the fact that a lifespan of 20 years is quite typical for breeching.

For reference purposes, it was decided to select two options (Modified A2, and B1b) along with extended ice protection (B2b) option for more detailed installation estimate. Include repair of support structure for the repair option (Modified A2) and replacement of support structure in the replacement option (B1b).

The existing support structure on Units 1 & 2 breeching requires some repair and should be replaced if the breeching is replaced. It was determined after the meeting that the pricing for the supports is not in the current estimate. Also, fairly extensive repairs would be required to the support structure. For pricing purposes, only a replacement is to be priced.

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APPENDIX C

Units 1 Stack Breeching Supports Report

Holyrood Thermal Generating Station



Suite E200, Bally Rou Place, 280 Torbay Rd. St. John's, Newfoundland, Canada A1A 3W8 Tel. (709) 754 6933 • Fax: (709) 754 2717 • www.hatch.ca

January 26, 2011

Mr. T. Collins Newfoundland and Labrador Hydro P.O. Box 12400 St. John's, NL A1B 4K7

Dear Sir:

Subject: Stack Breeching Supports, Unit #1, Holyrood, NL

Newfoundland and Labrador Hydro requested that Hatch engage an inspection company to perform a visual and ultrasonic thickness (UT) inspection of the structural support frames for the east and west side duct breeching of Unit 1. Please find attached a copy of the visual and UT inspection report prepared by TEAM Industrial Services Inc. In addition to the TEAM investigation, Hatch (Jeff Snook, P.Eng.) also carried out a visual inspection on January 18, 2011.

Inspection Summary

Unit 1 West Support

- · Overall structure is in poor condition. Severe corrosion on all structural members.
- Columns have severe pitting and loss of material over entire surface area. Certain areas have corroded through resulting in isolated holes. UT measurements indicate a general material loss of up to 40 percent of the assumed original thickness of 9.5 mm.
- Braces in North-South direction have severe pitting and loss of material over entire surface area with some areas corroding through resulting in isolated holes. UT measurements indicate a general material loss of up to 43 percent of the assumed original thickness of 9.5 mm.
- Braces in East-West direction exhibit less severe corrosion with UT measurements including a general material loss of up to 12 percent of the assumed original thickness of 6.4 m.
- Gusset plates have serious deterioration. Most were deteriorated to a point that it was impossible to
 obtain a measurement.
- Concrete piers appear to be in good condition.

Unit 1 East Support

- Overall structure is in slightly better condition than West support with isolated corrosion on all structural members except for the gusset plates which exhibit corrosion throughout.
- Columns have isolated areas of pitting and material loss. UT measurements indicate material loss in isolated areas of up to 40 percent of the assumed original thickness of 9.5 mm.

ISO 9001

H337689-0000-50-218-0001



⁶ Hatch 2011/01

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Mr. T. Collins Newfoundland and Labrador Hydro January 26, 2011

- Braces have isolated areas of pitting and material loss. UT measurements indicate material loss in isolated areas of up to 10 percent the assumed original thicknesses of 9.5 m (North-South bracing) and 6.4 m (East-West bracing).
- Gusset plates have severe deterioration. In general, they were in slightly better condition than the West
 support; however, some were deteriorated to a point it was impossible to find sufficient material to
 obtain a thickness measurement. In areas where measurement was possible, material loss of
 approximately 65 percent of the assumed original thickness of 9.5 mm was found. Also, several gusset
 plates are severely bent.
- · Concrete piers appear to be in good condition.

Recommendations

- Without a comprehensive structural analysis of the existing structures, it is difficult to ascertain an acceptable percentage of material loss. However, typically in investigations such as these, and in giving due regard to load and material safety factors used in design, we recommend 20 percent material loss as the limit beyond which the structure should be refurbished and/or replaced. As a result, Hatch recommends the entire West support structure be replaced immediately. Hatch also recommends that the Gusset Plates on the East support be replaced immediately. The columns and braces on the East support should be repaired locally and/or completely replaced. If repair is chosen as an option, all repaired members should be blasted and coated with a two coat epoxy system.
- It should be noted that the existing anchor bolt nuts are in all likelihood seized and cannot be removed.
 Therefore, when replacing the columns the existing anchor bolts will probably need to be cut off flush at the top of concrete and new epoxy adhesive anchors installed.
- We strongly advise that prior to repair and or replacement, a design review of the structures be
 implemented. We feel it would be good practice to ensure the supports are in compliance with all
 current codes. Also, a design review will ensure any future additional loadings such as the addition of
 insulation etc. are allowed for.

We would be pleased to offer our services to assist in preparing any repair and or replacement procedures and associated drawings. We can also assist if you determine a design review is necessary.

If you require any further assistance or have any questions, please do not hesitate to contact me at 709-754-6933 ext. 263.

Yours faithfully,

G.D. Saunders, P.Eng. Hatch St. John's, General Manager

DF:smb Attachment

ISO 9001

Page 2

H337689-0000-50-218-0001

Working Together SAFELY



Newfoundland & Labrador Hydro Breeching Support Inspection Holyrood, NL



Prepared For: Mr. Derrick French Hatch

Hatch

Prepared By: Jerramie Gowan Inspected By: Glenn Melindy

CGSB Level I Certification No. 10096

Reviewed By: Mr. Keith Gowan

Project Manager / CWB Level III Certification No. 2228 Team Industrial Services

January 23rd, 2011



Unit #1 West Breeching Support

Hatch January 23rd, 2011



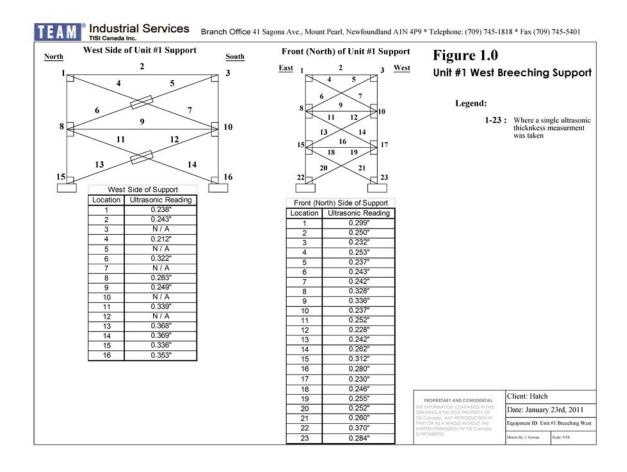
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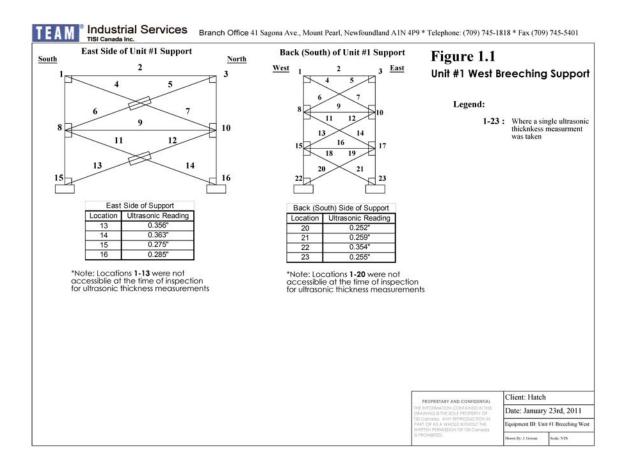
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Branch Office: 41 Sagona Ave, Mt. Pearl, NFLD. AlN 4P9 Telephone: 709-745-1818 * Fax 709-745-5401

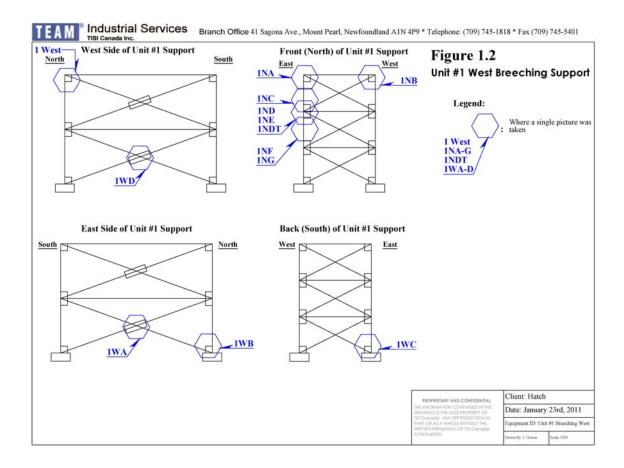
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HEAD OFFICE 389 Davis Road, Oakville, Ontario L6J 2X2 Telephone: (905) 845-9542 * Fax (905) 845-9551

Page __ of___ 007 U I R1













Overview of West support on Unit #1



Photograph Location 1 West

Hatch January 23rd, 2011



Unit #1 West Breeching Support Pictures



Photograph Location 1NA



Photograph Location 1NG

Hatch January 23rd, 2011



Unit #1 West Breeching Support Pictures



Photograph Location 1NC



Photograph Location 1ND

Hatch January 23rd, 2011







Photograph Location 1ND



Photograph Location 1NDT

Hatch January 23rd, 2011







Photograph Location 1NE



Photograph Location 1WA

Hatch

Branch Office 41 Sagona Ave, Mount Pearl, Newfoundland Telephone: (709) 745-1818 * Fax (709) 745-5401 January 23rd, 2011







Photograph Location 1WB



Photograph Location 1WD

Hatch January 23rd, 2011





Photograph Location 1WC



Photograph Location 1WC

Hatch January 23rd, 2011



Unit #1 East Breeching Support

Hatch January 23rd, 2011



ULTRASONIC

EXAMINATION REPORT

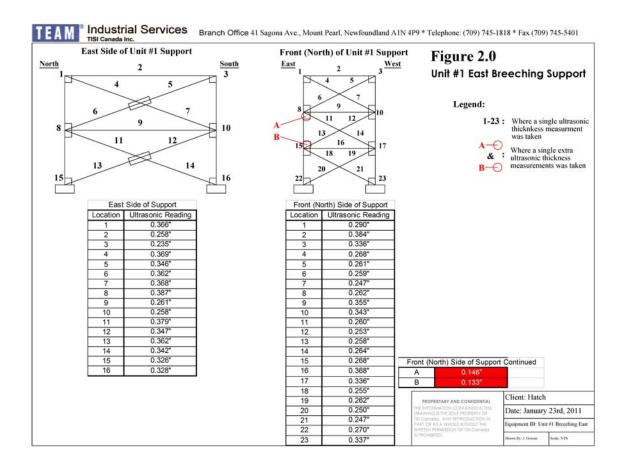
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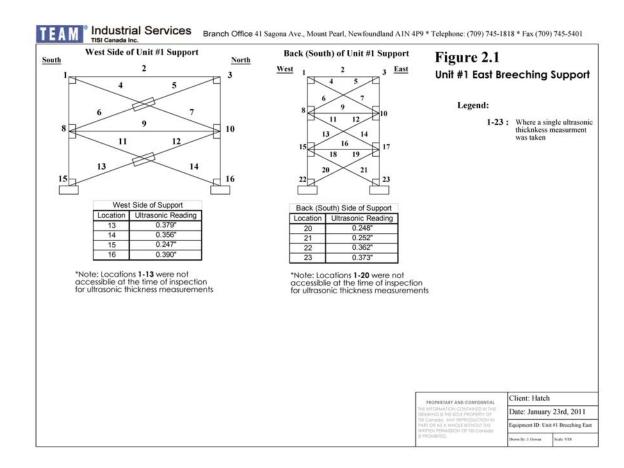
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Client Name: HATCH				Acceptance: Client Info				
Date/Time Of Examination: Jan 28, 2011				Procedure: UT-GP-01 REV. 1				
Work Location	: Holyrood, l	NL		Technique: A	SME V			
				P.O. Number:	Verbal			
Type of Fabri	cation:	Weld	Casting	Forgin	g Plat	e Oi	her	
Part/Assay No.:	/A	Dwg No.:	A	Heat No.:	'A	Pattern No.:	'A	
Scope: This	report covers	the ultrasonic	examination o	f the structural	steel undernea	ath the breeching	on unit	
No: 1 located							N. 100 N. 1 100 N. 1	
			UNIT 1 EA	AST				
-0.2.2.000		NA 3 100 14 0 100 100 100 740 1		ALIVERTA VICTORIA DE LA CONTRACTORIA DE LA CONTRACT	10.78.V. 14.07.00.4.00.00.00.00.00	0 10 14 14 15 18 1 10 15 17 -	Mark 2000 (47 AV 47	
Control of the Contro					AT ANY ADDRESS OF THE PARTY OF THE PARTY.	and bracing. See		
						t due to the loss o	-	
			onic readings co	ould not be tak	en in all waste	d and corroded a	reas. Please	
refer to photos	attached with	1111.						
Total P	arts Inspected	4	Total Part	s Accepted		Total Parts Reig	ected	
Total P	arts Inspected	d e	707	s Accepted		Total Parts Rejo	ected	
Total P Scan: N/A	CONTRACT OF THE PROPERTY OF TH	4	707	W. W. C.		386.26537	ected	
	N/A		707	W. W. C.		386.26537	ected	
Scan: N/A Surface Finish	N/A : As Groun		N	W. W. C.	TRAN	386.26537	ected	
Scan: N/A Surface Finish	N/A : As Groun	ıded	N	W. W. C.	TRAN Size	N/A	ected S/N	
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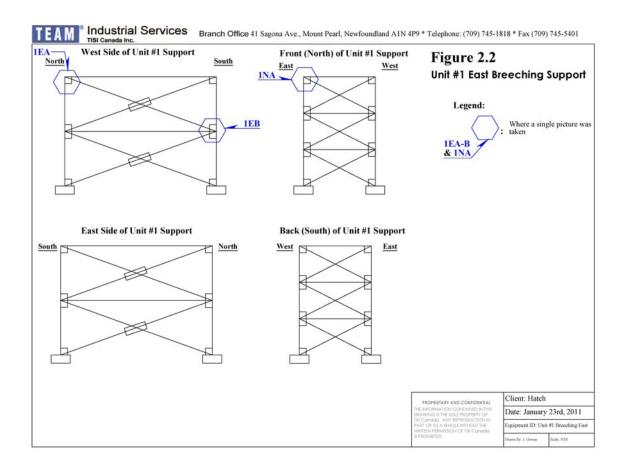
HEAD OFFICE 389 Davis Road, Oakville, Ontario L6J 2X2 Telephone: (905) 845-9542 * Fax (905) 845-9551

Page __of__

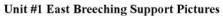
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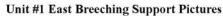
Overview of West support on Unit #1



Photograph Location 1EA

Hatch January 23rd, 2011







Photograph Location 1EB



Photograph Location 1NA

Branch Office 41 Sagona Ave, Mount Pearl, Newfoundland Telephone: (709) 745-1818 * Fax (709) 745-5401 January 23rd, 2011

Hatch



Technician Certifications

Hatch January 23rd, 2011









APPENDIX D

Estimate for Replacing

West Breeching Support and Repairing East Support



Fw: Estimate for Replacing West Breeching Support and Repairing East

Support

Nelson Seymour to: Nelson Seymour

02/22/2011 08:35 AM

---- Forwarded by Nelson Seymour/NLHydro on 02/22/2011 08:32 AM ----

Todd Collins/NLHydro

To: Date:

Nelson Seymour/NLHydro@NLHydro 02/21/2011 09:27 AM

Subject: Fw: Estimate for Replacing West Breeching Support and Repairing East Support

Hi Nelson;

The additional cost to refurbish/replace the Unit 1 Breeching support structure as opposed to a complete replacement of the support structure is \$20,428.

Todd C. Collins, P.Eng. Mechanical Design Engineer

NF Hydro

Phone: (709) 737 1342 Fax: (709) 737 1900 email: toddcollins@nlh.nl.ca

---- Forwarded by Todd Collins/NLHydro on 02/21/2011 09:06 AM -----

From:

john.g.adams@power.alstom.com ToddCollins@nlh.nl.ca 02/04/2011 02:24 PM

To:

Subject:

Re: Estimate for Replacing West Breeching Support and Repairing East Support

Hi Todd

The estimated price for the current option is \$154,128. The estimated price to supply and install two new breeching support structures was \$133,700. It would cost about \$20,428 more to repair the east breeching support rather than replacing both.

Regards John

ToddCollins@nlh.nl.ca

ToddCollins

@nlh.nl.ca

ToJohn G Adams/CAOTT01/Power/ALSTOM@GA

02/04/2011

02:15 PM

SubjectRe: Estimate for Replacing West Breeching Support and

Repairing East Support

John;

What is the lump sum price to proceed with the option discussed below as compared to the quote that you submitted last year that included a replacement of the support structures?

Todd C. Collins, P.Eng. Mechanical Design Engineer NF Hydro Phone: (709) 737 1342 Fax: (709) 737 1900 email: toddcollins@nlh.nl.ca