A REPORT TO

THE BOARD OF COMMISSIONERS OF PUBLIC UTILITIES

| | |
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| | Electrical |
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# UPGRADE UNIT 1 STACK BREECHING

## Holyrood Thermal Generating Station

**Revision 1, October 26, 2010**

newfoundland labrador hydro

a nalcor energy company

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# 1 INTRODUCTION

The Holyrood Thermal Generating Station (Holyrood) is an essential part of the Island Interconnected System, with three units providing a total capacity of 490 MW. The generating station was constructed in two stages. In 1971, Stage I was completed bringing on line two generating units, Units 1 and 2, capable of producing 150 MW each. In 1979, Stage II was completed bringing on line one additional generating unit, Unit 3, capable of producing 150 MW. In 1988 and 1989, Units 1 and 2 were up-rated to 170 MW. Holyrood (illustrated in Figure 1) represents approximately one third of Newfoundland and Labrador Hydro's (Hydro) total Island Interconnected generating capacity.

**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**

# 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 "Unit 1 Stack Breeching Thickness Scanning Report", Appendix A). The scan indicated that the casing was generally in good condition but localized areas required steel plate replacement due to corrosion. 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 replacement 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 1971. 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**

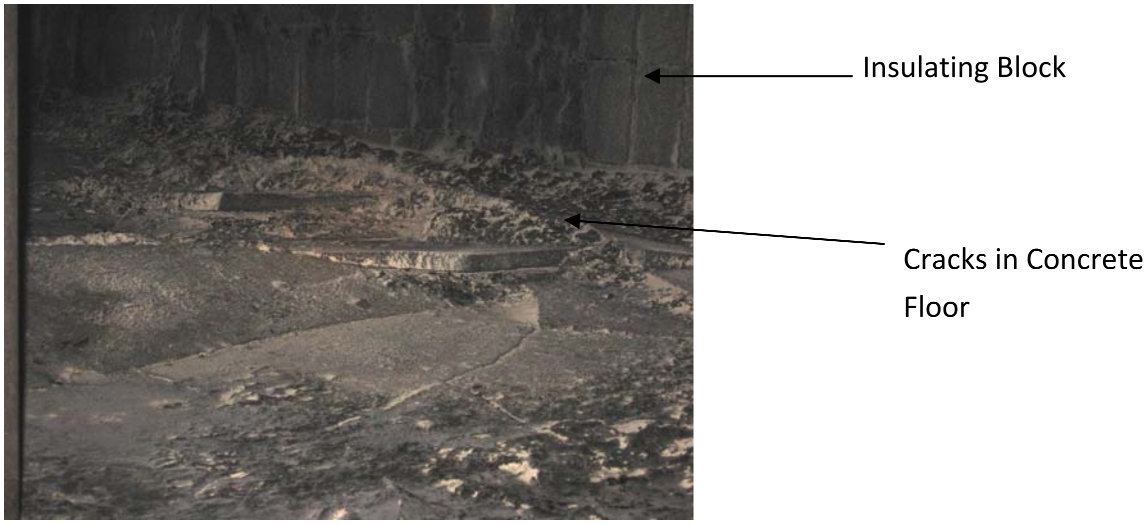


**Figure 6 – Unit 1 Breeching Concrete Floor**

Also, failure of the internal insulation blocks is caused by the breakdown of the adhesive membrane that bonds 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 of 2009, Hydro has switched to fuel oil with a sulfur content of 0.7 percent, reducing the possibility of sulfuric acid formation.

## 3.1 Age of Equipment or System

Unit 1 was commissioned in 1971. The existing oil fired boiler and steam turbine are 39 years old. The original stack breeching servicing Unit 1 was replaced in 1990 after 19 years of service. The existing stack breeching is approximately 20 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, absent an infeed from Lower Churchill.

## 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 History[4]**

| Year | Preventive Maintenance ($000) | Corrective Maintenance ($000) | Total Maintenance ($000) |
|---|---|---|---|
| 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

[1] Reference IC-NLH-20
[2] Reference PUB-NLH-4
[3] Reference PUB-NLH-5
[4] Reference IC-NLH-20

required and the cost to complete the repairs was estimated to be $100,000. However, 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. In addition, 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

The utility industry recognizes that boiler stack breeching may need refurbishment periodically, either completely or partially, after a twenty year life span. In 2009, Hydro had a condition assessment of the Holyrood stack breeching completed by Alstom Power. The assessment report (see 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 25$^{th}$, 2010 are also filed in Appendix B.[6]

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[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 monitor and control the flue gas temperature inside the stack breeching through the SCAH's during boiler operation to ensure that it does not drop below the sulfuric acid dew point, thereby preventing the formation of sulfuric acid. Also, in January of 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.

## 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 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 Alstom Engineering Report, "Condition Assessment of Stack Breeching at Holyrood Thermal Generating Station Units 1, 2, and 3", Appendix B, page B12). Past operating conditions have led to corrosion of the breeching plate and deterioration of the internal insulating liner and concrete floor. Hydro conducted thickness scanning on the breeching steel casing in August 2010 (see "Unit 1 Stack Breeching Thickness Scanning Report", Appendix A). 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, the external steel support structure has deteriorated to a point where a full replacement is necessary.

Failure of the breeching support structure during operation can result in an unplanned unit outage with a four week duration. An unscheduled unit outage during the peak winter load demand would result in a loss of 170 MW of power generation 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 $2,691,879 (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 five alternatives over a study period of ten years. See Cost Benefit Analysis Section 4.3 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 five alternatives. The study period for the CBA was ten 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 2010-2016 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 2010-2016 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, 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. For the purposes of this calculation, it was assumed that the forced outage would occur during the peak winter load requirement. In order to meet the requirements of the Island Interconnected System during the peak load requirement, 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 at four weeks and was assumed to occur in January of the year 2013. The projected Island Interconnected System loads for January of 2013 were determined by prorating the actual system loads that occurred in January of 2009. The additional cost to operate the gas turbines during the outage period was calculated at $2,691,879, 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 $53,000 per year which is based on an average of the ten year maintenance history presented in Section 3.4 – Maintenance History, Table 1. Also, in the event of a failure of the support structure, it is anticipated that a complete replacement of the breeching would be required with cost as high as $3.5M. The replacement cost for Alternative 1 was not 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 $2,478,908.

[8] Reference IC-NLH-22

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 $1,662,698.

Alternative 3 – Refurbish Unit 1 Stack Breeching Casing, Replace Expansion Joints, Replace Support Structure, and Continue To Maintain The Internal Insulation Liner: [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, installing new support structures, installing an external insulation system, and installing an ice protection shield. Upon completion of Alternative 3, the annual O&M cost was estimated at $53,000 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 3. The CPW of this alternative is a cost of $1,878,153.

[9] Reference IC-NLH-22

[10] Reference IC-NLH-22

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 $1,731,164.

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 ten year study period. There are no quantifiable benefits associated with Alternative 5. The CPW of this alternative is a cost of $3,302,275. [13]

[11] Reference IC-NLH-19
[12] Reference IC-NLH-22
[13] Reference IC-NLH-22

Unit 1 stack breeching was replaced 20 years ago. Economic conditions in the province and throughout 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 thirteen 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 but predicts the requirement for significant reoccurring refurbishment cost and a forced outage within the ten year study period. Alternative 3 will provide a solution to upgrade the breeching servicing Unit 1 for the next ten 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 ten 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 ten 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 2 is the least cost option and is the recommended alternative. The results of the CBA are illustrated below in Table 2.

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[14] Reference IC-NLH-16 and PUB-NLH-6

**Table 2: Cost Benefit Analysis**[15]

| HRD Stack Breeching<br>Alternative Comparison<br>*Cumulative Net Present Value*<br>*To The Year*<br>2020 | | |
|---|---|---|
| **Alternatives** | **Cumulative Net Present Value (CPW)** | **CPW Difference between Alternative and the Least Cost Alternative** |
| 1. Status quo | 2,478,908 | 816,210 |
| 2. Refurbish - Option 1 | 1,662,698 | 0 |
| 3. Refurbish - Option 2 | 1,878,153 | 215,455 |
| 4. Refurbish - Option 3 | 1,731,164 | 68,466 |
| 5. Replace - Option 4 | 3,302,275 | 1,639,577 |

## 4.4 Legislative or Regulatory Requirements

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

## 4.5 Historical Information

The original stack breeching servicing Unit 1 was installed in 1967, constructed from one-quarter 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 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.

[15] Reference IC-NLH-19

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. 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 a failure of the stack breeching 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 $2,691,879 (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 is twenty years old and has 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)* | **2011** | **2012** | **Beyond** | **Total** |
|---|---|---|---|---|
| **Material Supply** | 0.0 | 0.0 | 0.0 | 0.0 |
| **Labour** | 114.4 | 0.0 | 0.0 | 114.4 |
| **Consultant** | 0.0 | 0.0 | 0.0 | 0.0 |
| **Contract Work** | 1,364.7 | 0.0 | 0.0 | 1,364.7 |
| **Other Direct Costs** | 2.0 | 0.0 | 0.0 | 2.0 |
| **O/H, AFUDC & Escln.** | 140.4 | 0.0 | 0.0 | 140.4 |
| **Contingency** | 148.1 | 0.0 | 0.0 | 148.1 |
| **TOTAL** | **1,769.6** | **0.0** | **0.0** | **1,769.6** |

## 5.2 Project Schedule

The anticipated project schedule is shown in Table 4.

**Table 4: Project Milestones**

| Activity | Milestone |
|---|---|
| Project Kick-off Meeting | January 2011 |
| Complete Design Transmittal | January 2011 |
| Develop RFP for Professional Engineering Services | January 2011 |
| Complete Detailed Engineering Design & Develop Contract | February 2011 |
| Issue Tender & Award Contract | March 2011 |
| Installation | August 2011 |
| Commissioning | September 2011 |
| Project Final Documentation and Closeout | December 2011 |

# APPENDIX A

## Units 1 Stack Breeching Thickness Scanning Report

## Holyrood Thermal Generating Station

TEAM® Industrial Services
TISI Canada Inc.

NF HYDRO

UNIT #1 AIRHEATER TO STACK DUCTING

1

TEAM® Industrial Services
TISI Canada Inc.

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TEAM® Industrial Services
TISI Canada Inc.

**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.

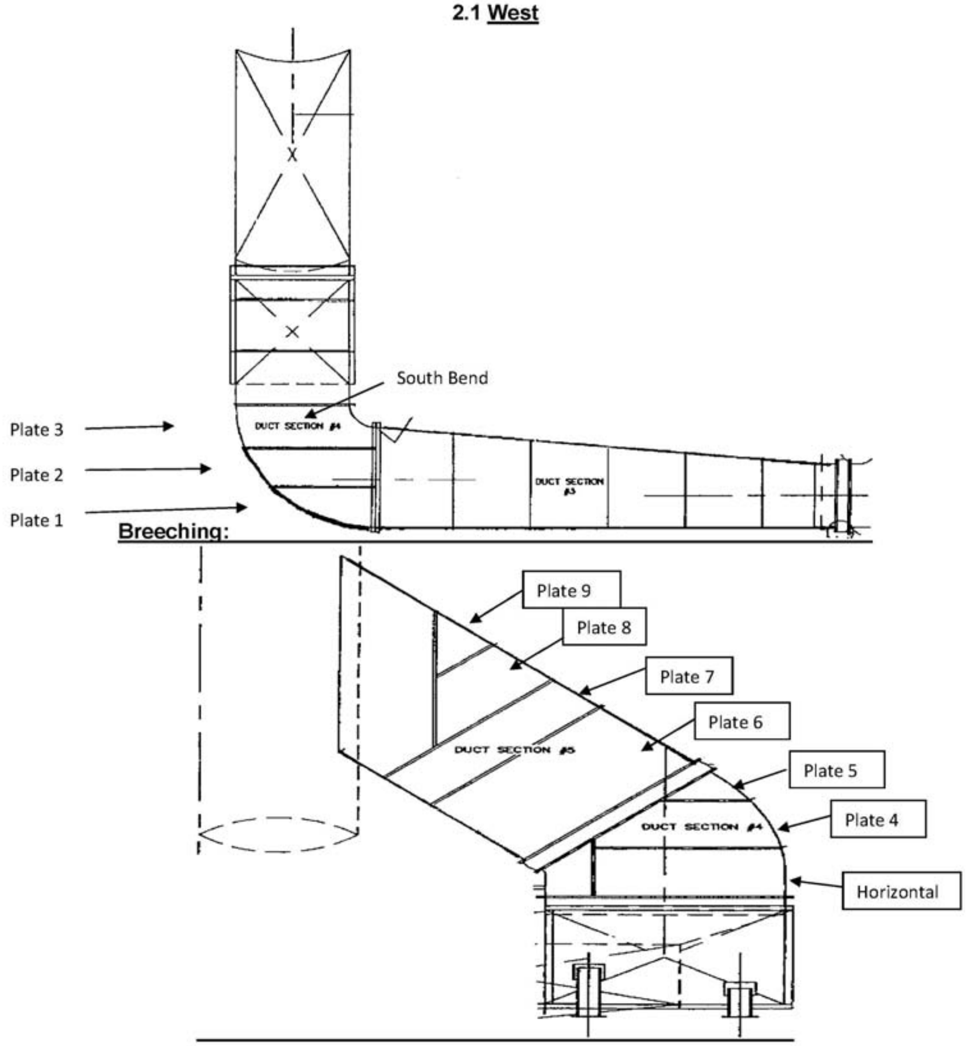
**1.3 Access**

External access was by means of fixed scaffolding.

TEAM® Industrial Services
TISI Canada Inc.

2.0 Inspection

2.1 West

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**TEAM® Industrial Services**
**TISI Canada Inc.**

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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T | .254 | .253 | .253 | .251 | .212 | .254 | .254 | .249 | .250 | .250 | .251 | .269 | .269 | .262 |
| B | .252 | .253 | .245 | .253 | .253 | .248 | .253 | .240 | .231 | .250 | .249 | .268 | .268 | .269 |
| M | .243 | .250 | .254 | .249 | .246 | .250 | .245 | .250 | .239 | .252 | .238 | .269 | .263 | .264 |

SECTION #3 WEST

| L | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T | .253 | .254 | .251 | .252 | .252 | .254 | .253 | .254 | .250 | .244 | .251 | .269 | .269 | .268 |
| B | .253 | .254 | .239 | .254 | .250 | .253 | .254 | .249 | .252 | N/A | N/A | N/A | N/A | N/A |
| M | .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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | .246 | .248 | .249 | .245 | .248 | .248 | .248 | .248 | .246 | .247 | .245 | .261 | .266 | .258 |
| B | .247 | .248 | .247 | .248 | .248 | .248 | .249 | .248 | .247 | .249 | .236 | .262 | .251 | .245 |
| C | .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 |
| E | .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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | .247 | .246 | .246 | .245 | .242 | .246 | .244 | .244 | .244 | .245 | .248 | .266 | .266 | .257 |
| B | .244 | .247 | .244 | .246 | .246 | .245 | .243 | .244 | .243 | .243 | .246 | .266 | .267 | .261 |
| C | .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 |
| E | .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

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TEAM® Industrial Services
TISI Canada Inc.

SECTION # 4 (WEST)

Working South to North

Plate #1

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .249 | .252 | .253 | N/A |
| 2 | .248 | .250 | .250 | .252 |

Plate #2

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .246 | .253 | .251 | .252 |
| 2 | .250 | .250 | .251 | .250 |

Plate #3

| Location | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | .249 | .253 | .249 | .253 | .246 |
| 2 | .249 | .251 | .250 | .248 | .248 |
| 3 | N/A | .253 | .254 | .253 | .247 |

Horizontal

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .249 | .255 | .251 | .247 |
| 2 | .250 | .249 | .250 | .240 |
| 3 | .254 | .250 | .249 | .251 |

Plate #4

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .250 | .250 | .250 | .231 |
| 2 | .252 | .255 | .255 | .250 |
| 3 | .253 | .256 | .257 | .251 |

Plate #5

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .248 | .248 | .251 | .256 |
| 2 | .228 | .229 | .251 | .250 |

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TEAM® Industrial Services
TISI Canada Inc.

SECTION # 4 (EAST)

Working South to North

Plate #1

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .251 | .251 | .250 | N/A |
| 2 | N/A | N/A | N/A | .250 |

Plate #2

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .247 | .253 | .248 | .250 |
| 2 | .248 | .251 | .252 | .249 |

Plate #3

| Location | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | .249 | .250 | .253 | .253 | .251 |
| 2 | .250 | .254 | .253 | .251 | .249 |
| 3 | N/A | .255 | .254 | .246 | .251 |

Horizontal

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .249 | .250 | .250 | .249 |
| 2 | .229 | **.172** | **.197** | **.190** |

Plate #4

N/A

Plate #5

N/A

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TEAM® Industrial Services
TISI Canada Inc.

SECTION # 4 (NORTH)

Working East to West

Plate # 1

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .250 | .251 | .250 | .251 |
| 2 | .250 | .248 | .249 | .250 |
| 3 | .251 | .250 | .249 | .251 |
| 4 | .252 | .258 | .248 | .249 |

Plate # 2

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .252 | .253 | .258 | .258 |
| 2 | .254 | .244 | .226 | .258 |
| 3 | .252 | .230 | .203 | .195 |

Plate # 3

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .209 | .227 | .228 | **.191** |
| 2 | .234 | .249 | .227 | .219 |
| 3 | .227 | .234 | .235 | .208 |

Horizontal

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .228 | .231 | .250 | .244 |
| 2 | **.199** | .253 | .254 | .250 |
| 3 | .204 | .251 | .250 | .251 |

Plate # 4

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .249 | .251 | .252 | .250 |
| 2 | .255 | .253 | .250 | .251 |

Plate # 5

| Location | A | B |
|---|---|---|
| 1 | .220 | .249 |

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TEAM® Industrial Services
TISI Canada Inc.

SECTION # 4 (SOUTH)

Working East to West

South Bend

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .245 | .250 | .252 | .253 |

Horizontal

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .251 | .240 | .249 | .250 |
| 2 | .246 | .250 | .250 | .249 |
| 3 | .241 | .249 | .247 | .250 |

Plate # 4

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .209 | .250 | .251 | .254 |
| 2 | .220 | .254 | .254 | .253 |

Plate # 5

| Location | A | B |
|---|---|---|
| 1 | .230 | .250 |

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TEAM® Industrial Services
TISI Canada Inc.

SECTION # 5 (NORTH)

Working East to West

Plate # 6

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .240 | .237 | .249 | .248 |
| 2 | .249 | .249 | .254 | .251 |
| 3 | .248 | .248 | .251 | .247 |

Plate # 7

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .250 | .250 | .251 | .249 |
| 2 | .252 | .249 | .248 | .248 |
| 3 | .252 | .251 | .250 | .250 |

Plate # 8

| Location | A | B | C |
|---|---|---|---|
| 1 | .251 | .251 | .249 |
| 2 | .251 | .250 | .248 |
| 3 | .247 | .245 | .241 |

Plate # 9

| Location | A | B |
|---|---|---|
| 1 | .249 | .251 |
| 2 | .249 | .252 |

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TEAM® Industrial Services
TISI Canada Inc.

SECTION # 5 (SOUTH)

Working West to East

Plate # 6

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .245 | .248 | .241 | .247 |
| 2 | .250 | .246 | .250 | .250 |
| 3 | .250 | .246 | .250 | .250 |

Plate # 7

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .247 | .250 | .247 | .247 |
| 2 | .246 | .246 | .245 | .245 |
| 3 | .247 | .246 | .247 | .246 |

Plate # 8

| Location | A | B | C |
|---|---|---|---|
| 1 | .250 | .250 | .245 |
| 2 | .250 | .249 | .249 |
| 3 | .251 | .246 | .251 |

Plate # 9

| Location | A | B |
|---|---|---|
| 1 | .247 | .251 |
| 2 | .240 | .251 |

TEAM® Industrial Services
TISI Canada Inc.

SECTION # 5 (WEST)

Working North to South

Plate # 6

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .252 | .235 | .250 | .210 |
| 2 | .250 | .250 | .248 | .235 |
| 3 | .251 | .250 | .255 | .255 |

Plate # 7

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .234 | .255 | .250 | .252 |
| 2 | .252 | .244 | .244 | .250 |
| 3 | .252 | .250 | .253 | .244 |

Plate # 8

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .210 | .230 | .229 | .241 |
| 2 | .215 | .229 | .240 | .248 |

Plate # 9

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .250 | .248 | .250 | .246 |
| 2 | .251 | .247 | .251 | .250 |

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**TEAM® Industrial Services**
**TISI Canada Inc.**

SECTION # 5 (EAST)

Working North to South

Plate # 6

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .251 | N/A | N/A | .239 |

- Location #1 located at bottom.

TEAM® Industrial Services
TISI Canada Inc.

**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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T | .250 | .252 | .246 | .249 | .246 | .250 | .247 | .253 | .251 | .249 | .247 | .246 | .218 | .229 |
| B | .249 | .251 | .239 | .250 | .249 | .252 | .249 | .251 | .249 | .242 | .239 | .236 | .242 | .239 |
| M | .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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T | .249 | .259 | .258 | .259 | .257 | .247 | .255 | .258 | .257 | .249 | .255 | .227 | .239 | .239 |
| B | .249 | .255 | .257 | .258 | .257 | .256 | .255 | .257 | .259 | .255 | .255 | **.181** | .219 | **.194** |
| M | .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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | .249 | .251 | .250 | .249 | .247 | .252 | .248 | .249 | .249 | .243 | .249 | .202 | .221 | **.198** |
| B | .250 | .250 | .250 | .249 | .252 | .250 | .244 | .246 | .249 | **.191** | .249 | .214 | **.172** | .226 |
| C | .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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | .252 | .232 | .249 | .256 | .262 | .262 | .259 | .251 | .258 | .255 | .251 | .249 | .247 | .247 |
| B | .251 | .250 | .248 | .252 | .260 | .260 | .258 | .258 | .259 | .254 | .254 | **.190** | **.192** | .210 |
| C | .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 |
| E | .247 | .249 | .248 | .251 | .261 | .260 | | | | | | | | |

- Location #1 starts l 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

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TEAM® Industrial Services
TISI Canada Inc.

SECTION # 4 (EAST)

Working South to North

Plate #1

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .252 | .250 | .246 | N/A |
| 2 | .243 | .249 | .253 | .255 |

Plate #2

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .253 | .253 | .248 | N/A |
| 2 | .253 | .251 | .252 | .242 |

Plate #3

| Location | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | .229 | .249 | .249 | .249 | .227 |
| 2 | .251 | .255 | .253 | .253 | .249 |
| 3 | N/A | .254 | .254 | .251 | .244 |

Horizontal

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .255 | .255 | .253 | .252 |
| 2 | .248 | .250 | .253 | .249 |
| 3 | .252 | .253 | .249 | .239 |

Plate #4

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | **.198** | .255 | .255 | **Hole** |
| 2 | .251 | .244 | .253 | .239 |
| 3 | **.199** | .254 | .253 | .225 |

Plate #5

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .254 | **.199** | **.199** | .219 |
| 2 | .248 | .209 | .229 | .218 |

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**TEAM® Industrial Services**
**TISI Canada Inc.**

SECTION # 4 (WEST)

Working South to North

Plate #1

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | **.198** | .252 | .255 | N/A |
| 2 | .238 | .251 | .250 | .250 |

Plate #2

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .252 | .253 | .253 | N/A |
| 2 | .253 | .255 | .255 | .251 |

Plate #3

| Location | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | .208 | .217 | .252 | .253 | .248 |
| 2 | .228 | .250 | .250 | .254 | .237 |
| 3 | N/A | .230 | .253 | .245 | .252 |

Horizontal

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | **.199** | N/A | N/A | .250 |
| 2 | .201 | N/A | N/A | .251 |

Plate #4

N/A

Plate #5

N/A

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TEAM® Industrial Services
TISI Canada Inc.

SECTION # 4 (NORTH)

Working East to West

Plate # 1

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .217 | .255 | .251 | .255 |
| 2 | **.195** | .246 | .250 | .255 |
| 3 | .206 | .253 | .254 | .250 |
| 4 | **.181** | .252 | .252 | .248 |

Plate # 2

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .229 | .249 | .249 | .249 |
| 2 | .251 | .255 | .253 | .253 |
| 3 | N/A | .254 | .254 | .251 |

Plate # 3

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .254 | .253 | .249 | .244 |
| 2 | .250 | .249 | .244 | .209 |
| 3 | .244 | .244 | .249 | .217 |

Horizontal

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .250 | .248 | .246 | .248 |
| 2 | **.165** | **.177** | **.171** | **.198** |
| 3 | .249 | .246 | **.198** | .239 |

Plate # 4

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .250 | .253 | .254 | .241 |
| 2 | .254 | .243 | **.162** | **.189** |

Plate # 5

| Location | A | B |
|---|---|---|
| 1 | **.199** | **.197** |

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**TEAM® Industrial Services**
**TISI Canada Inc.**

SECTION # 4 (SOUTH)

Working East to West

South Bend

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .252 | .250 | .253 | .249 |

Horizontal

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .253 | .253 | .252 | .252 |
| 2 | **.160** | .232 | .232 | .249 |
| 3 | **.149** | .226 | .254 | .236 |

Plate # 4

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .254 | .255 | .253 | .223 |
| 2 | .255 | .250 | .228 | **.199** |

Plate # 5

| Location | A | B |
|---|---|---|
| 1 | **.196** | .210 |

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TEAM® Industrial Services
TISI Canada Inc.

SECTION # 5 (NORTH)

Working East to West

Plate # 6

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .248 | .251 | .250 | .250 |
| 2 | .250 | .235 | .253 | .251 |
| 3 | .251 | .240 | .254 | .250 |

Plate # 7

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .239 | .250 | .254 | .249 |
| 2 | .210 | .255 | .254 | .250 |
| 3 | .222 | .223 | .254 | .252 |

Plate # 8

| Location | A | B | C |
|---|---|---|---|
| 1 | .250 | .227 | .250 |
| 2 | .221 | .240 | .240 |
| 3 | .240 | .244 | .252 |

Plate # 9

| Location | A | B |
|---|---|---|
| 1 | **.196** | **.174** |
| 2 | **.199** | **.194** |

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TISI Canada Inc.

SECTION # 5 (SOUTH)

Working East to West

Plate # 6

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .249 | .253 | .220 | .249 |
| 2 | .245 | .251 | .249 | .250 |
| 3 | .251 | .250 | .250 | .253 |

Plate # 7

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .250 | .252 | .250 | .250 |
| 2 | .251 | .251 | .250 | .250 |
| 3 | .250 | .255 | .254 | .251 |

Plate # 8

| Location | A | B | C |
|---|---|---|---|
| 1 | .250 | .221 | .253 |
| 2 | .251 | .248 | .245 |
| 3 | **.195** | .253 | .250 |

Plate # 9

| Location | A | B |
|---|---|---|
| 1 | .239 | **.199** |
| 2 | .231 | .240 |

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TEAM® Industrial Services
TISI Canada Inc.

SECTION # 5 (EAST)

Working South to North

Plate # 6

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | **.189** | .216 | .207 | .246 |
| 2 | .250 | .249 | **.194** | .241 |
| 3 | .249 | .245 | .241 | **.176** |

Plate # 7

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .244 | .237 | .250 | .248 |
| 2 | .250 | .250 | .249 | .250 |
| 3 | .251 | .248 | .241 | **.198** |

Plate #8

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .250 | .253 | .240 | .236 |
| 2 | .253 | .239 | .236 | .242 |

Plate # 9

| Location | A | B | C | D |
|---|---|---|---|---|
| 1 | .230 | **.183** | **.179** | .218 |
| 2 | .231 | .218 | .213 | .221 |

**TEAM® Industrial Services**
**TISI Canada Inc.**

SECTION # 5 (WEST)

Working North to South

Plate # 6

| | A | B | C | D |
|---|---|---|---|---|
| 1 | .249 | N/A | N/A | .235 |

- Location #1 located at bottom.

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**3.0 Photographs:**

Hole – East Breeching

S/W Corner of Horizontal

Hole – East Breeching

N/E Corner above Horizontal

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Typical Deterioration around support structure East/West


Typical Deterioration around support structure east/West

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TEAM®

# ULTRASONIC EXAMINATION REPORT

ISO 9001:2008

**Branch Office:** 41 Sagona Ave, Mt. Pearl, NFLD. A1N 4P9 Telephone: 709-745-1818 * Fax 709-745-5401

| | |
|---|---|
| Job Number: 52080638 | Client Specifications: QA/QC |
| Client Name: Hatch | Acceptance: Client info |
| Date/Time Of Examination: August 24-31, 2010 | Procedure: UT– GP– 01 REV 1 |
| Work Location: Holyrood, NL | Technique: ASME V |
| | P.O. Number: Verbal |

**Type of Fabrication:** Weld Casting Forging Plate x Other

| | | | |
|---|---|---|---|
| **Part/Assy No.:** N/A | **Dwg No.:** N/A | **Heat No.:** N/A | **Pattern No.:** N/A |

**Scope:** This report covers the ultrasonic thickness measurements and visual inspection of Unit # 1 Airheater to Stack Ducting located at NF Hydro, Holyrood, NL.

**Results:** See the attached sheets for ultrasonic thickness measurements, photographs and results.

All readings are recorded in inches and the drawings are not to scale.
Only accessible areas were inspected.

| Total Parts Inspected | Total Parts Accepted | Total Parts Rejected |
|---|---|---|
| N/A | N/A | N/A |

**Scan:** 0 deg.

**Surface Finish:** Painted

| ULTRASONIC EQUIPMENT | | | | TRANSDUCER | | | |
|---|---|---|---|---|---|---|---|
| **Make** | **Model** | **S/N** | **Cal. Date** | **Angle** | **Size** | **Frequency** | **S/N** |
| Panametrics | 37DLPlus | 071524109 | Aug 24,2010 | 0 | .434 | 5MHz | 600648 |
| | | | | | | | |
| | | | | | | | |

| | |
|---|---|
| **Calibration Block:** 0.100”-0.500” | **Serial No.:** 06-6438 |
| **Couplant:** Exosen 30 | **Batch No.:** 11006303 |

This Certificate or Report is valid only for the work which was specifically requested. The Company is not responsible for any views or opinions expressed by employees performing this work which fall outside the terms of reference. All certificates and/or reports are the result of work performed in conformance with applicable specifications and standards to the best of our ability and talent. However, the company will not be responsible for deviances within the normal limits of accuracy in accordance with the standard practices. **Final Code acceptance shall require Client/Manufacturer representative signature.**

| | |
|---|---|
| **TEAM TECHNICIAN:** **Cyril Pretty** (Print Name) Signature | **Certification: 4353** ACCP Level II ☐<br>CGSB 48.9712 Level 1 X SNT-TC-1A Level II X |
| **CLIENT REPRESENTATIVE FINAL ACCEPTANCE: N/A** (Print Name) Signature Date | |

**HEAD OFFICE**
389 Davis Road, Oakville, Ontario L6J 2X2
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Page 1 of 1

007U I R0

TEAM® Industrial Services
TISI Canada Inc.

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

ALSTOM

# 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**

**December 18, 2008**
**Rev. 1 – March 4, 2009**
**Rev. 2 – August 28, 2009**
**Rev. 3 – March 25, 2010**
**Rev. 4 – July 2, 2010**

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**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.**

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**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
3) 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 $ft^2$ 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.

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 1½" 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 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 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.

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:

1) 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)

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

   *Cons: 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..

   *Pros: 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 due to gas cooling 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*

*Cons: added cost of external insulation and cladding c/w protection against damage; break-down 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.

   *Pros: 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 due to gas cooling will be minimized or eliminated if external insulation is maintained; improved access for duct inspection and cleaning*

   *Cons: 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 (*Breeching Solution A2*) 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) (*Breeching Solution B1a*) - ¼" 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*) - ¼" Corten or equivalent high temperature carbon steel c/w 6" of external water repellent insulation c/w watertight high quality cladding and flashing

c) (*Breeching Solution B1c*) - 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

*Pros: 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*

*Cons: 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) 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) (*Protection Solution B2a*) - light-weight (LW), 1½" catwalk grating on the top panels (over aluminium cladding) attached to stack and side panels

b) (*Protection Solution B2b*) - 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) (*Protection Solution B2d*) - extra heavy gage, ribbed aluminium or steel cladding on the top panels

*Pros: 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*

*Cons: 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

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

   *Cons: 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 Jt 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 Jt 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 Jt 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) <u>Replace with metallic joints, but review the selection *(Expansion Jt Solution 4)*</u>: 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) <u>Replace the expansion joints with cloth joints, properly engineered *(Expansion Jt Solution 5)*</u>: 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.

**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.<br>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

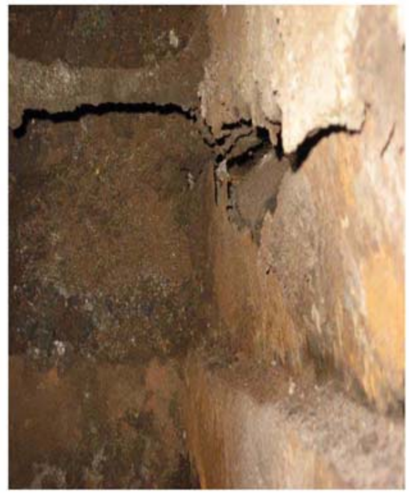

Fig. 9: Unit 1 – Duct corroded through

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**

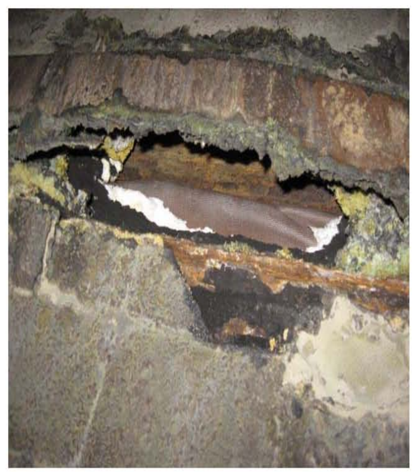

**Fig. 15: Unit 1 – Damaged expansion joint**

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

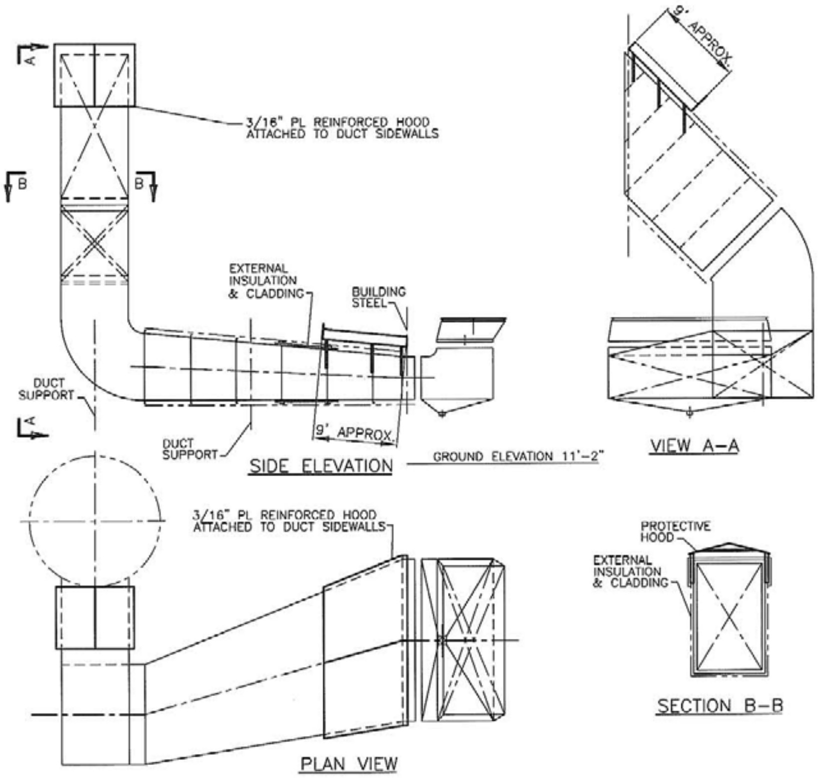


**Fig. 27: Proposed cladding protection – protective hood**

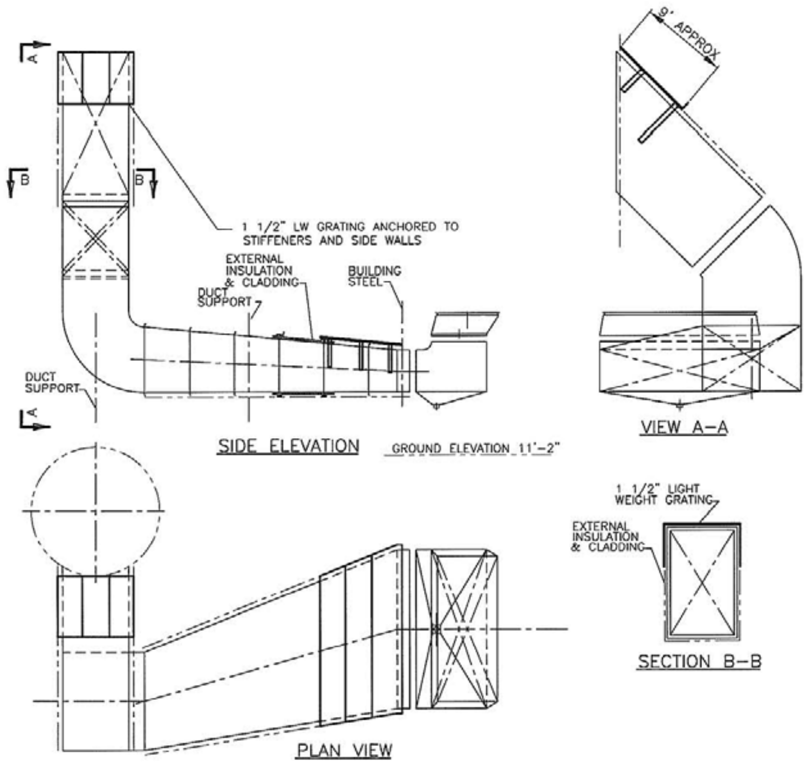


**Fig. 28: Proposed cladding protection – catwalk grating**

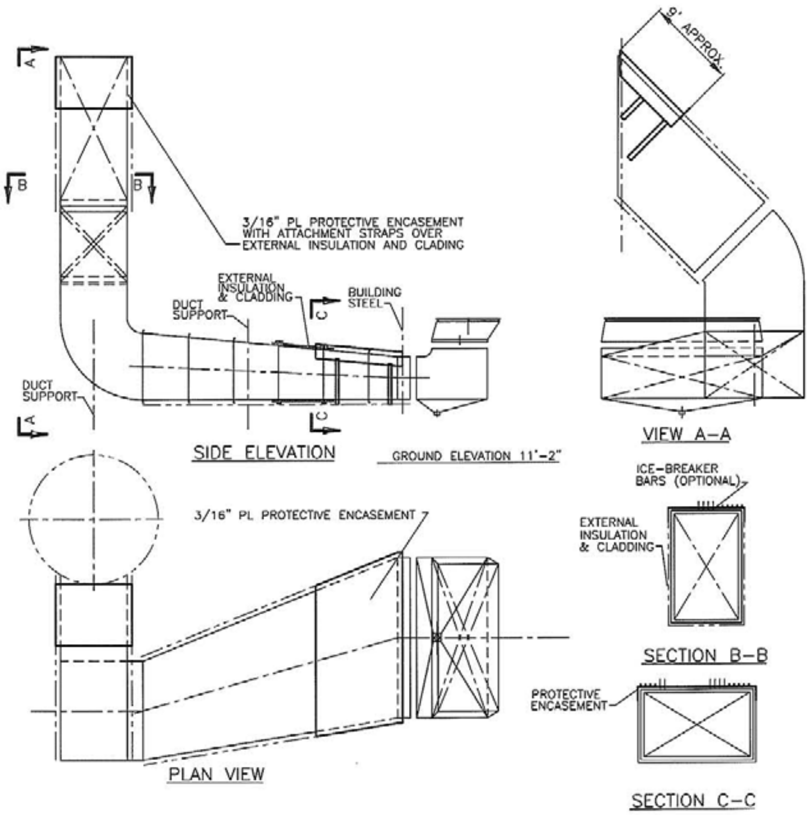


**Fig. 29: Proposed cladding protection – 7ga. plate encasement**

Joint 1

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

Joint 2 - corner

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** Power Service

**INDICATIVE PRICING ESTIMATE**

| | | | |
|---|---|---|---|
| CONTRACT # | 40833010 | ESTIMATE TYPE: | INDICATIVE |
| CUSTOMER: | NLH | PROJECT TYPE: | SUPPLY & ERECT |
| SITE: | Holyrood, NF | DATE: | 19-Aug-2009 |
| PROP. DWG: | | | Rev 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**<br>- Based on removing 1610 ft² of blocks. (Assumed)<br>- Casing and expansion joints repairs are not included due to unknown condition. These repairs can be done during annual maintenance.<br>- 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**<br>- Corten Skin, mild steel stiffeners, primed<br>- 6" mineral Fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding.<br>- 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:<br>- Primed and top coat<br>- C.S. material | $214,252 |

| Breeching Support Structure Replacement For U1 & U2 | S&E (Indicative Prices) |
|---|---|
| Replace Breeching Support Structure for U1 & U2 Only:<br>- SP-6 blast c/w primer and top coat<br>- End frames are assembled as a unit<br>- Welding CWB 47.1<br>- Material G40.21 44W<br>- 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. | $153,661 |

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.

# Powering Asset Performance

HYDRO

**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** **December 18, 2008**

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PROVINCE OF NEWFOUNDLAND
PERMIT HOLDER
This Permit Allows
ALSTOM CANADA INC. (POWER)
John McMillan P.Eng.
To practice Professional Engineering
in Newfoundland and Labrador.
Permit No. as issued by APEGN Y0126
which is valid for the year 2008

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

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**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 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
3) 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 $ft^2$ 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 1½" 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 - 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:

1) 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)

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

   *Cons: 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..

   *Pros: 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 due to gas cooling 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; break-down 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) <u>keep current duct, add 6" of external insulation and remove internal liner blocks</u> 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) <u>Replace the entire breeching</u>:

1) <u>original duct design</u>, made of

   a) ¼" 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) ¼" 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

*Pros: 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*

*Cons: 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) original duct design, construction alternatives as per 1), added protection against damage caused by ice falling from stack and powerhouse, as shown below:
   a) light-weight (LW), 1½" catwalk grating on the top panels (over aluminium cladding) attached to stack and side panels
   b) 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

   *Pros: 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*

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

*Cons: 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**

1) 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) Install cloth seal over the metallic expansion joints: 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: 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.

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

# 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 $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

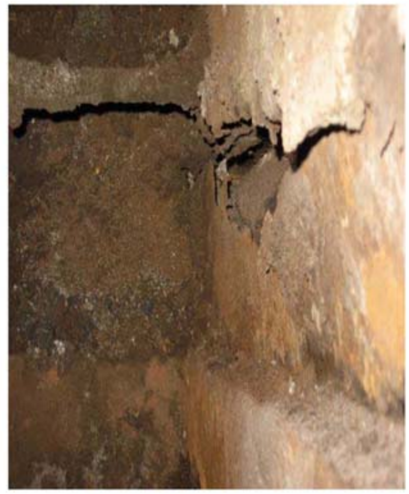


Fig. 9: Unit 1 – Duct corroded through

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**

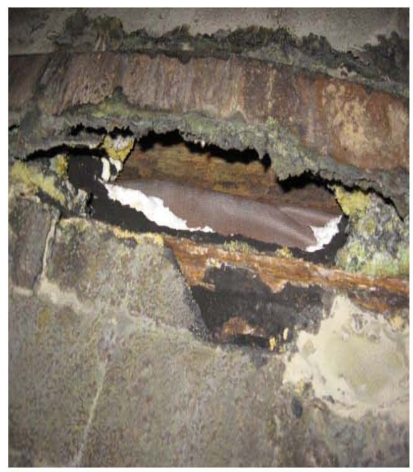


**Fig. 15: Unit 1 – Damaged expansion joint**

**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

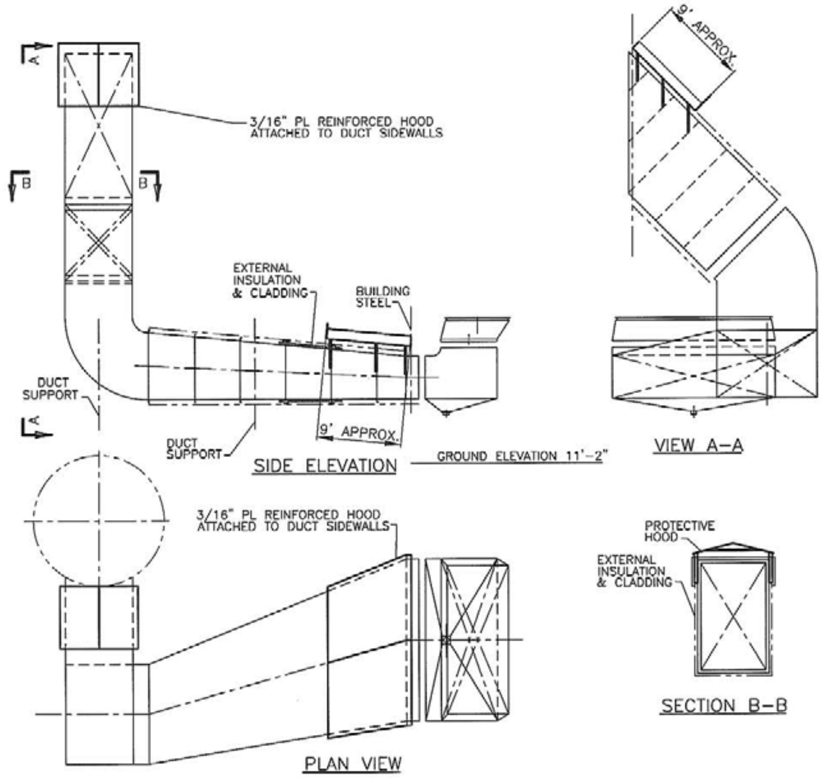



**Fig. 27: Proposed cladding protection – protective hood**

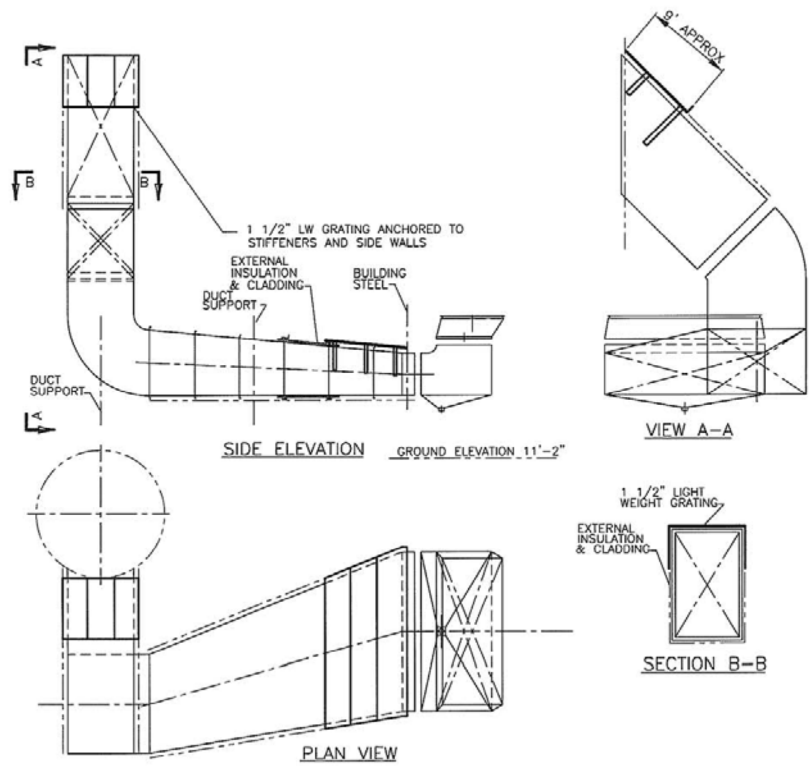



**Fig. 28: Proposed cladding protection – catwalk grating**

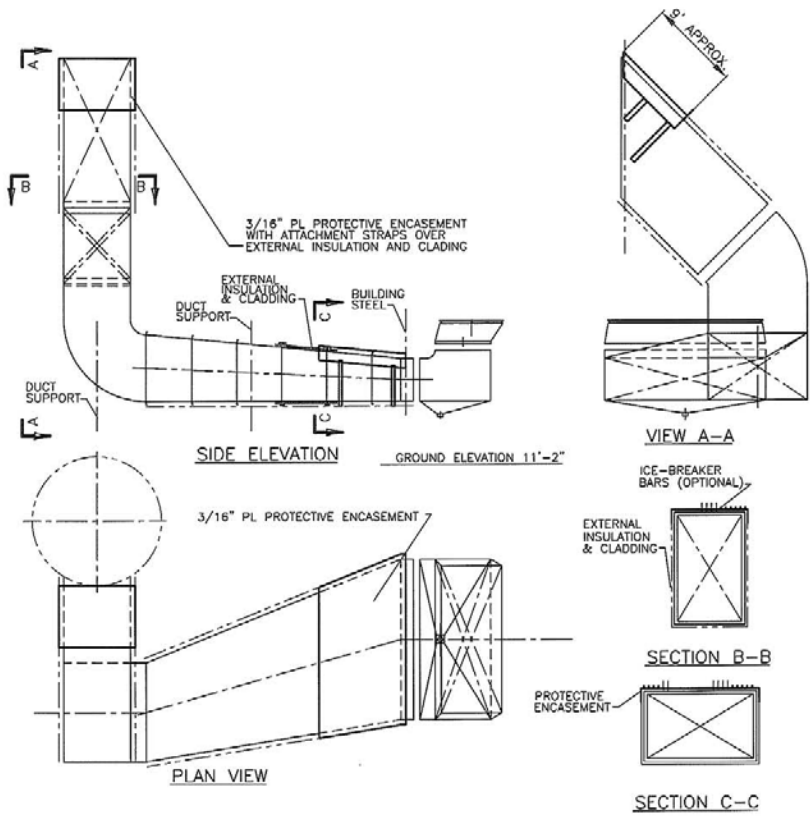



**Fig. 29: Proposed cladding protection – 7ga. plate encasement**

Joint 1

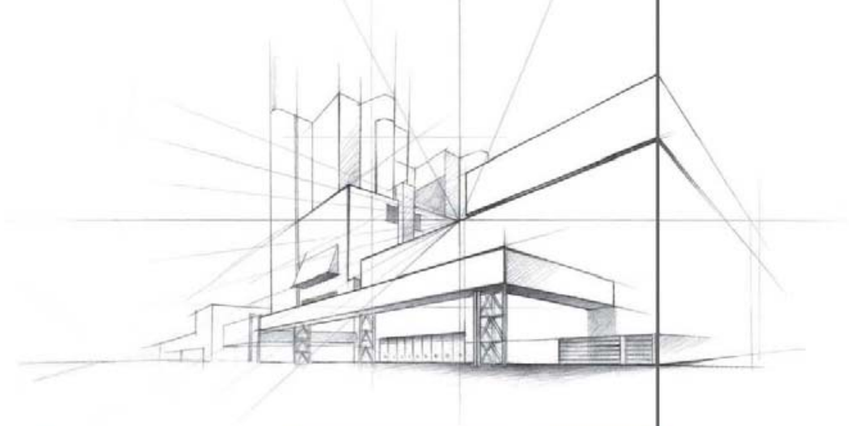
Fig. 30: Unit 3 – Expansion joint, hot air duct from air heater

Joint 2 - corner

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

Powering **Asset** Performance



HYDRO

**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**

**December 18, 2008**
**Rev. 1 – March 4, 2009**

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ALSTOM CANADA INC. (POWER)
John McMillan P.Eng.
To practice Professional Engineering in Newfoundland and Labrador.
Permit No. as issued by APEGN Y0126
which is valid for the year 2008

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

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**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
3) 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 $ft^2$ 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 1½" 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

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 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 - 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:

1) 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)

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

   *Cons: 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..

*Pros: 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 due to gas cooling 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*

*Cons: added cost of external insulation and cladding c/w protection against damage; break-down 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.

*Pros: 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 due to gas cooling will be minimized or eliminated if external insulation is maintained; improved access for duct inspection and cleaning*

*Cons: 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 (*Breeching Solution A2*) 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) (*Breeching Solution B1a*) - ¼" 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*) - ¼" Corten or equivalent high temperature carbon steel c/w 6" of external water repellent insulation c/w watertight high quality cladding and flashing

c) (*Breeching Solution B1c*) - 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

*Pros: 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*

*Cons: 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) 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) (*Protection Solution B2a*) - light-weight (LW), 1½" catwalk grating on the top panels (over aluminium cladding) attached to stack and side panels

b) (*Protection Solution B2b*) - 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) (*Protection Solution B2d*) - extra heavy gage, ribbed aluminium or steel cladding on the top panels

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*Pros: 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*

*Cons: 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

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

   *Cons: 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 Jt 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 Jt 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 Jt 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 Jt 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 Jt 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.

# 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.<br>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**

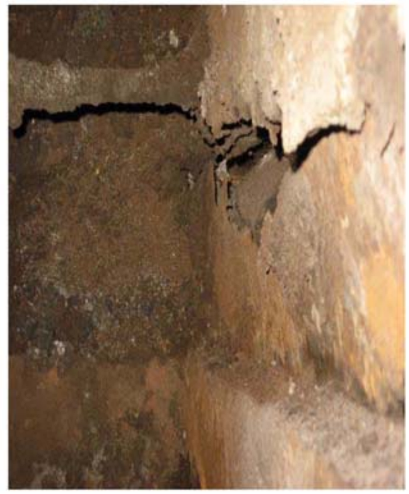


**Fig. 9: Unit 1 – Duct corroded through**

**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**

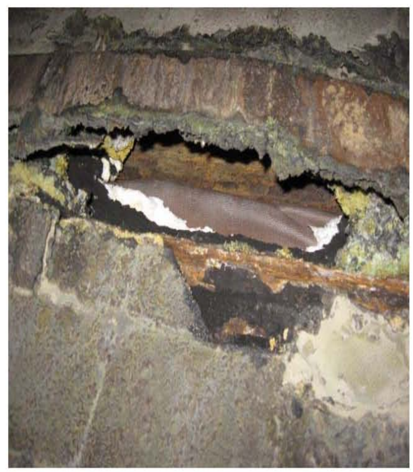


**Fig. 15: Unit 1 – Damaged expansion joint**

**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**

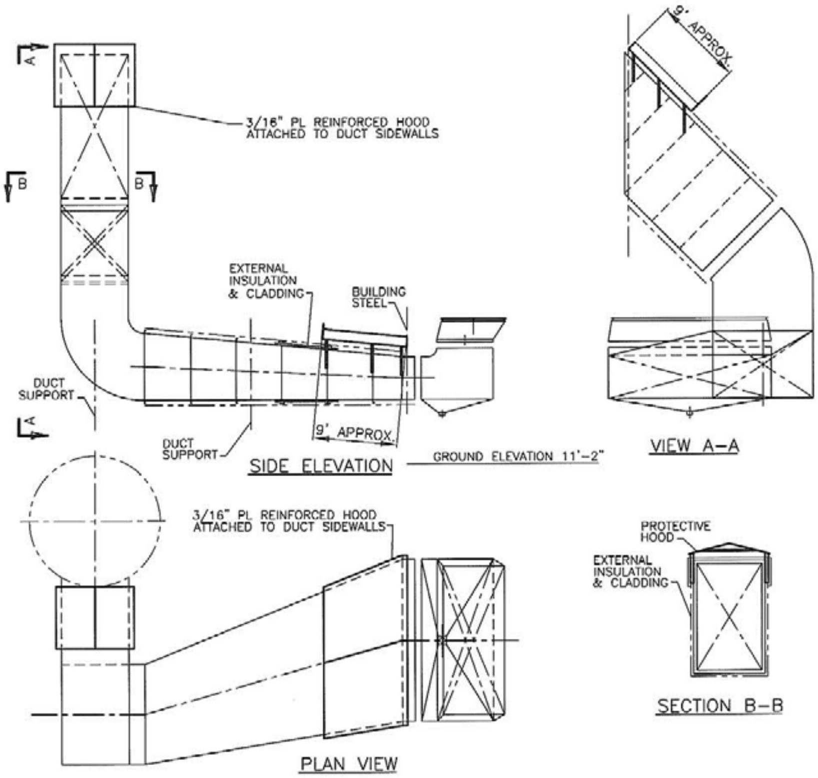



**Fig. 27: Proposed cladding protection – protective hood**

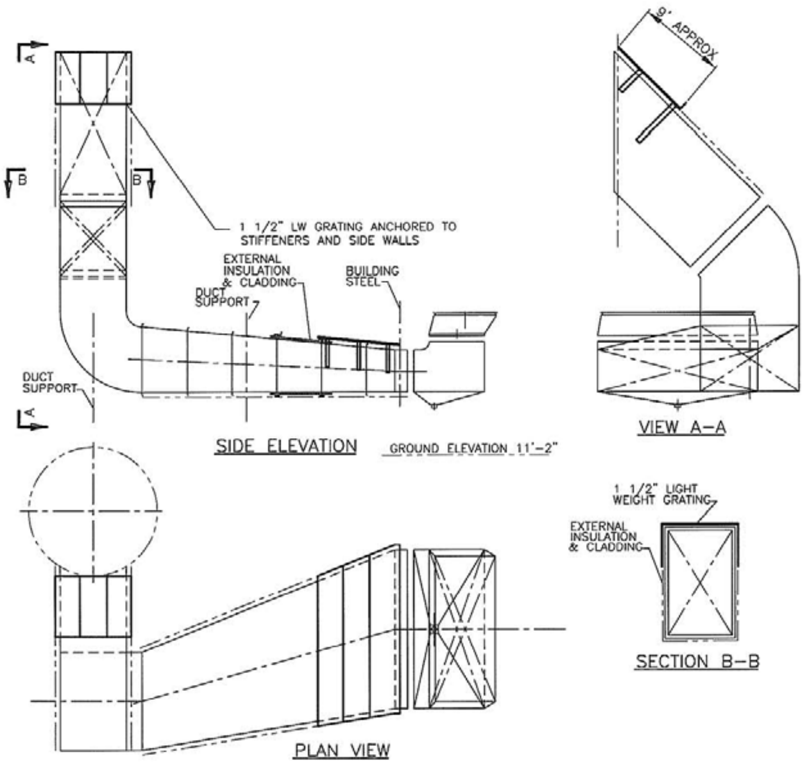



**Fig. 28: Proposed cladding protection – catwalk grating**

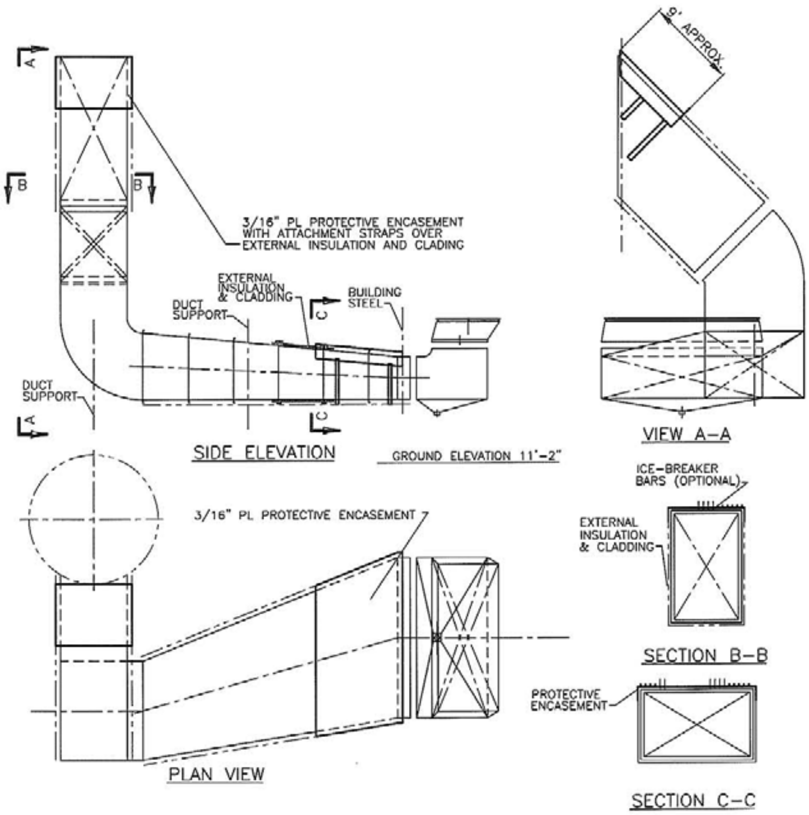
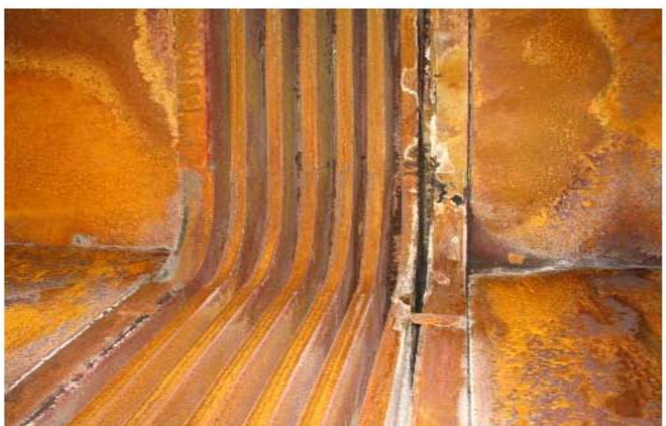



**Fig. 29: Proposed cladding protection – 7ga. plate encasement**

Joint 1

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



Joint 2 - corner

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 Power Service

**INDICATIVE PRICING ESTIMATE**

| | | | |
|---|---|---|---|
| CONTRACT # | 40833010 | ESTIMATE TYPE: | INDICATIVE |
| CUSTOMER: | NLH | PROJECT TYPE: | SUPPLY & ERECT |
| SITE: | Holyrood, NF | DATE: | 9-Feb-2009 |
| PROP. DWG: | | | |
| SCOPE: | Air Heater to Stack Breeching Study | | |

| **Breeching Solution Alternatives For U1, U2 & U3** | **S&E (Indicative Prices)** |
|---|---|
| **Breeching Solution A1 - Repair Insul. Blocks and Casing As Reg'd - U1, U2 & U3**<br>- Based on repairing 1610 ft² of blocks.<br>- Casing and expansion joints repairs are not included due to unknown condition. These repairs can be done during annual maintenance. | **$370,000** |
| **Breeching Solution A2 - Repair Insul. Blocks and Casing As Reg'd. Add 4" New External Insulation. - U1,U2 & U3**<br>- Based on repairing 1610 ft² of blocks.<br>- Casing and expansion joints repairs are not included due to unknown condition. These repairs can be done during annual maintenance. | **$1,488,000** |
| **Breeching Solution A3 - Repair Casing As Reg'd. Remove Internal Insul. Add 6" New External Insulation.- U1, U2 & U3**<br>- Tear-out of all blocks.<br>- Casing and expansion joints repairs are not included due to unknown condition. These repairs can be done during annual maintenance. | **$1,528,000** |
| **Breeching Solution B1a - New 1/4" C.S. Breeching with New Exp Jts and New 6" External Insulation. - U1, U2 & U3**<br>- All mild steel skin and stiffeners, primed<br>- 6" mineral fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding.<br>- Scaffolding Included | **$7,607,000** |
| **Breeching Solution B1b - New 1/4" Corten Breeching with New Exp Jts and New 6" External Insulation. - U1, U2 & U3**<br>- Corten Skin, mild steel stiffeners, primed<br>- 6" mineral Fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding.<br>- Scaffolding Included | **$7,624,000** |
| **Breeching Solution B1c - New 3/16" 304 S.S. Breeching with New Exp Jts and New 4" External Insulation. - U1, U2 & U3**<br>- 304 S.S. Skin, mild steel stiffeners, MS primed<br>- 4" mineral Fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding.<br>- Scaffolding Included | **$7,932,000** |
| **Breeching Solution B1d - New 3/16" Avesta Plate Breeching with New Exp Jts and New 4" External Insulation. - U1, U2 & U3**<br>- Avesta (2205) Skin, mild steel stiffeners, MS primed<br>- 4" mineral Fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding.<br>- Scaffolding Included | **8,178,000** |

**ALSTOM** Power Service

**INDICATIVE PRICING ESTIMATE**

| | | | |
|---|---|---|---|
| CONTRACT # | 40833010 | ESTIMATE TYPE: | INDICATIVE |
| CUSTOMER: | NLH | PROJECT TYPE: | SUPPLY & ERECT |
| SITE: | Holyrood, NF | DATE: | 9-Feb-2009 |
| PROP. DWG: | | | |
| SCOPE: | Air Heater to Stack Breeching Study | | |

| | |
|---|---|
| **Breeching Solution 3 - New 1/4" Corten Breeching with New Exp Jts and New 3" Internal Insulation. - U1, U2 & U3**<br>- Corten Skin, mild steel stiffeners, primed<br>- 3" ceramic wool and finish with 10 gauge S.S. liner.<br>- Scaffolding Included | **$8,540,000** |
| **Ice Protection Solution Alternatives For U1 & U2** | **S&E (Indicative Prices)** |
| Protection Solution B2a - Light-Wt (LW) 1-1/2" Grating, U1 & U2 Only | **$178,000** |
| Protection Solution B2b - U-shaped 7 ga Plate Encasement Slide Over Top Panels, U1 & U2 Only | **$186,000** |
| Protection Solution B2c - 3/16" C.S. Hood Over duct, U1 & U2 Only | **$189,000** |
| Protection Solution B2d - Extra Heavy Gage, Ribbed Al or Steel Cladding on Top Panels, U1 & U2 Only | 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 2 - Install Cloth Seal Over the Esisting Metallic Expansion Joint - U3 Only | **$88,000** |
| Expansion Jt Solution 3 - Replace the Expansion Joint In-kind (Metallic) - U3 Only | **$97,000** |
| Expansion Jt Solution 4 - Replace the Expansion Joint with Metallic New Design - U3 Only | **$98,000** |
| Expansion Jt Solution 5 - Replace the Expansion Joint with Fabric Joints - U3 Only | **$100,000** |

Notes:

(1) Construction estimate on ice protection and expansion joint is based on being on site in conjunction with the maintenance work.

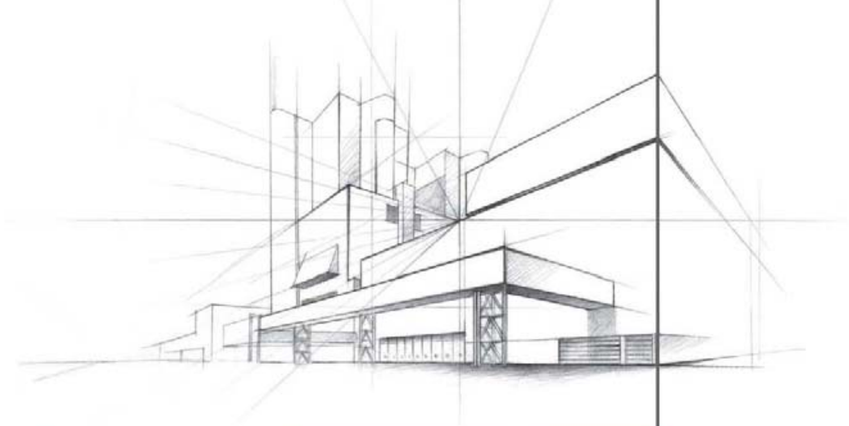
(2) For Unit #3 (B&W), we have no drawings. For future firm price proposal, we are expecting NLH to provide the necessary drawings of the existing ducting for us to work from.

(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.

# Powering Asset Performance



HYDRO

**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**

**December 18, 2008**
**Rev. 1 – March 4, 2009**
**Rev. 2 – August 28, 2009**

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LICENSED PROFESSIONAL ENGINEER
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PROVINCE OF ONTARIO

REV. 2 - [signature] 2009-08-28

**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.**

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**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
3) 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 $ft^2$ 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 1½" 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

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 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

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:

1) 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)

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

   *Cons: 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..

*<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; break-down 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) <u>keep current duct, add 6" of external insulation and remove internal liner blocks and silicate concrete (*Breeching Solution A3*)</u>; 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) <u>Replace the entire breeching</u>:

1) <u>original duct design</u>, made of

   a) <u>(*Breeching Solution B1a*)</u> - ¼" 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) (*Breeching Solution B1b*) - ¼" Corten or equivalent high temperature carbon steel c/w 6" of external water repellent insulation c/w watertight high quality cladding and flashing

c) (*Breeching Solution B1c*) - 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

*Pros: 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*

*Cons: 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) 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) (*Protection Solution B2a*) - light-weight (LW), 1½" catwalk grating on the top panels (over aluminium cladding) attached to stack and side panels

b) (*Protection Solution B2b*) - 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) (*Protection Solution B2d*) - extra heavy gage, ribbed aluminium or steel cladding on the top panels

*Pros: 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*

*Cons: 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

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

   *Cons: 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 Jt 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 Jt 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 Jt 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 Jt 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 Jt 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.

**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.<br>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

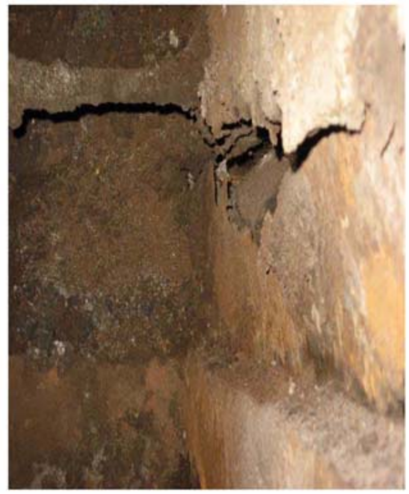

Fig. 9: Unit 1 – Duct corroded through

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

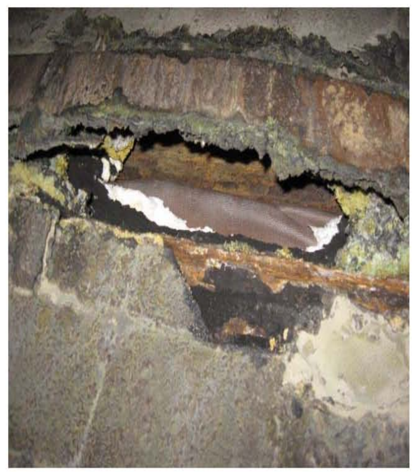

Fig. 15: Unit 1 – Damaged expansion joint

**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**

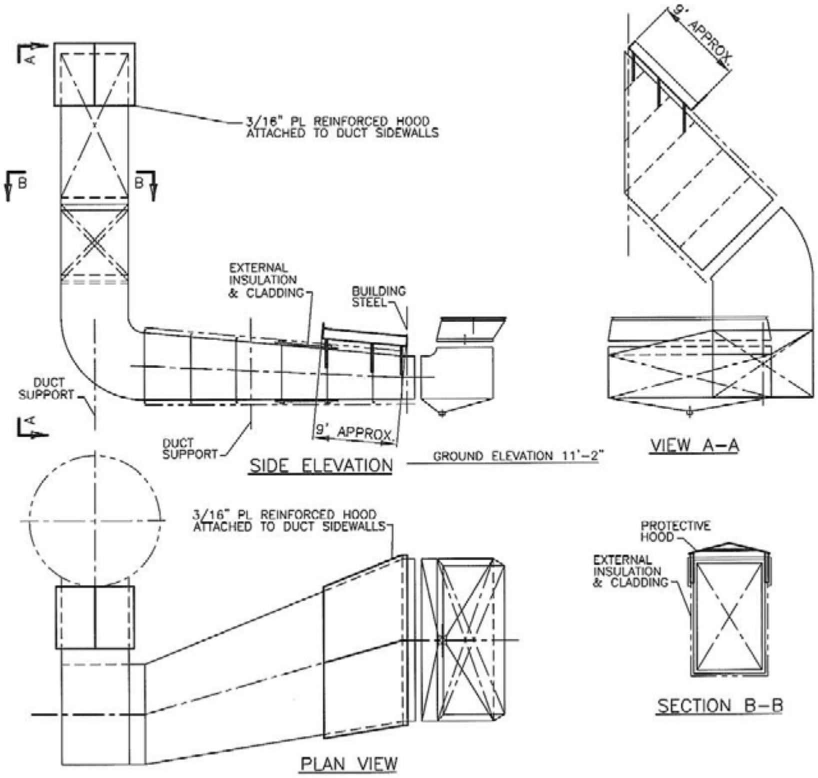


**Fig. 27: Proposed cladding protection – protective hood**

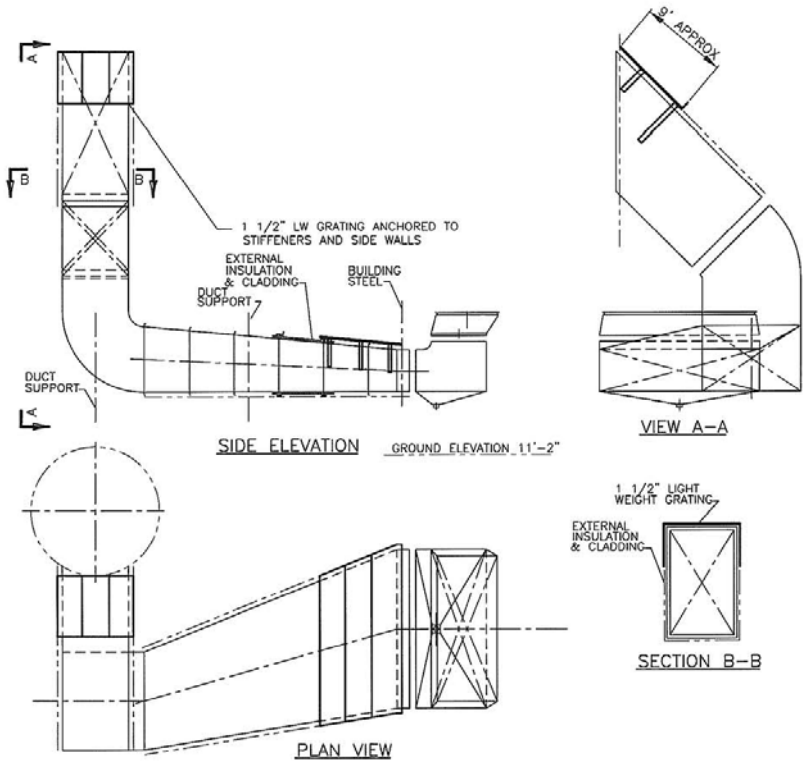


**Fig. 28: Proposed cladding protection – catwalk grating**

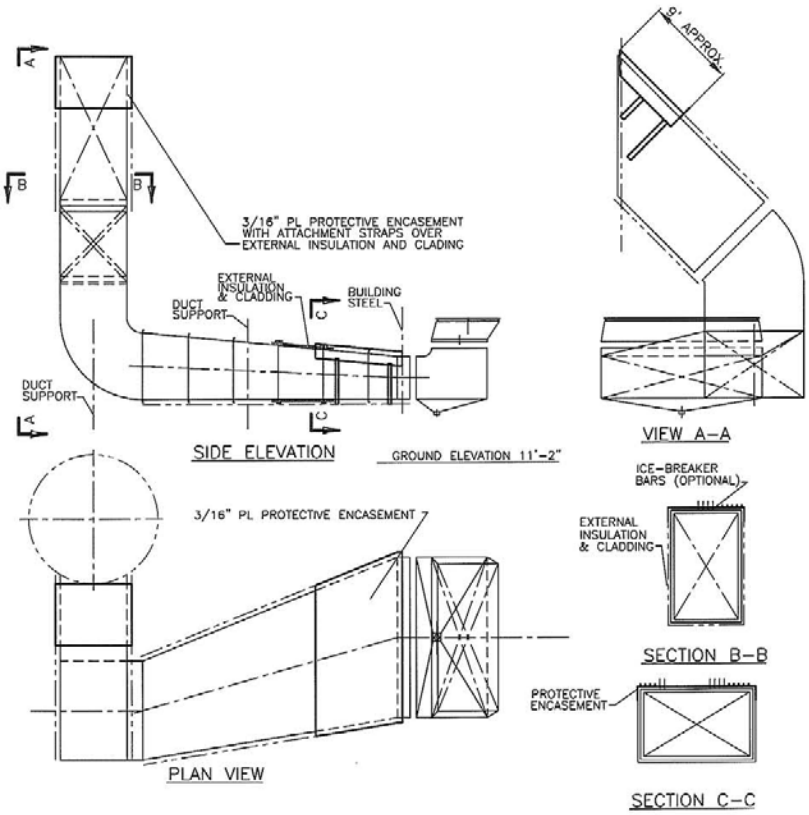


**Fig. 29: Proposed cladding protection – 7ga. plate encasement**

Joint 1

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

Joint 2 - corner

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** Power Service

**INDICATIVE 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**<br>- Based on repairing 1610 ft² of blocks.<br>- Casing and expansion joints repairs are not included due to unknown condition. These repairs can be done during annual maintenance.<br>- 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**<br>- Corten Skin, mild steel stiffeners, primed<br>- 6" mineral Fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding.<br>- 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:<br>- Primed and top coat<br>- C.S. material | $214,252 |

| Breeching Support Structure Replacement For U1 & U2 | S&E (Indicative Prices) |
|---|---|
| Replace Breeching Support Structure for U1 & U2 Only:<br>- SP-6 blast c/w primer and top coat<br>- End frames are assembled as a unit<br>- Welding CWB 47.1<br>- Material G40.21 44W<br>- 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. | $153,661 |

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

December 18, 2008
Rev. 1 – March 4, 2009
Rev. 2 – August 28, 2009
Rev. 3 – March 25, 2010

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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.**

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**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
3) 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 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.

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 1½" 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.

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:

1) 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)

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

   *Cons: 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..

   *Pros: 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 due to gas cooling 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*

*Cons: added cost of external insulation and cladding c/w protection against damage; break-down 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.

   *Pros: 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 due to gas cooling will be minimized or eliminated if external insulation is maintained; improved access for duct inspection and cleaning*

   *Cons: 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 (*Breeching Solution A2*) 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) (*Breeching Solution B1a*) - ¼" 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*) - ¼" Corten or equivalent high temperature carbon steel c/w 6" of external water repellent insulation c/w watertight high quality cladding and flashing

   c) (*Breeching Solution B1c*) - 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) (*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

*Pros: 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*

*Cons: 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) 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) (*Protection Solution B2a*) - light-weight (LW), 1½" catwalk grating on the top panels (over aluminium cladding) attached to stack and side panels

b) (*Protection Solution B2b*) - 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) (*Protection Solution B2d*) - extra heavy gage, ribbed aluminium or steel cladding on the top panels

*Pros: 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*

*Cons: 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

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

   *Cons: 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 Jt 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 Jt 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 Jt 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 Jt 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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5) Replace the expansion joints with cloth joints, properly engineered *(Expansion Jt 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.