

1    Q.    **Re: Project B-12 Upgrade Unit 2 Stack Breeching**

2            Provide copies of all previous drafts or revisions of the Alstom Report at Appendix

3            A, as identified at page A2 of Appendix A.

4

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6    A.    Please refer to the attachment.



# **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**

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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.



## 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 than 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.

## **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), rendering 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<sup>2</sup> 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.

## **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.



## 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 than 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  $\pm 30\%$ , and is 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; breakdown of the internal insulation material and adhesive membrane will likely not subside, may become worse; the internal liner will still have to be maintained, therefore prohibitive cost of repairs will remain; continuing difficulties accessing the sites for inspection; cleaning ash and debris from the duct floor remains impaired;*

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

*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) -  $\frac{1}{4}$ " 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) -  $\frac{1}{4}$ " 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 be 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.
- 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. 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**

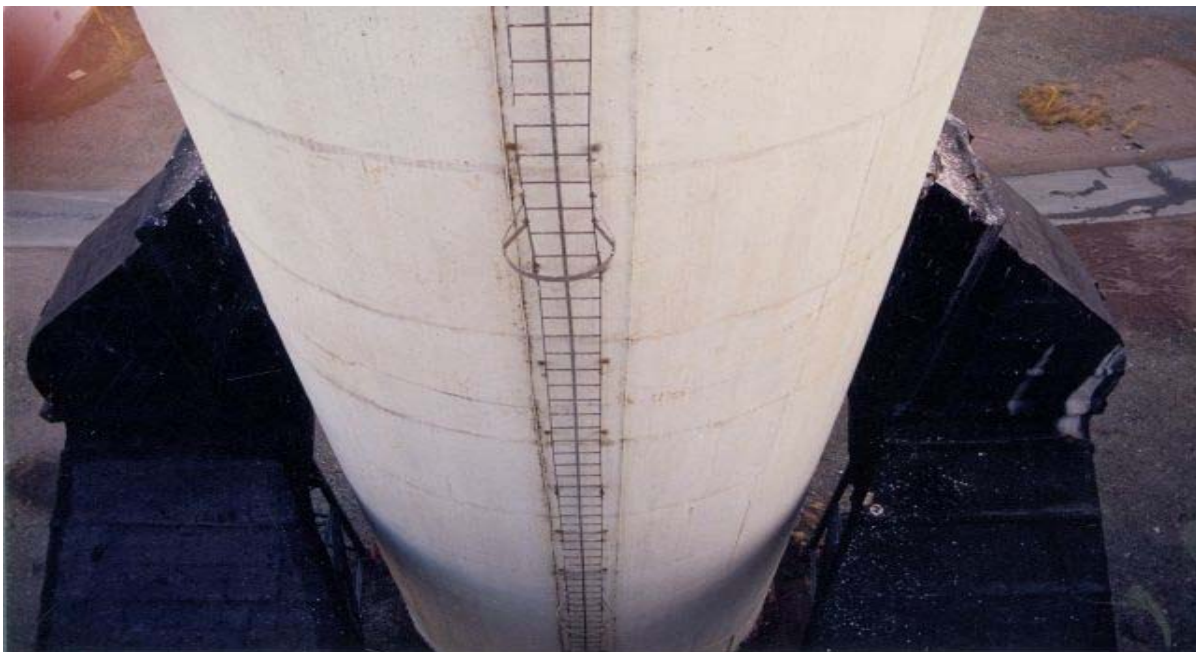


**Fig. 4: Original Breeching, bend section – Unit 1 or 2**





**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**





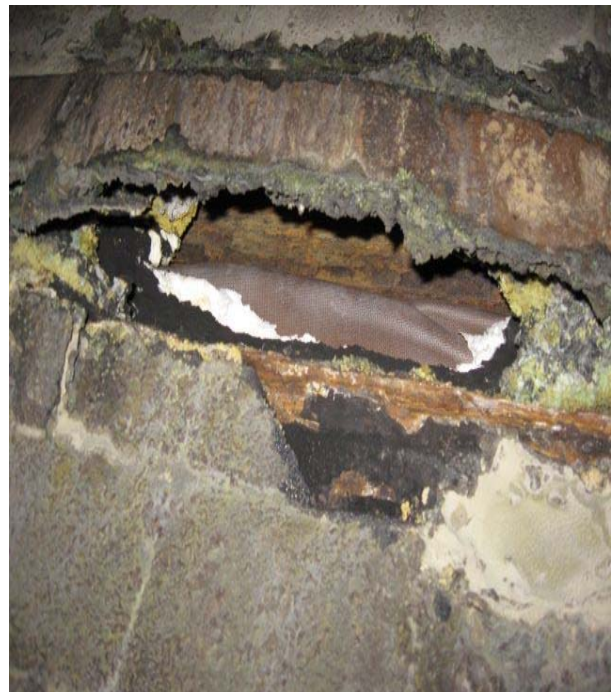
**Fig. 12: Unit 1 – Replaced blocks**



**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**



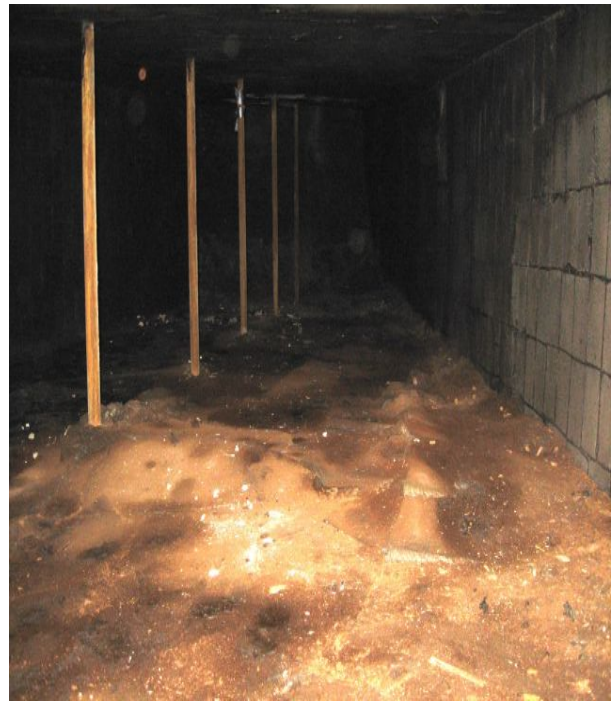
**Fig. 18: Unit 2 – Missing insulation blocks**



**Fig. 19: Unit 2 – Missing insulation blocks**



**Fig. 20: Unit 2 – Cracked cement floor**



**Fig. 21: Unit 2 – Cracked cement floor**

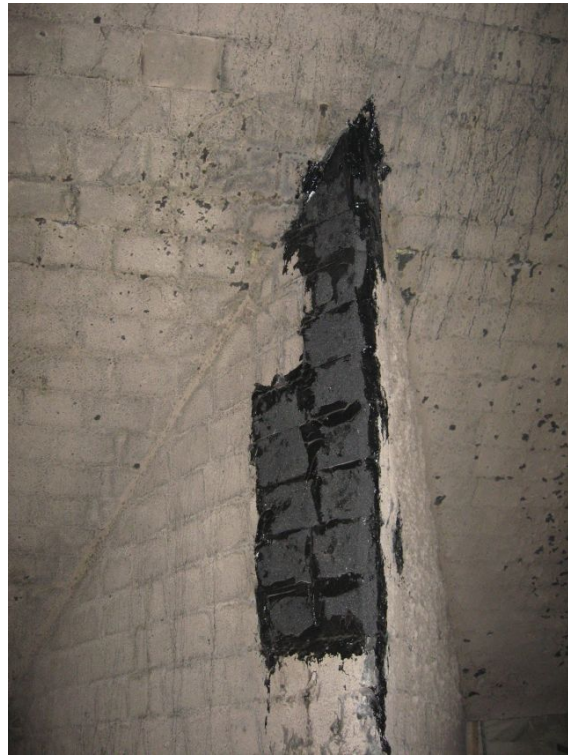


**Fig.22: Unit 2 – External coating break down**





**Fig. 23: Unit 3 – Repairs 2007**



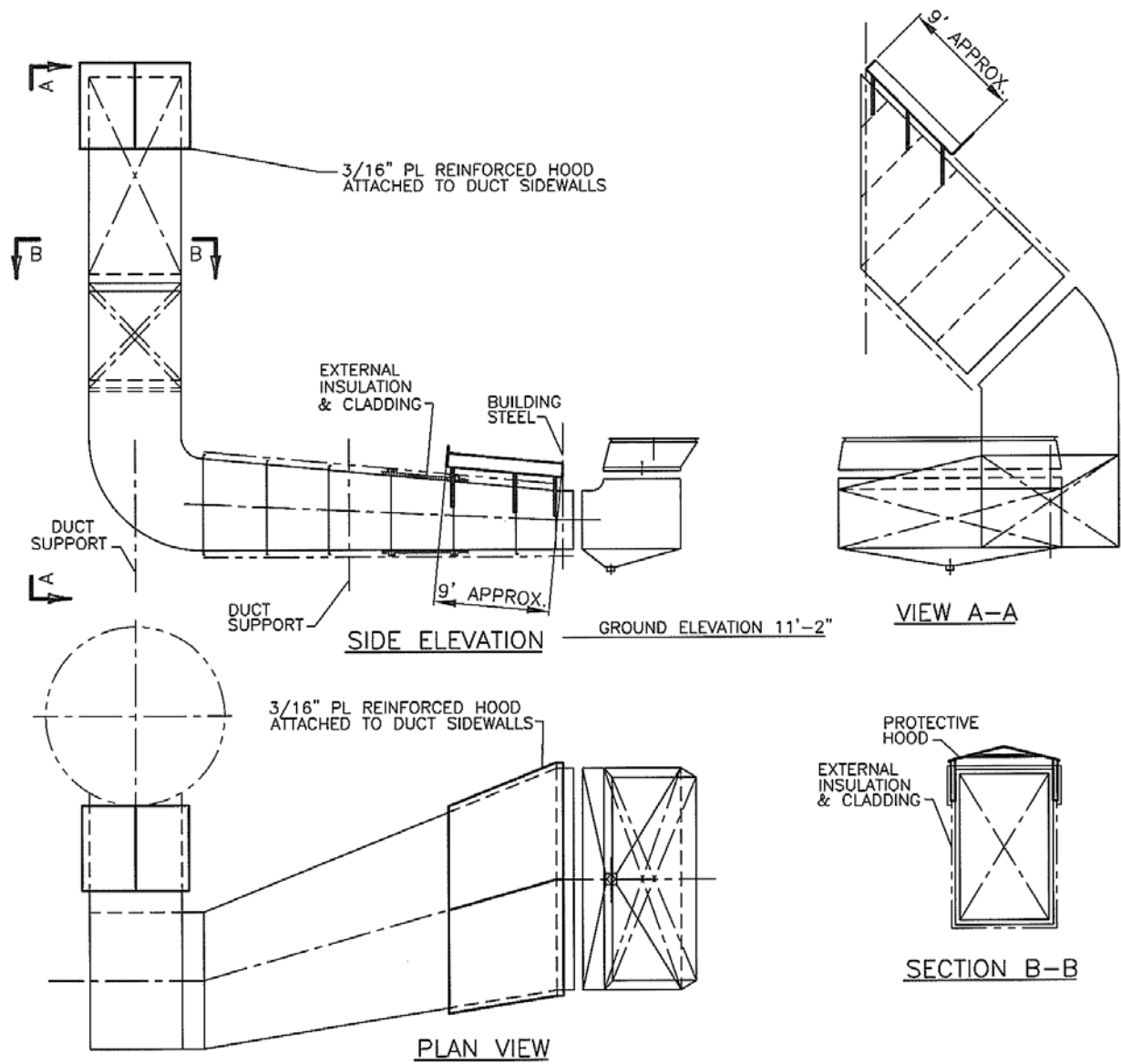
**Fig. 24: Unit 3 – Crotch repairs**



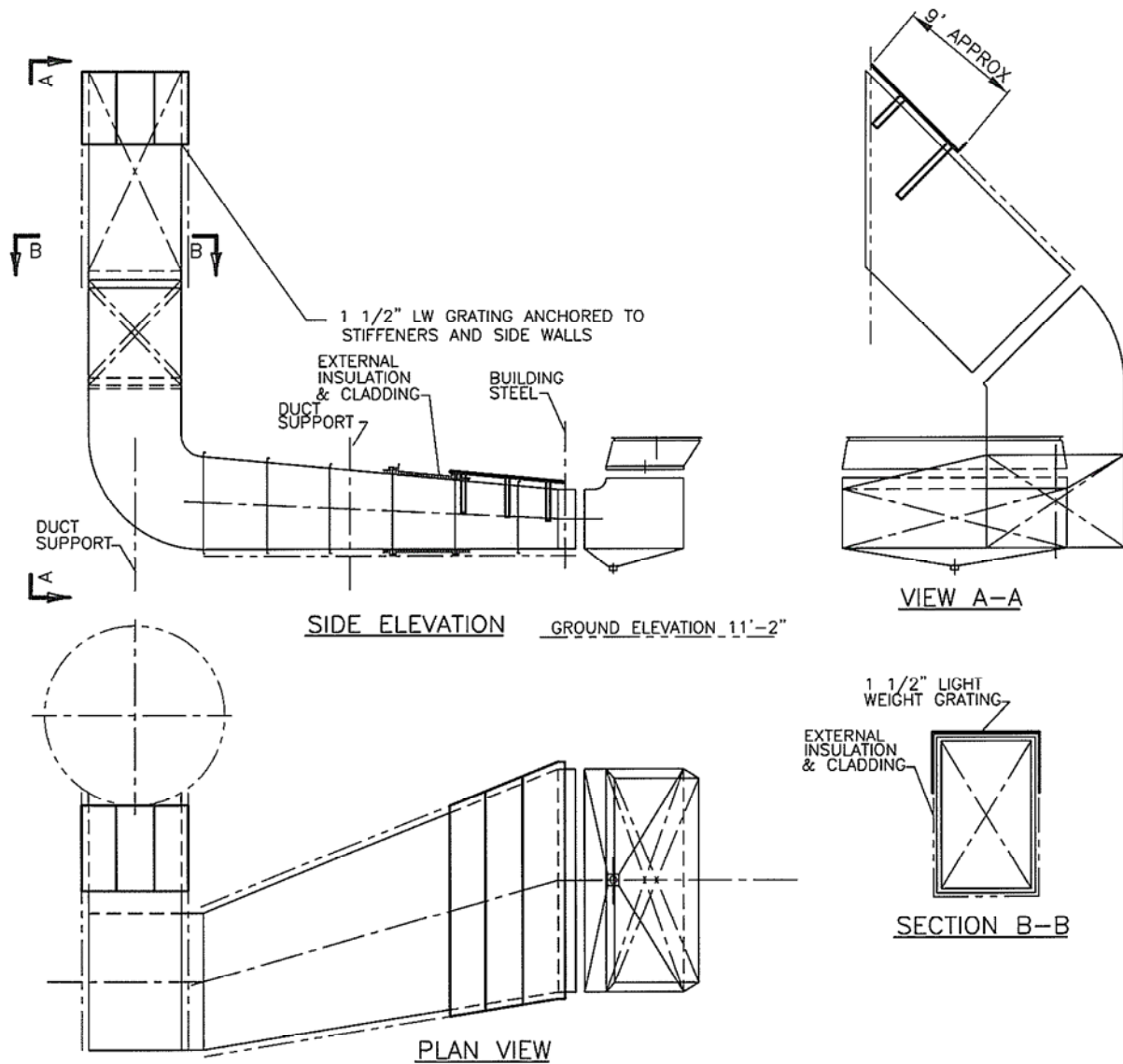
**Fig. 25: Unit 3 – Patched casing (from inside)**



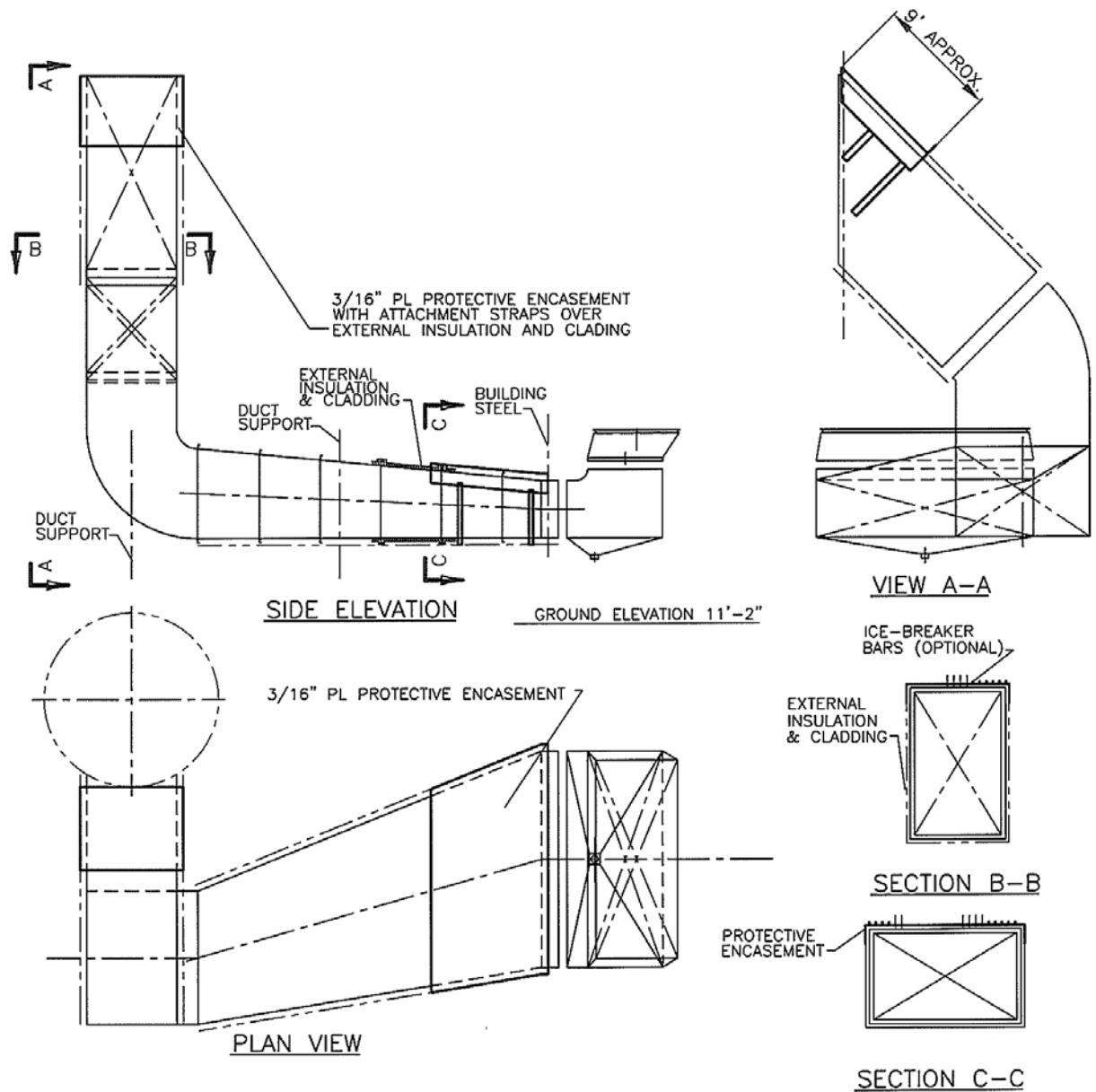
**Fig. 26: Unit 3 – Top near the stack**



**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**



Power Service

## INDICATIVE PRICING ESTIMATE

**CONTRACT #** 40833010  
**CUSTOMER:** NLH  
**SITE:** Holyrood, NF  
**PROP. DWG:**  
**SCOPE:** Air Heater to Stack Breeching Study

**ESTIMATE TYPE:** INDICATIVE  
**PROJECT TYPE:** SUPPLY & ERECT  
**DATE:** 19-Aug-2009  
 Rev 2 - 29/06/2010

Breeching Solution Alternatives For U1, U2 & U3	S&E (Indicative Prices)
<b>Breeching Solution A2 Mod - Remove Rogue Insul. Blocks and Repair Casing As Reg'd. Add 6" New External Insulation. - U1,U2 &amp; U3</b> - Based on removing 1610 ft <sup>2</sup> of blocks. (Assumed) - Casing and expansion joints repairs are not included due to unknown condition. These repairs can be done during annual maintenance. - To be done at the same time as annual maintenance.	\$1,318,080
<b>Breeching Solution B1b - New 1/4" Corten Breeching with New Exp Jts and New 6" External Insulation. - U1, U2 &amp; U3</b> - Corten Skin, mild steel stiffeners, primed - 6" mineral Fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding. - Scaffolding Included	\$7,678,456
Ice Protection Solution Alternatives For U1 & U2	S&E (Indicative Prices)
Protection Solution B2b - U-shaped 7 ga Plate Encasement Slide Over Top Panels, U1 & U2 Only: - Primed and top coat - C.S. material	\$214,252
Breeching Support Structure Replacement For U1 & U2	S&E (Indicative Prices)
Replace Breeching Support Structure for U1 & U2 Only: - SP-6 blast c/w primer and top coat - End frames are assembled as a unit - Welding CWB 47.1 - Material G40.21 44W - To be installed at the same time with B1b breeching solution only. Additional cost is required with A2 breeching solution since the existing breeching is not removed.	\$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.





# **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.



## 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 than 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.

## **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), rendering 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.

## **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<sup>2</sup> 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.

## **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.

## **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 than 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  $\pm 30\%$ , and is 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) -  $\frac{1}{4}$ " 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) -  $\frac{1}{4}$ " 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 be 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.



- 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**

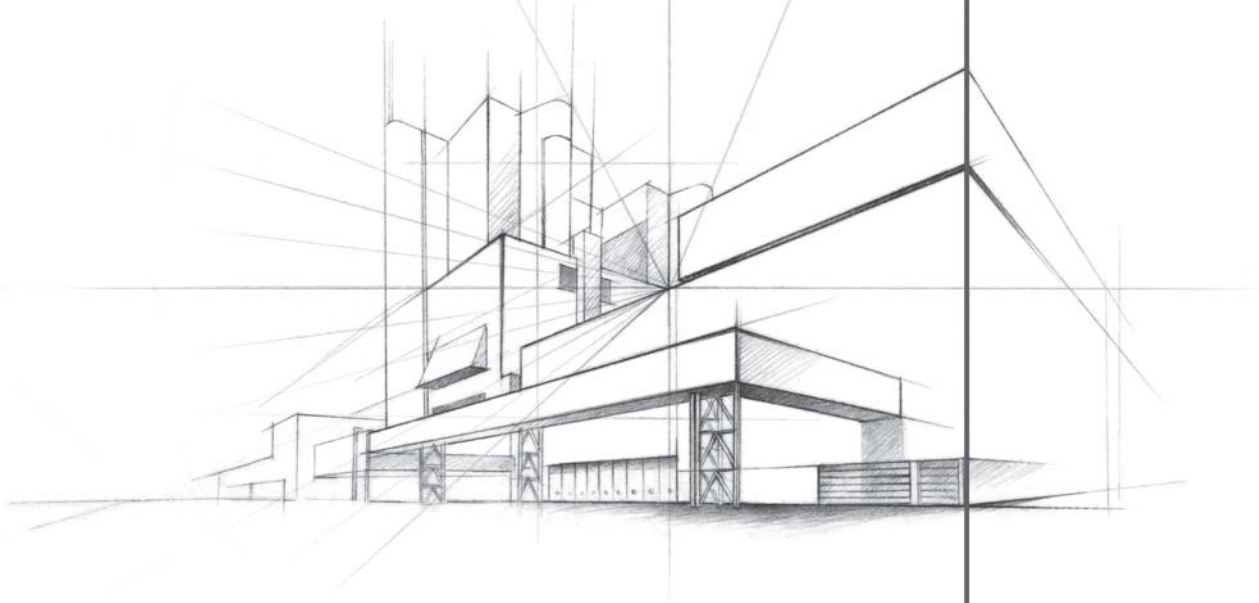
A meeting was held at Holyrood site on March 5, 2009 to review the findings of the Study as issued in Revision 1 dated March 4, 2009.

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.

# Powering **Asset** Performance



**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**



# **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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REV. 2 - *Jim* 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 than 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.

## **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), rendering 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.

## **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<sup>2</sup> 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.

## **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.

## **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 than 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  $\pm 30\%$ , and is 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) -  $\frac{1}{4}$ " 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) -  $\frac{1}{4}$ " 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),  $1\frac{1}{2}$ " 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 be 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.
- 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. 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**

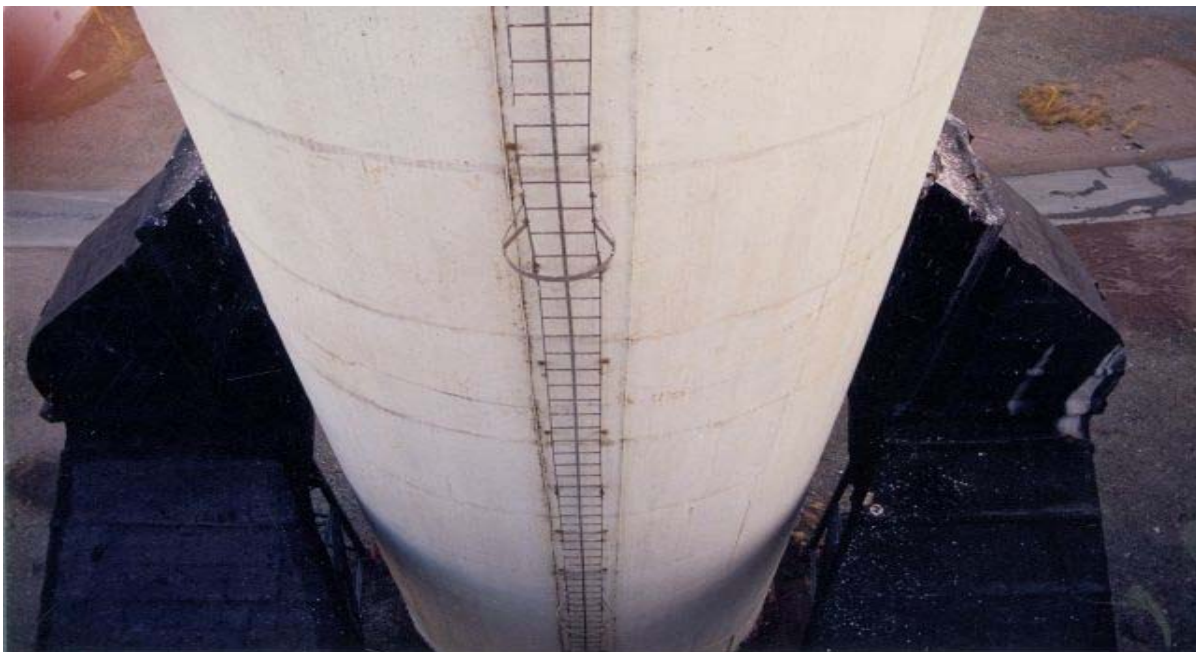


**Fig. 4: Original Breeching, bend section – Unit 1 or 2**





**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 Breaching, 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**



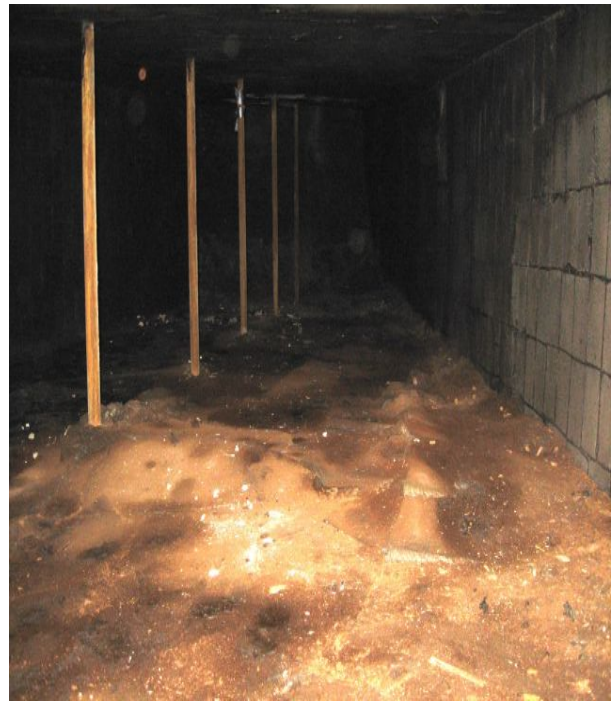
**Fig. 18: Unit 2 – Missing insulation blocks**



**Fig. 19: Unit 2 – Missing insulation blocks**



**Fig. 20: Unit 2 – Cracked cement floor**



**Fig. 21: Unit 2 – Cracked cement floor**

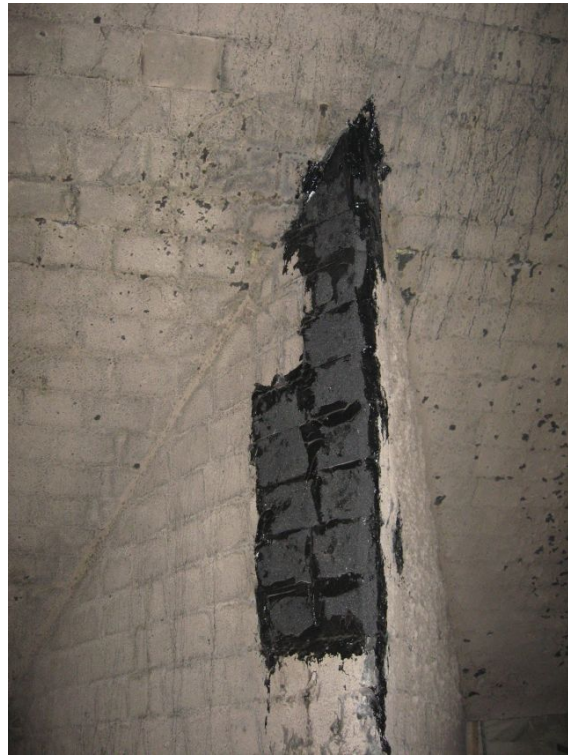


**Fig.22: Unit 2 – External coating break down**





**Fig. 23: Unit 3 – Repairs 2007**



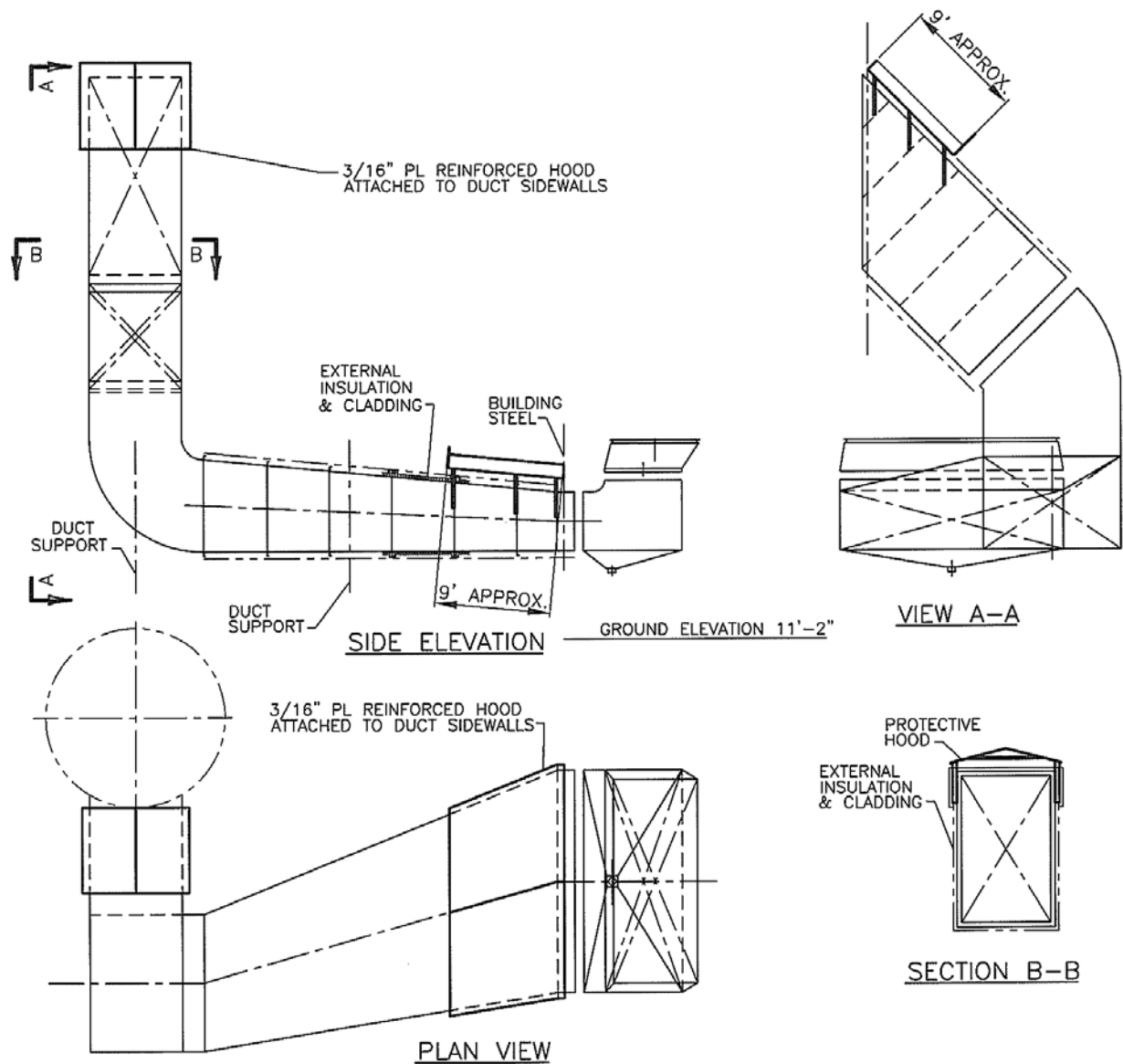
**Fig. 24: Unit 3 – Crotch repairs**



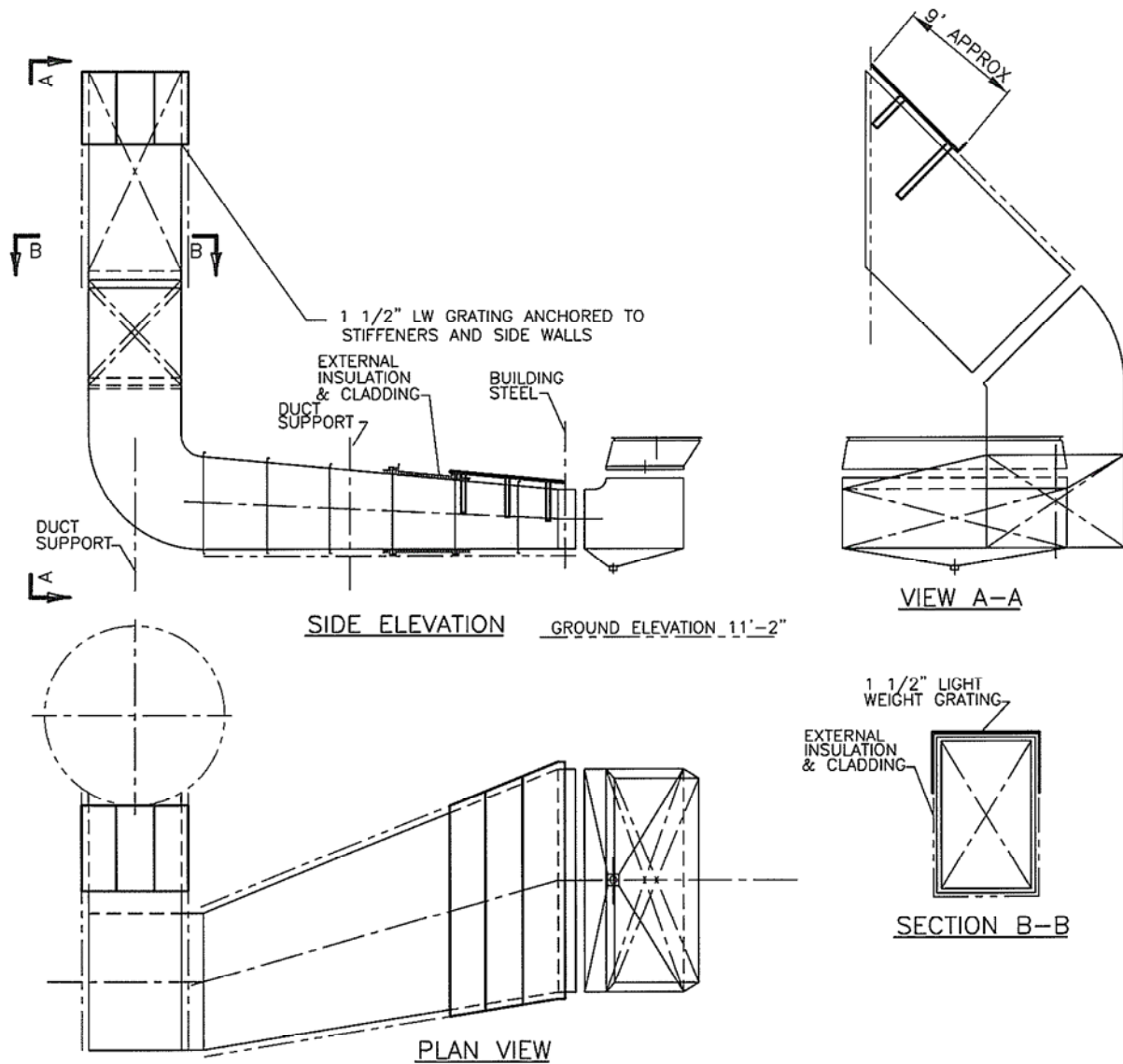
**Fig. 25: Unit 3 – Patched casing (from inside)**



**Fig. 26: Unit 3 – Top near the stack**

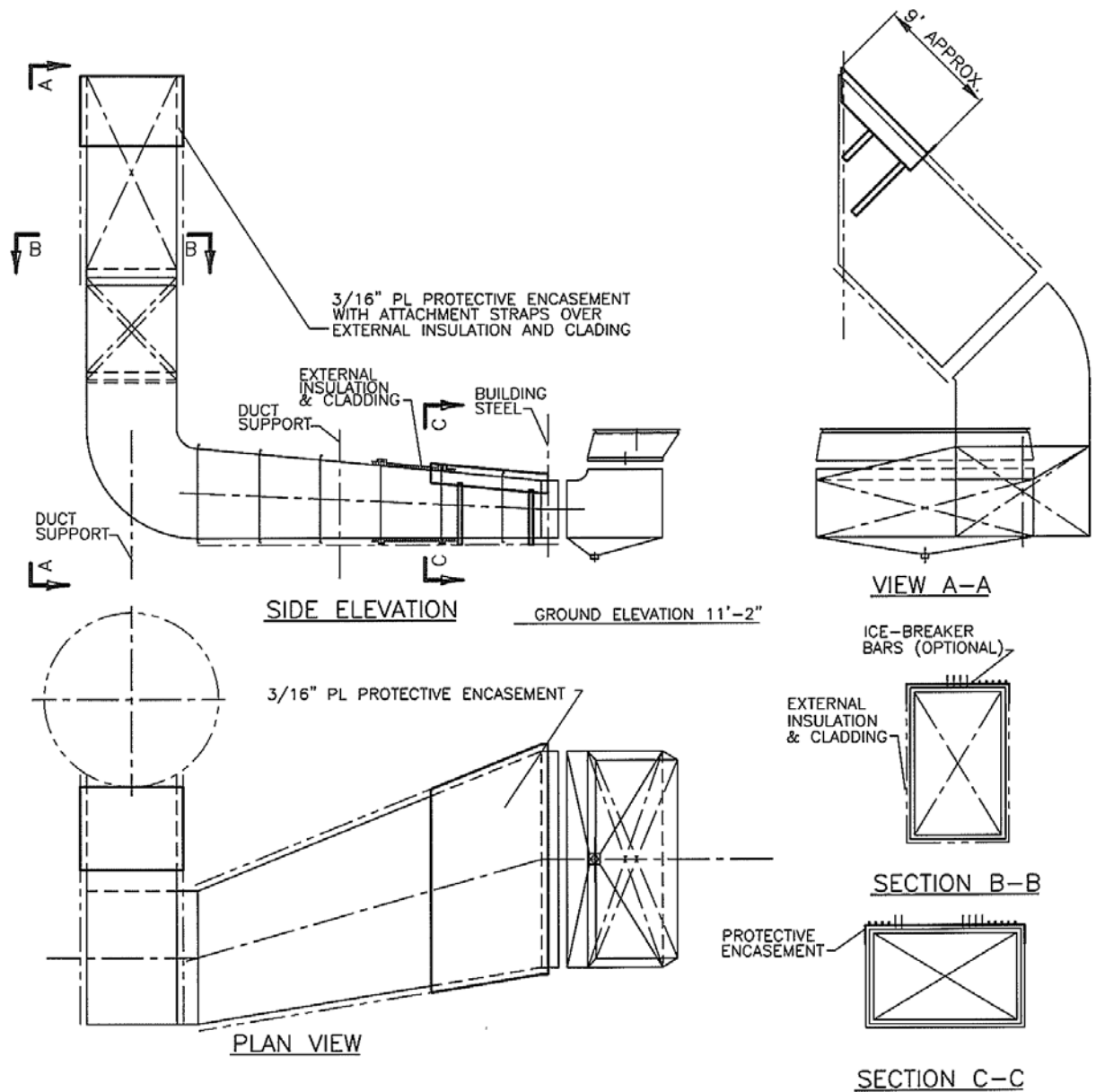


**Fig. 27: Proposed cladding protection – protective hood**



**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**



Power Service

## INDICATIVE PRICING ESTIMATE

**CONTRACT #** 40833010  
**CUSTOMER:** NLH  
**SITE:** Holyrood, NF  
**PROP. DWG:**  
**SCOPE:** Air Heater to Stack Breeching Study

**ESTIMATE TYPE:** INDICATIVE  
**PROJECT TYPE:** SUPPLY & ERECT  
**DATE:** 19-Aug-2009

Breeching Solution Alternatives For U1, U2 & U3	S&E (Indicative Prices)
<b>Breeching Solution A2 - Repair Insul. Blocks and Casing As Reg'd. Add 4" New External Insulation. - U1,U2 &amp; U3</b> - Based on repairing 1610 ft <sup>2</sup> of blocks. - Casing and expansion joints repairs are not included due to unknown condition. These repairs can be done during annual maintenance. - To be done at the same time as annual maintenance.	\$1,504,806
<b>Breeching Solution B1b - New 1/4" Corten Breeching with New Exp Jts and New 6" External Insulation. - U1, U2 &amp; U3</b> - Corten Skin, mild steel stiffeners, primed - 6" mineral Fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding. - Scaffolding Included	\$7,678,456
Ice Protection Solution Alternatives For U1 & U2	S&E (Indicative Prices)
<b>Protection Solution B2b - U-shaped 7 ga Plate Encasement Slide Over Top Panels, U1 &amp; U2 Only:</b> - Primed and top coat - C.S. material	\$214,252
Breeching Support Structure Replacement For U1 & U2	S&E (Indicative Prices)
<b>Replace Breeching Support Structure for U1 &amp; U2 Only:</b> - SP-6 blast c/w primer and top coat - End frames are assembled as a unit - Welding CWB 47.1 - Material G40.21 44W - To be installed at the same time with B1b breeching solution only. Additional cost is required with A2 breeching solution since the existing breeching is not removed.	\$153,661

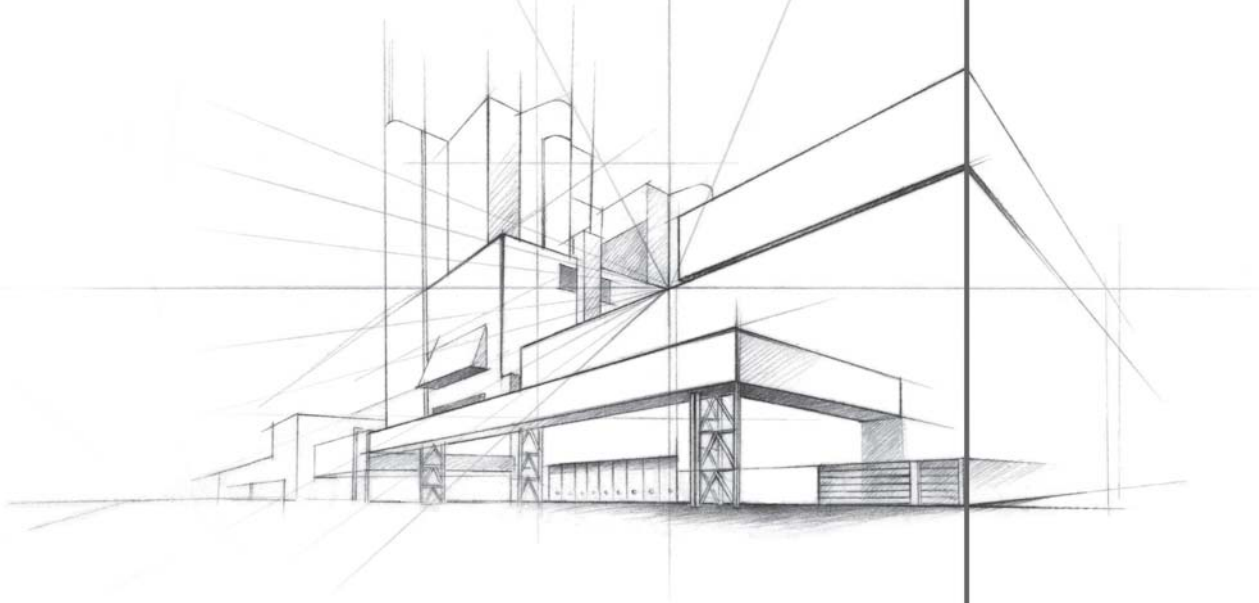
## Notes:

- (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.





# Powering **Asset** Performance



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



# **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**

## DISCLAIMER STATEMENT

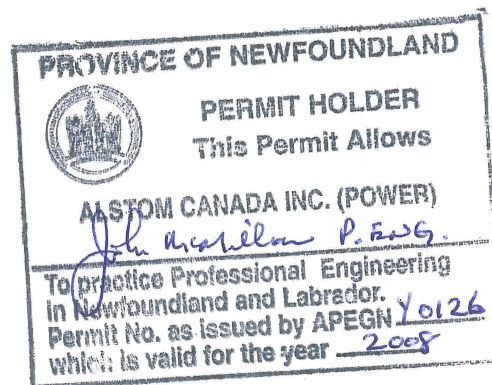
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**This report was prepared by Pavel Kratina, P. Eng.  
and was reviewed by John McMillan, P.Eng.**

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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 upgrades 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 than 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.

## **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), rendering 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.



## **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<sup>2</sup> 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.

## **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.

## **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 than 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 – 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  $\pm 30\%$ , and is 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) -  $\frac{1}{4}$ " 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) -  $\frac{1}{4}$ " 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),  $1\frac{1}{2}$ " 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 be 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.

- 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. 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**

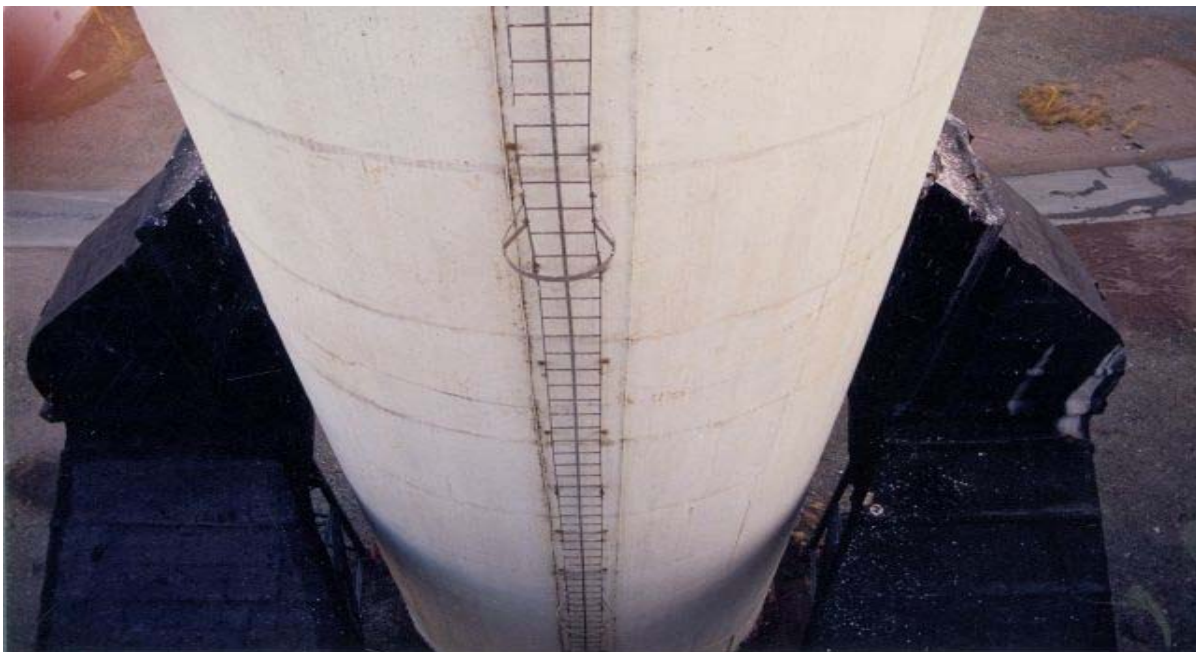


**Fig. 4: Original Breeching, bend section – Unit 1 or 2**





**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 Breaching, 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**





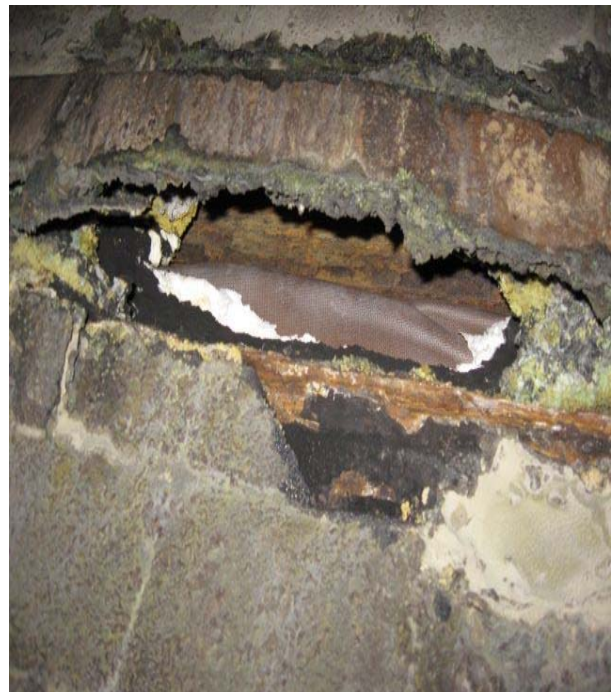
**Fig. 12: Unit 1 – Replaced blocks**



**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**



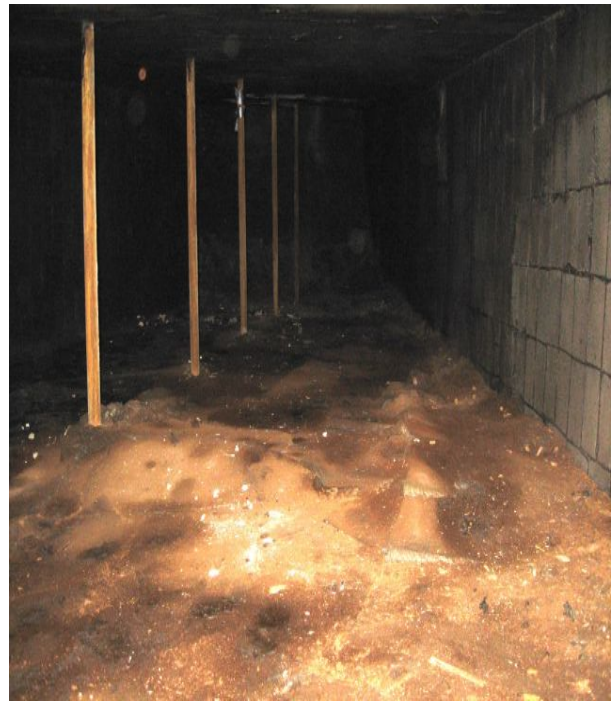
**Fig. 18: Unit 2 – Missing insulation blocks**



**Fig. 19: Unit 2 – Missing insulation blocks**



**Fig. 20: Unit 2 – Cracked cement floor**



**Fig. 21: Unit 2 – Cracked cement floor**

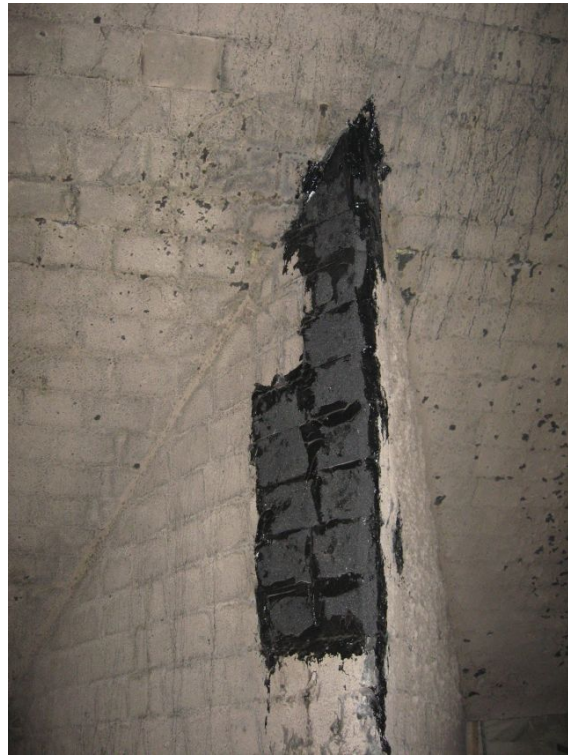


**Fig.22: Unit 2 – External coating break down**





**Fig. 23: Unit 3 – Repairs 2007**



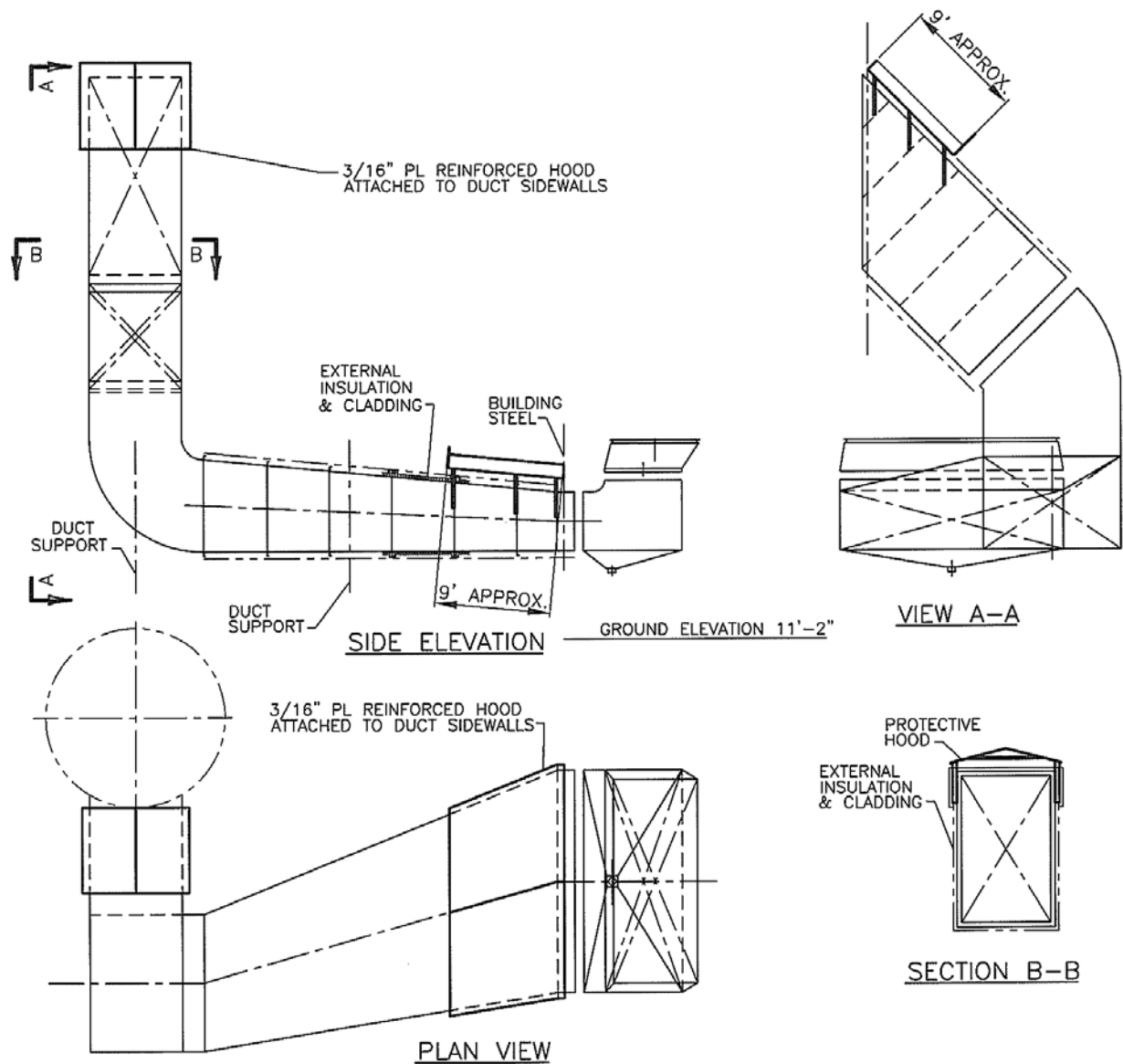
**Fig. 24: Unit 3 – Crotch repairs**



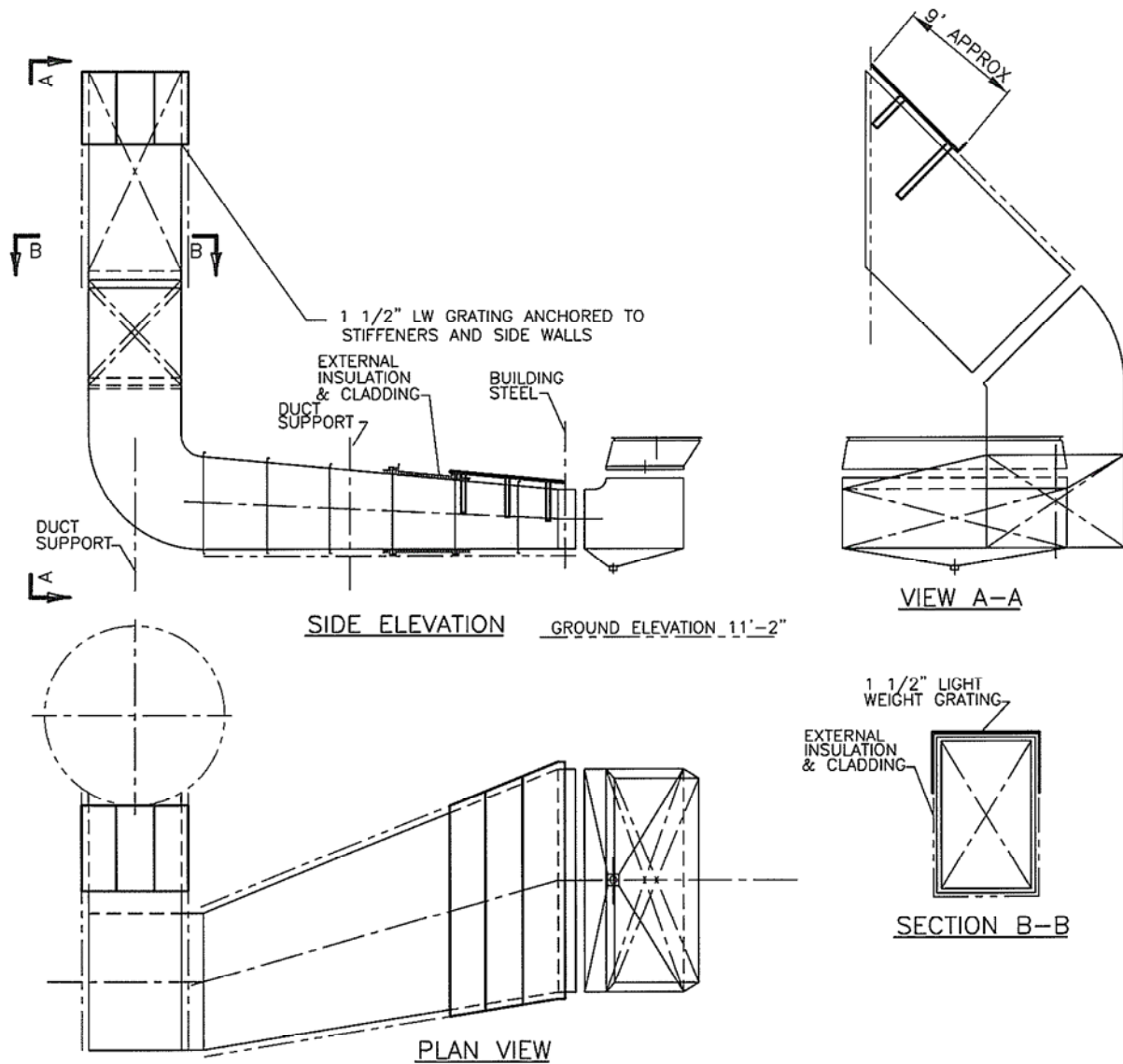
**Fig. 25: Unit 3 – Patched casing (from inside)**



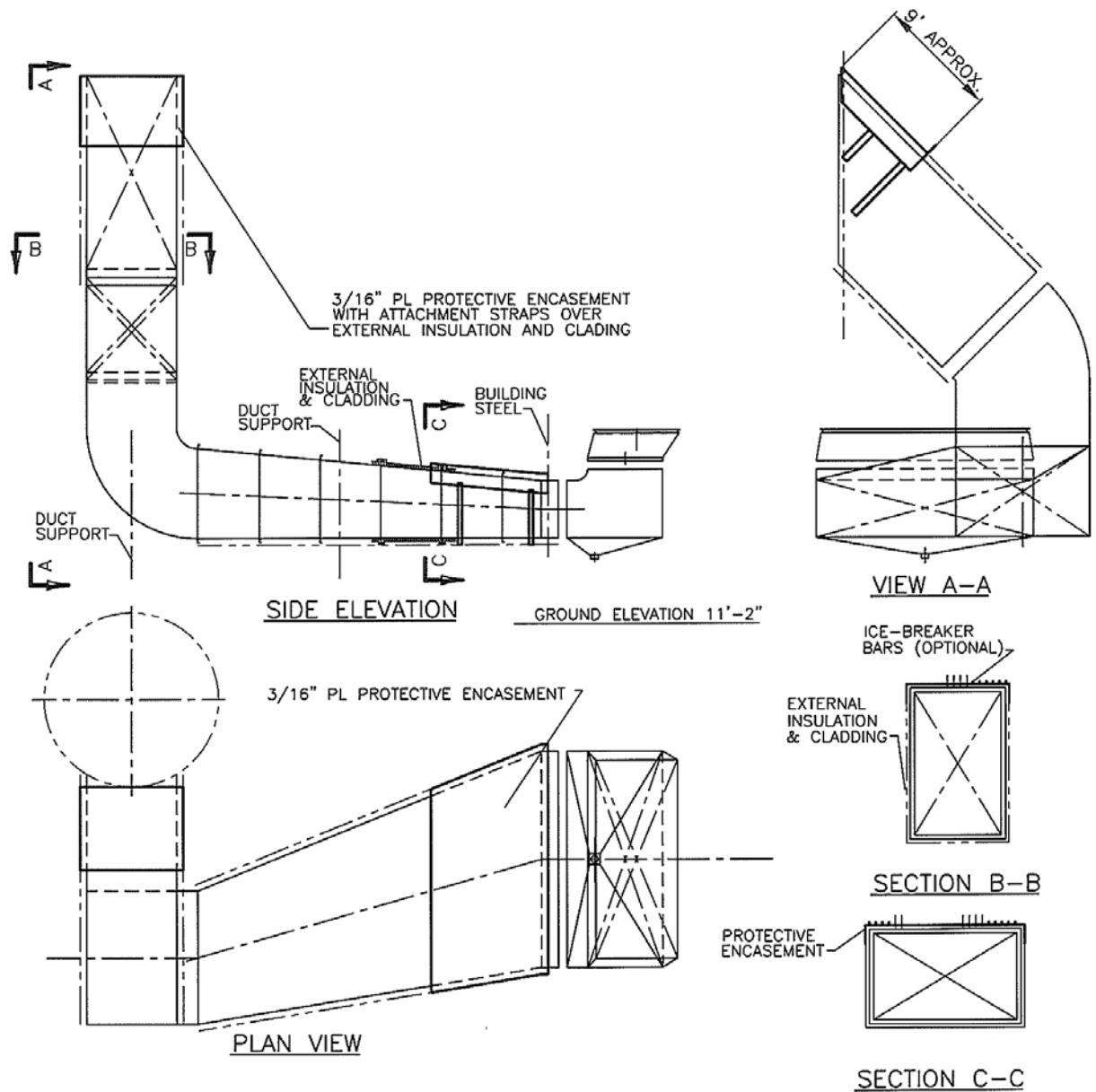
**Fig. 26: Unit 3 – Top near the stack**



**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**

		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)
<b>Breeching Solution A1 - Repair Insul. Blocks and Casing As Reg'd - U1, U2 &amp; U3</b> - Based on repairing 1610 ft <sup>2</sup> of blocks. - Casing and expansion joints repairs are not included due to unknown condition. These repairs can be done during annual maintenance.	\$370,000
<b>Breeching Solution A2 - Repair Insul. Blocks and Casing As Reg'd. Add 4" New External Insulation. - U1,U2 &amp; U3</b> - Based on repairing 1610 ft <sup>2</sup> of blocks. - Casing and expansion joints repairs are not included due to unknown condition. These repairs can be done during annual maintenance.	\$1,488,000
<b>Breeching Solution A3 - Repair Casing As Reg'd. Remove Internal Insul. Add 6" New External Insulation.- U1, U2 &amp; U3</b> - Tear-out of all blocks. - Casing and expansion joints repairs are not included due to unknown condition. These repairs can be done during annual maintenance.	\$1,528,000
<b>Breeching Solution B1a - New 1/4" C.S. Breeching with New Exp Jts and New 6" External Insulation. - U1, U2 &amp; U3</b> - All mild steel skin and stiffeners, primed - 6" mineral fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding. - Scaffolding Included	\$7,607,000
<b>Breeching Solution B1b - New 1/4" Corten Breeching with New Exp Jts and New 6" External Insulation. - U1, U2 &amp; U3</b> - Corten Skin, mild steel stiffeners, primed - 6" mineral Fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding. - Scaffolding Included	\$7,624,000
<b>Breeching Solution B1c - New 3/16" 304 S.S. Breeching with New Exp Jts and New 4" External Insulation. - U1, U2 &amp; U3</b> - 304 S.S. Skin, mild steel stiffeners, MS primed - 4" mineral Fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding. - Scaffolding Included	\$7,932,000
<b>Breeching Solution B1d - New 3/16" Avesta Plate Breeching with New Exp Jts and New 4" External Insulation. - U1, U2 &amp; U3</b> - Avesta (2205) Skin, mild steel stiffeners, MS primed - 4" mineral Fibre board and finish with 0.040" box rib aluminium jacket for water tight cladding. - Scaffolding Included	8,178,000

		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 Breaching Study		

<b>Breeching Solution 3 - New 1/4" Corten Breeching with New Exp Jts and New 3" Internal Insulation. - U1, U2 &amp; U3</b> - Corten Skin, mild steel stiffeners, primed - 3" ceramic wool and finish with 10 gauge S.S. liner. - Scaffolding Included	<b>\$8,540,000</b>
<b>Ice Protection Solution Alternatives For U1 &amp; U2</b>	<b>S&amp;E (Indicative Prices)</b>
Protection Solution B2a - Light-Wt (LW) 1-1/2" Grating, U1 & U2 Only	<b>\$178,000</b>
Protection Solution B2b - U-shaped 7 ga Plate Encasement Slide Over Top Panels, U1 & U2 Only	<b>\$186,000</b>
Protection Solution B2c - 3/16" C.S. Hood Over duct, U1 & U2 Only	<b>\$189,000</b>
Protection Solution B2d - Extra Heavy Gage, Ribbed Al or Steel Cladding on Top Panels, U1 & U2 Only	No suitable material for this application
<b>Expansion Joint Solution Alternatives For U3</b>	<b>S&amp;E (Indicative Prices)</b>
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 Existing Metallic Expansion Joint - U3 Only	<b>\$88,000</b>
Expansion Jt Solution 3 - Replace the Expansion Joint In-kind (Metallic) - U3 Only	<b>\$97,000</b>
Expansion Jt Solution 4 - Replace the Expansion Joint with Metallic New Design - U3 Only	<b>\$98,000</b>
Expansion Jt Solution 5 - Replace the Expansion Joint with Fabric Joints - U3 Only	<b>\$100,000</b>

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.

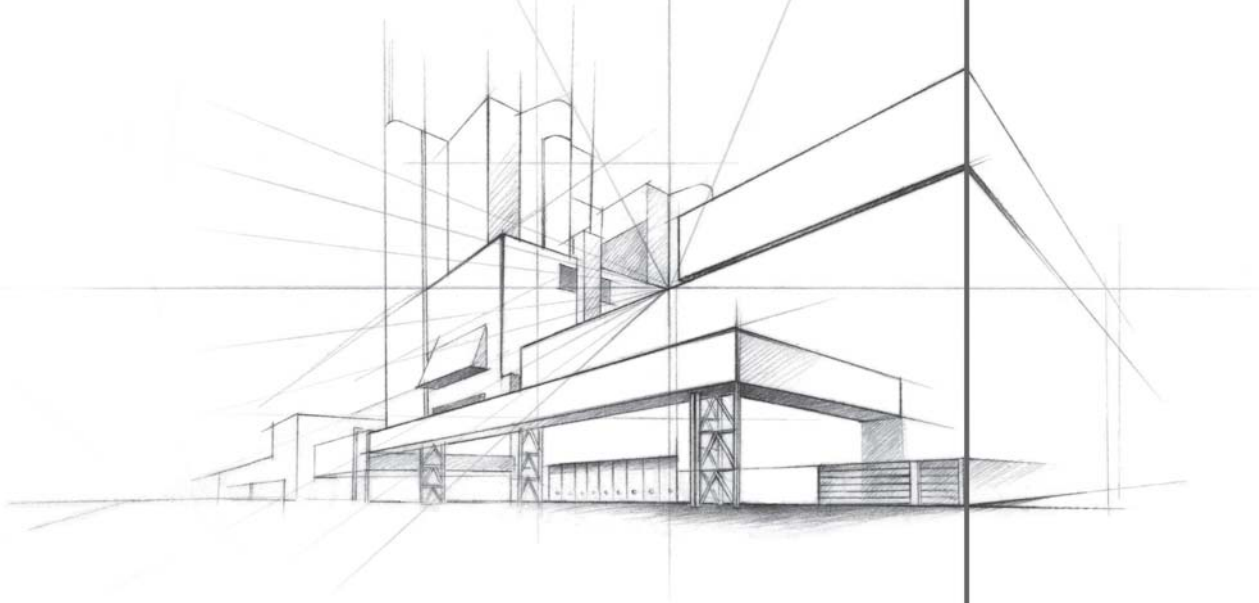
(4) For U3 expansion joint repair, it should be done on time and & material because the condition is not known

(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



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



## **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**

### DISCLAIMER STATEMENT

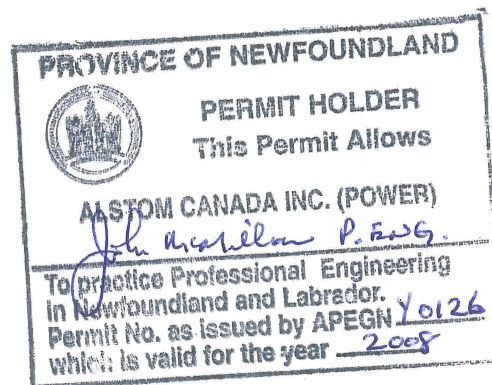
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**This report was prepared by Pavel Kratina, P. Eng.  
and was reviewed by John McMillan, P.Eng.**

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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 upgrades 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 than 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.



## **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), rendering 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.

## **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<sup>2</sup> 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.



## **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.

## **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 than 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 – 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*

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

**B) Replace the entire breeching:**

- 1) original duct design, made of
  - a)  $\frac{1}{4}$ " 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)  $\frac{1}{4}$ " 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





*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 be 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 extend 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 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: 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**

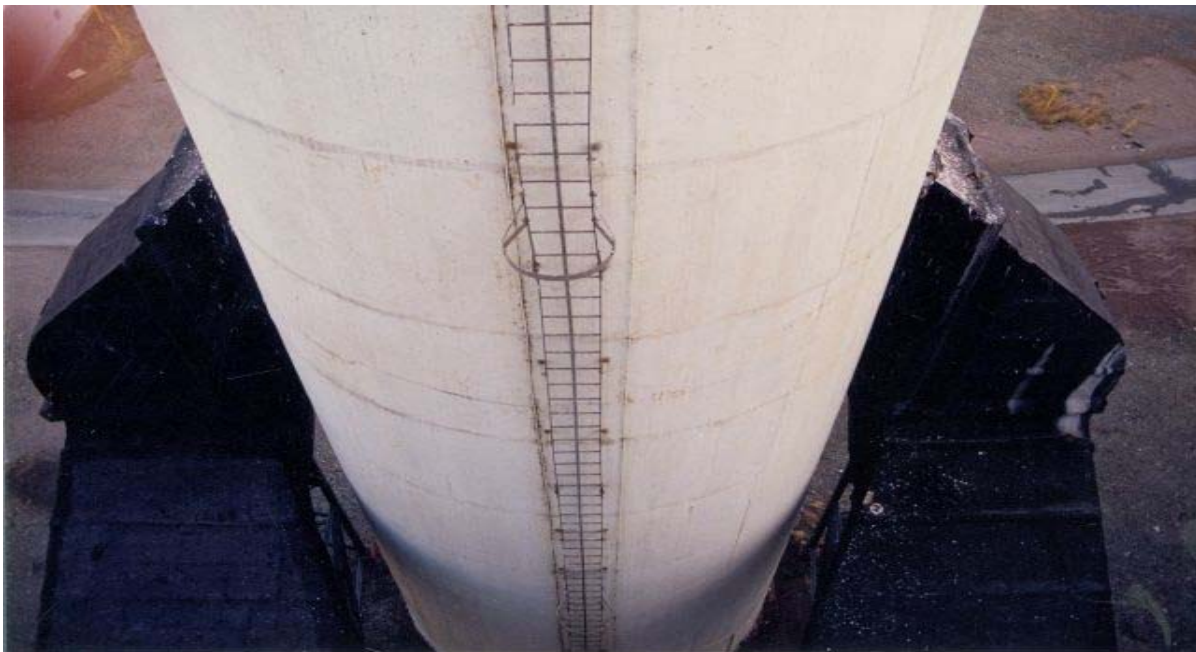


**Fig. 4: Original Breeching, bend section – Unit 1 or 2**





**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**



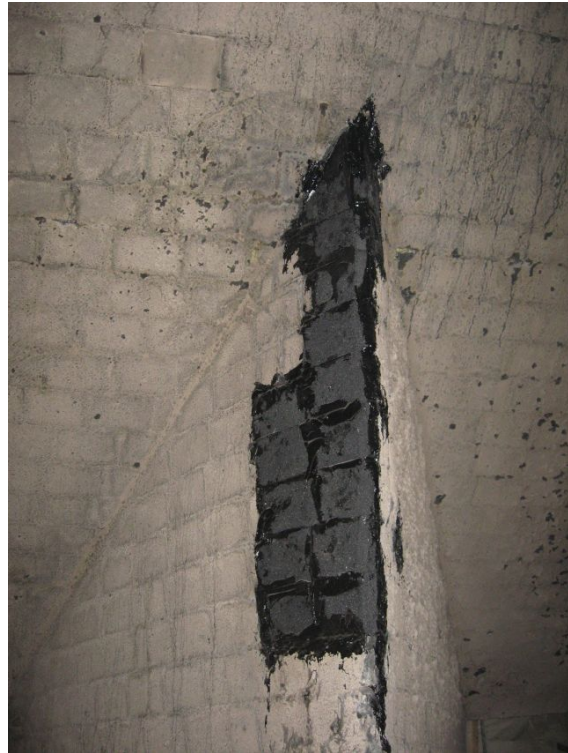
**Fig. 21: Unit 2 – Cracked cement floor**



**Fig.22: Unit 2 – External coating break down**



**Fig. 23: Unit 3 – Repairs 2007**



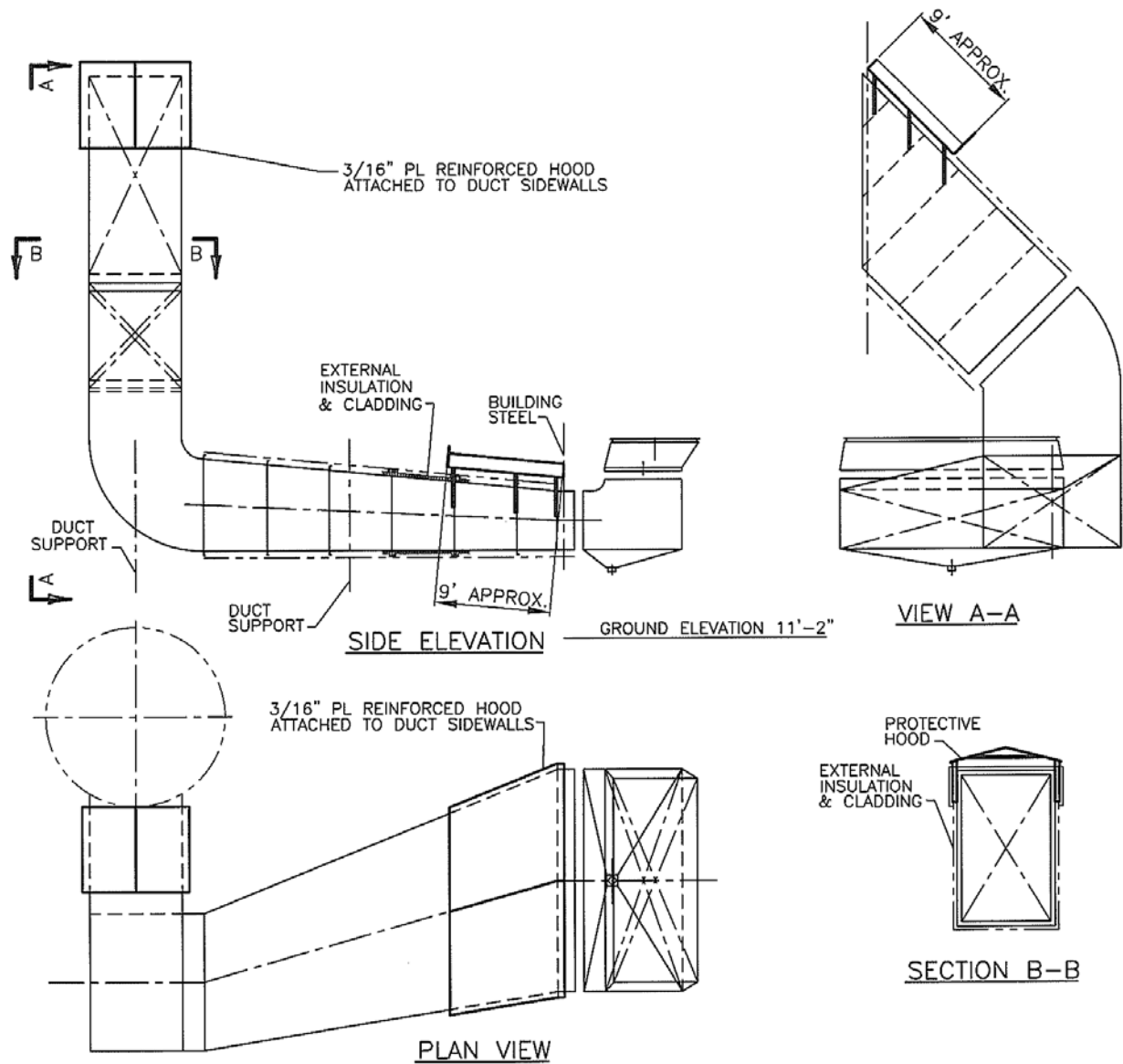
**Fig. 24: Unit 3 – Crotch repairs**



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

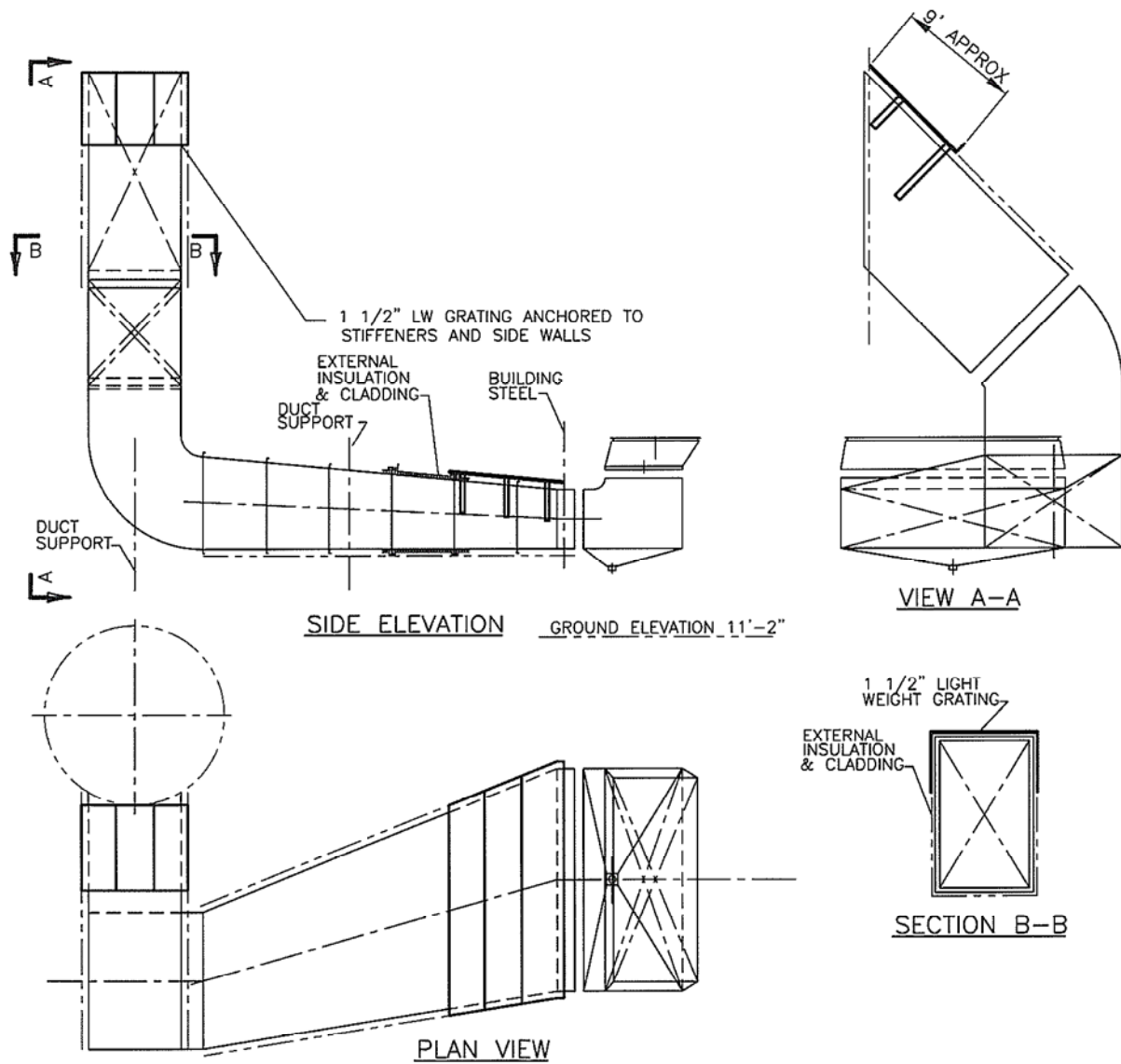


**Fig. 26: Unit 3 – Top near the stack**

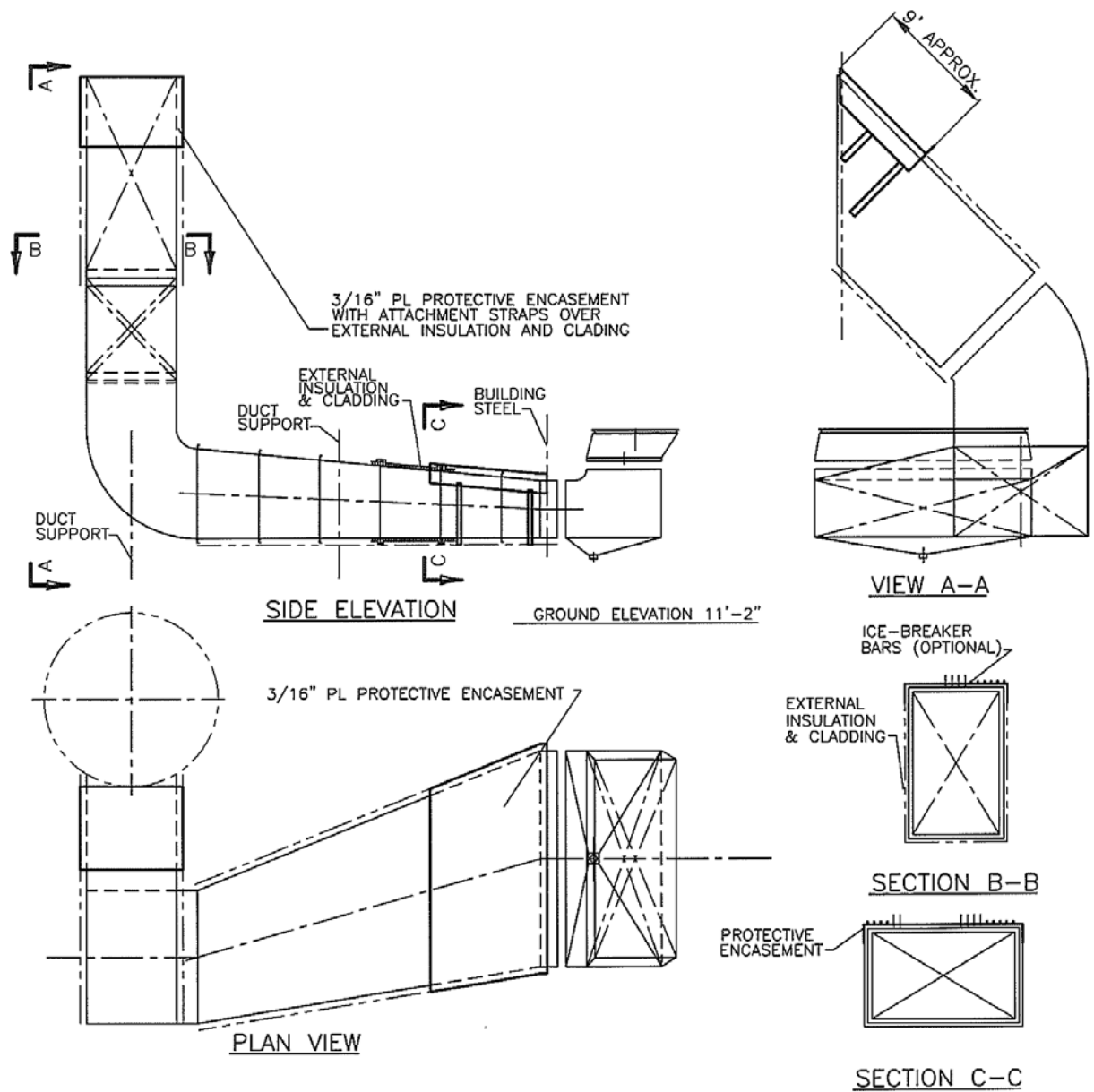


**Fig. 27: Proposed cladding protection – protective hood**





**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**

