Q. Please provide the inspection report and any other report authorized by Alstrom (*sic*) in relation to this matter.

A. The following related reports are provided:

1. Alstom Metallurgical Report, November 15, 2005
2. Alstom Engineering Report, February 6, 2006
3. Alstom Technical Services Report, March 6, 2006
4. Alstom Metallurgical Report, March 8, 2006
5. Alstom NDT Report, May 6, 2006

METALLURGICAL REPORT

November 15, 2005

EVALUATION OF A WATERWALL TUBE

NEWFOUNDLAND & LABRADOR HYDRO
HOLYROOD GENERATING STATION
UNIT NUMBER 2
CONTRACT NO. 04968
PSA -85800/LN-05J656
MTC-05-376

PREPARED FOR:

NEWFOUNDLAND & LABRADOR HYDRO

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PREPARED BY:

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EXECUTIVE SUMMARY

A section of furnace wall tubing removed from Unit 2 at Newfoundland & Labrador Hydro's Holyrood Steam Station has been destructively analyzed in an effort to determine why the tubing had developed a blister on the furnace side of the element following more than 30 years of service. The sample reportedly was taken from east wall tube 41 at an elevation close to the top of the burner (approximately 55'), a location where a number of blistered tubes were found during a recent outage. According to background information, similar blistering (and failure) occurred in the furnace walls during a similar outage in April of 2005, all of which were associated with the 49' to 54' elevation range.

Destructive examination of the waterwall tube established that the blistered area of the tube had been severely overheated, with tube metal temperatures having approached, but not exceeded, the lower critical transformation temperature for SA-210, Grade A1 material. Evidence of the overheating damage included large, blocky carbides and extensive creep cavities observed along the grain boundaries within the blistered region of the sample. A short distance away from the blister, the microstructure of the tubing showed no visible effects of overheating.

The blistering observed in this sample was a direct result of overheating caused by excessive internal deposits. In turn, the deposits were an indication of problems with the control of boiler water chemistry for this unit. This type of damage begins when contaminants contained in the boiler water accumulate on the internal surface of the tubing, with the most rapid deposition occurring in high heat flux areas of the furnace. These deposits disrupt effective heat transfer through the tube wall, resulting in a gradual but significant increases in tube metal temperature as the deposits increase in thickness. This is an autocatalytic process in which the rate of deposition increases as the metal temperature rises, which then causes further increases in metal temperature. Because the strength of the carbon steel tubing material drops rapidly above approximately 900°F, the tube wall begins to swell when the metal temperature reaches this critical level. If the deposits are localized, as they were in this case, then the overheating also will be localized, and a blister will form in the tube wall. Once metal temperatures within the overheated areas exceed approximately 1200°F, the time to failure would be in the order of minutes.

In addition to the overheating damage, examination of the sample uncovered a through-wall crack-like penetration that had initiated on the internal surface of the tube within a portion of the blistered area. Because there was no evidence in the sample of any widespread corrosion attack, it was believed that the penetration originated at a tube defect and that it grew slowly by preferential corrosion over the course of many operating cycles. Once the penetration had progressed to a critical size, the tube leaked. The fact that the through-wall penetration and the blistering had occurred within the same general vicinity of the tube was nothing more than coincidental.

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In order to reduce the risk of additional overheating damage in the furnace wall, it is recommended that a nondestructive inspection of the furnace wall tubes be conducted to identify and replace any tube in which visible swelling is detected. The boiler should then be thoroughly chemically cleaned to remove excessive deposits. Additionally, the water chemistry practice for this unit should be reviewed in order to ensure that the ingress of contamination into the boiler is adequately controlled during future operation of the unit.

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November 15, 2005

METALLURGICAL REPORT:

Evaluation of a Waterwall Tube
Newfoundland & Labrador Hydro
Holyrood Generating Station, Unit 2
PSA-85800/LN-05J656
Contract No. 4968
MTC-05-376

1.0 INTRODUCTION

A section of waterwall tubing removed from Unit 2 at Newfoundland & Labrador Hydro's Holyrood Generating Station was submitted to the Materials Technology Center (MTC) for destructive analysis. The sample, shown in Figure 1 as it appeared when received from the field, was taken from east furnace waterwall tube 41 from D corner at the top burner elevation (approximately 55'). According to information provided by the customer, the sample was selected for evaluation because it was considered representative of the condition of a number of blistered tubes discovered in this same area of the unit during a recent outage. Reportedly, three similar furnace wall tube leaks had been identified previously in this unit in April 2005.

Steam for Unit 2 at Holyrood Generating Station is supplied by a heavy oil, tangentially fired, natural circulation boiler that was manufactured for Newfoundland & Labrador Hydro by Combustion Engineering (C-E) under the terms of contract 4968. The unit was rated for a steam flow of 1,167,500 lbs/hr MCR and a drum pressure of 2055 psi. The operating SH and RH outlet pressure are 1955 psi and 462 psi respectively, both at an operating temperature 1005°F. According to information provided, the unit burns #6 Venezuelan oil, which contains high levels of both sulfur and vanadium. At the time of sample removal, the unit had not been chemically cleaned in more than 30 years. The tubing itself was specified to be 2.5" OD x 0.210" MWT, SA-210 Grade A1 material.

The purpose of the analysis was, first, to determine the cause(s) of blistering in the tubing, and, second, to determine the relevance of the failures to the condition of the waterwall tubing remaining in service. Pursuant to that end, a program of testing was initiated that included a visual examination, dimensional measurements, chemical analysis, and metallography.

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2.0 RESULTS

2.1 Visual Examination

The sample was inspected visually with the aid of a stereomicroscope to characterize the appearance of the blistered area and to detect any evidence of other type of damage, such as cracking, heavy deposits, or abnormal patterns of wastage, that might assist in identifying the cause(s) of the damage.

As indicated in Figure 1, there were two distinguishing features of the outer surface of the tube; one was a small blister that was visible on the furnace side of the tube, and the other was a tiny longitudinal split in the tube wall (~0.2") bcated within the blistered area but away from the most severely swelled areas of the tube crown. Examination of the sample away from the blister revealed a thick layer of ash/deposits covering the length of the sample, beneath which the bare metal surface of the tubing was smooth. There was no evidence of swelling in the areas of the sample away from the blister.

Examination of the internal surface of the sample revealed a thick internal deposit within the local area of the blister, while the rest of the sample showed only a thin layer of deposit. Apart from the blistering, there were no signs of any abnormal ID corrosion activity on the surface of the tube.

2.2 Dimensional Measurements

The outer diameter (OD), inner diameter (ID), and wall thickness of the tubing were measured at selected locations along the length of the sample in order to detect any swelling that may have occurred away from the blistered region and to quantify the extent of any service-induced wastage. The results of the measurements, which are recorded in Table 1, demonstrated that the swelling in the sample was in fact confined to the blistered area, with no measurable swelling detected in the other areas of the sample. Likewise, wall thickness readings showed that wall loss due to internal or external wastage had been minimal, with a minimum wall thickness reading of 0.203" measured on the furnace side of WW-41, as compared to a minimum specified thickness value of 0.210".

2.3 Chemistry Results

A specimen of the tubing material was chemically analyzed to verify that the correct material had been installed and that there were no compositional anomalies that could have adversely affected the serviceability of the tubing. The results of the analysis, which are recorded in Table 2, confirmed that the composition of the material was consistent with the requirements established by ASME for SA-210, Grade A1 tubing. In addition, all nonspecified and residual

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elements were found to be at levels where their presence would have no significant effect on the long-term serviceability of the tubing.

2.4 Metallography

Specimens were obtained from selected locations on the sample so that a more detailed examination could be made of the condition of the tubing both at and away from the blister location. These specimens were polished and etched to facilitate analysis of the macrostructure and microstructure by light optical microscopy.

The condition of the furnace side of the tubing in the blister area is documented in Figure 2. Examination of the microstructure in this area revealed the presence of extensive creep cavitation and large, blocky carbides along the grain boundaries. However, in the absence of any evidence of phase transformation, it was evident that tube metal temperatures within the rupture zone had *not* exceeded the lower critical transformation temperature for carbon steel tubing, which is ~1350°F. In contrast, the casing side of the tube at the blister elevation (Figure 3) and both the furnace and casing sides of the tube away from the blistered area (Figure 4) exhibited no evidence of overheating.

The micrographs on the top and bottom right of Figure 2 showed an area of corrosion attack that had propagated completely through the tube wall to form a leak path. The through-wall penetration was located within the blistered area but obviously away from the area where the swelling was greatest. Because there was no evidence of any widespread corrosion activity noted in other areas of the sample, it was believed that the penetration originated at a tube defect and that it grew slowly by preferential corrosion over the course of many operating cycles. Once the penetration had progressed to a critical size, the tube leaked.

The hardness of the tubing material was measured using a Vickers Hardness Tester with a 20 kg test load. The results of the testing are presented in Table 3, where it may be seen that the low hardness readings taken at the blister site were reflective of overheating damage in the sample. At all other locations, the hardness values were within a range considered normal for service-exposed SA-210, Grade A1 material.

3.0 CONCLUSIONS

Destructive examination of the waterwall tube established that the blistered area of the tube had been severely overheated, with tube metal temperatures having approached, but not exceeded, the lower critical transformation temperature for SA-210, Grade A1 material. Evidence of the overheating damage included large, blocky carbides and extensive creep cavities observed along the grain boundaries within the blistered region of the sample. A short distance away from the blister, the microstructure of the tubing showed no visible effects of overheating.

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The blistering observed in this sample was a direct result of overheating caused by excessive internal deposits. In turn, the deposits were an indication of problems with the control of boiler water chemistry for this unit. This type of damage begins when contaminants contained in the boiler water accumulate on the internal surface of the tubing, with the most rapid deposition occurring in high heat flux areas of the furnace. These deposits disrupt effective heat transfer through the tube wall, resulting in a gradual but significant increases in tube metal temperature as the deposits increase in thickness. This is an autocatalytic process in which the rate of deposition increases as the metal temperature rises, which then causes further increases in metal temperature. Because the strength of the carbon steel tubing material drops rapidly above approximately 900°F, the tube wall begins to swell when the metal temperature reaches this critical level. If the deposits are localized, as they were in this case, then the overheating also will be localized, and a blister will form in the tube wall. Once metal temperatures within the overheated areas exceed approximately 1200°F, the time to failure would be in the order of minutes.

In addition to the overheating damage, examination of the sample uncovered a through-wall crack-like penetration that had initiated on the internal surface of the tube within a portion of the blistered area. Because there was no evidence in the sample of any widespread corrosion attack, it was believed that the penetration originated at a tube defect and that it grew slowly by preferential corrosion over the course of many operating cycles. Once the penetration had progressed to a critical size, the tube leaked. The fact that the through-wall penetration and the blistering had occurred within the same general vicinity of the tube was nothing more than coincidental.

4.0 RECOMMENDATIONS

In order to reduce the risk of additional overheating damage in the furnace wall, it is recommended that a nondestructive inspection of the furnace wall tubes be conducted to identify and replace any tube in which visible swelling is detected. The boiler should then be thoroughly chemically cleaned to remove excessive deposits. Additionally, the water chemistry practice for this unit should be reviewed in order to ensure that the ingress of contamination into the boiler is adequately controlled during future operation of the unit.

Liu Wei

Karen W. Liu

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Table 1. Dimensional Measurements

	Outer Diameter (in.)		*Inner Diameter (in.)*		*Wall Thickness (in.)*		
Sample	*Avg.*	*Range*	*Avg.*	*Range*	*Location*	*Avg.*	*Range*
WW-41 Away from blister 2.5" OD x 0.210" MWT	2.496	2.492-2.500	2.062	2.058-2.065	*Furnace Side*	0.210	0.207-0.214
					Casing Side	0.220	0.218-0.223
WW-41 Adjacent to blister 2.5" OD x 0.210" MWT	2.494	2.490-2.496	2.065	2.062-2.070	*Furnace Side*	0.207	0.203-0.213
					Casing Side	0.221	0.218-0.224

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Table 2. Chemistry Results

Chemical Composition (Weight Percent)		
Element	***WW-41***	***ASME SPEC. SA-210, GRADE A1***
Carbon	0.20	0.27 (max.)
Manganese	0.67	0.93 (max.)
Phosphorus	0.015	0.035 (max.)
Sulfur	0.012	0.035 (max.)
Silicon	0.26	0.10 (min.)
Nickel	0.02	---
Chromium	0.01	---
Molybdenum	<0.01	---
Vanadium	0.006	----
Columbium	<0.001	----
Titanium	0.001	---
Cobalt	0.009	----
Copper	0.03	---
Aluminum	0.002	----
Boron	<0.001	---
Tungsten	<0.01	
Arsenic	0.008	----
Tin	0.002	----
Zirconium	<0.001	----

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Table 3. Hardness Measurements

HARDNESS VALUES-HV (HRB)			
Sample	***Location***	***Average***	***Range***
WW-41 Away from blister	Furnace Side	125 (69)	123 (68)-127 (70)
	Casing Side	133 (72)	130 (71)-135 (73)
WW-41 Within blister	Furnace Side	130 (71)	113 (64)-139 (75)
	Casing Side	142 (76)	140 (75)-143 (76)

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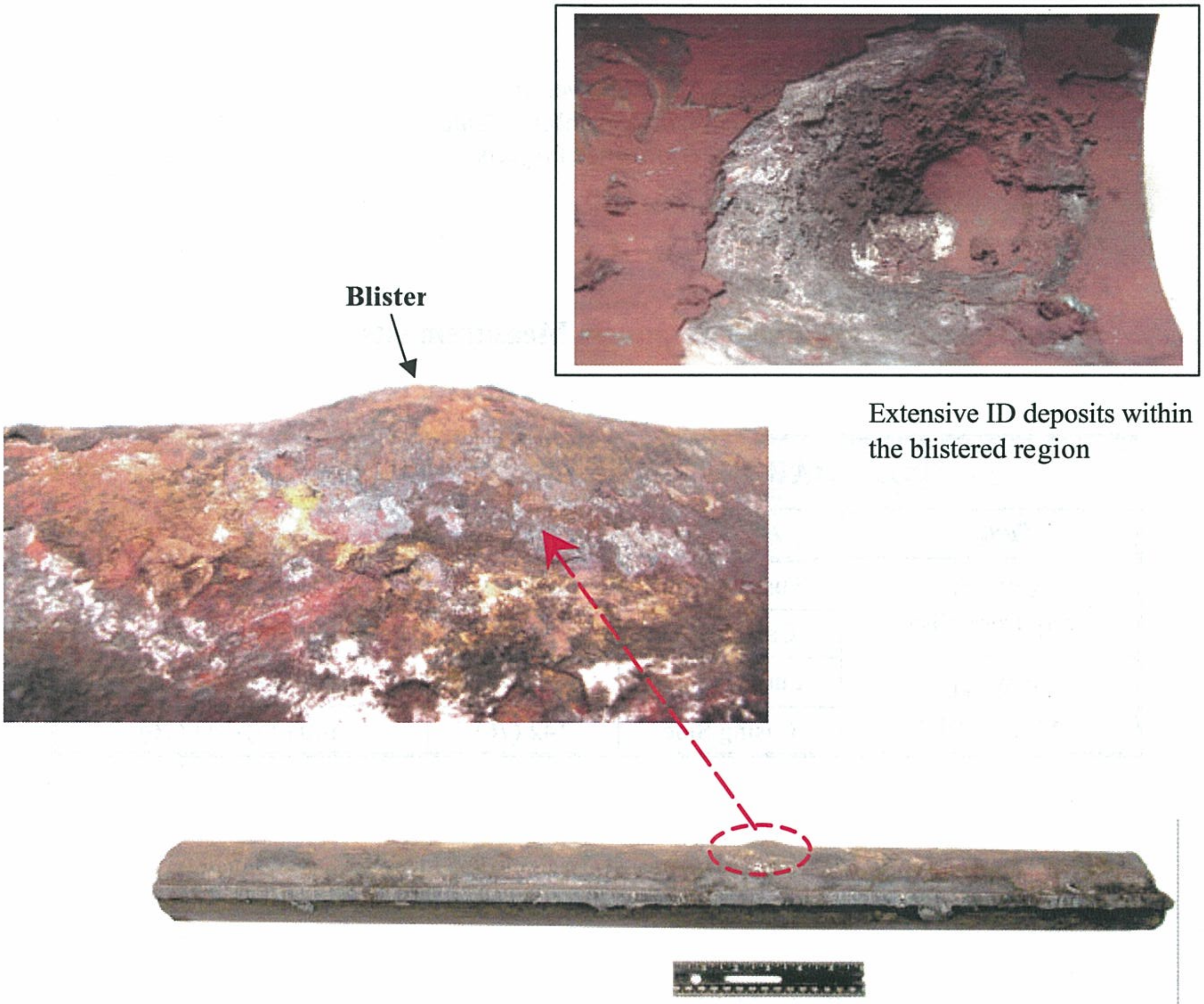

Figure 1. Documenting the Section of Waterwall Tubing Removed from Unit 2 at Newfoundland & Labrador Hydro's Holyrood Steam Station, As It Appeared When Received from the Field.

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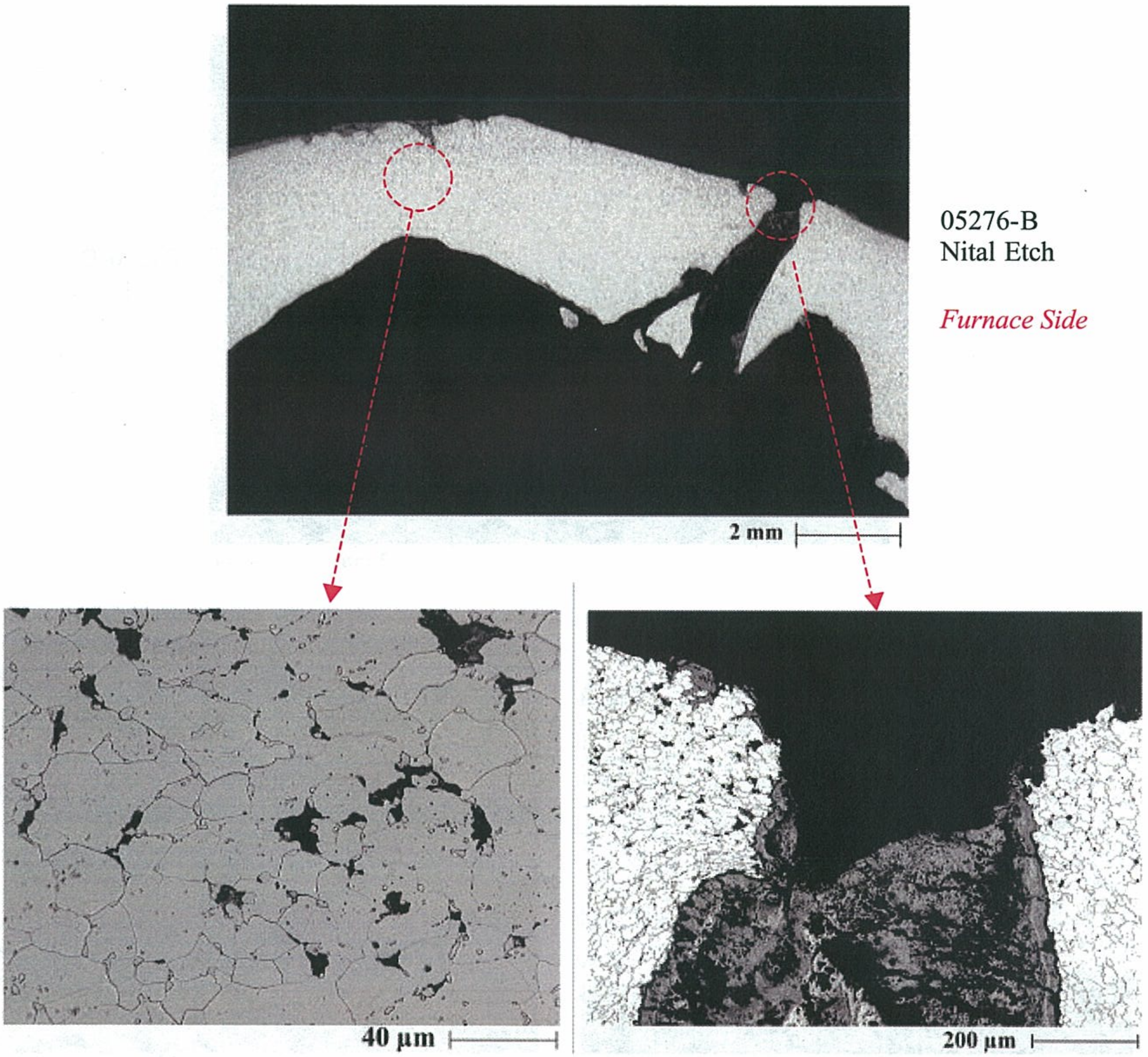

Figure 2. Documenting the Condition of the Macrostructure and Microstructure at the Blister Location. Showing The Extensive Creep Cavitation And Large, Blocky Carbides That Were Observed Along Grain Boundaries (bottom, left). Also Showing a Crack-like Penetration that had Propagated Completely Through the Tube Wall by Preferential Corrosion at What was Believed to be a Defect Area (bottom, right).

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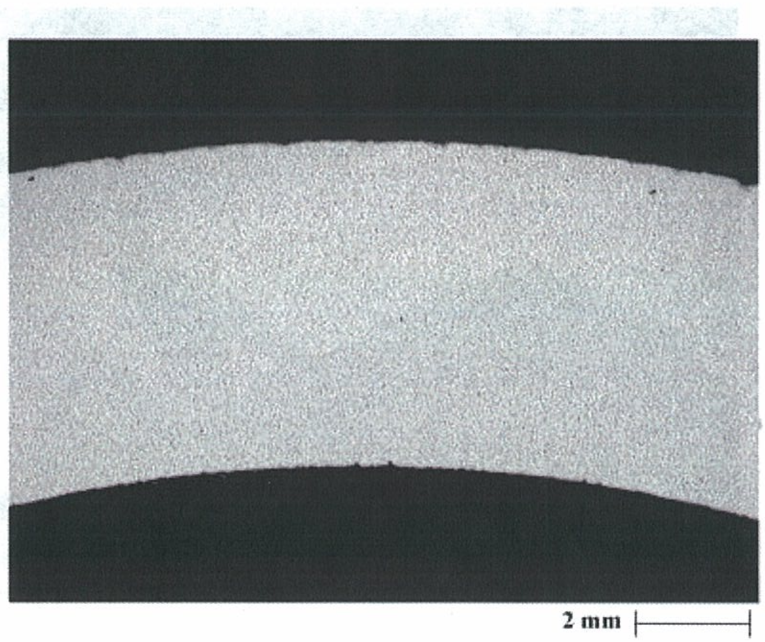
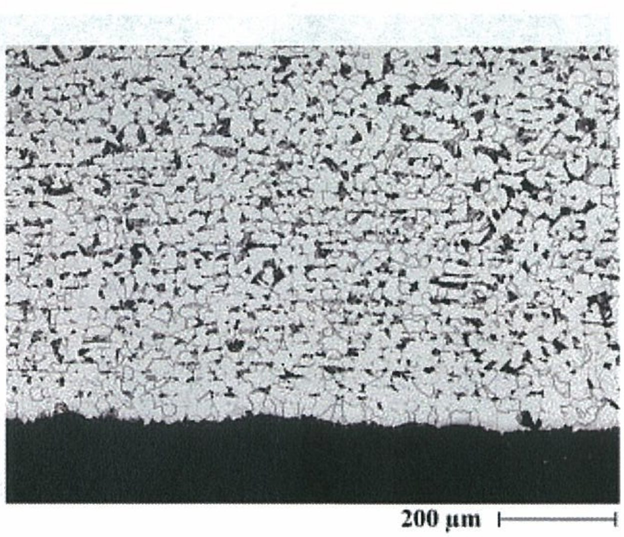


05276-B
Nital Etch

Casing Side



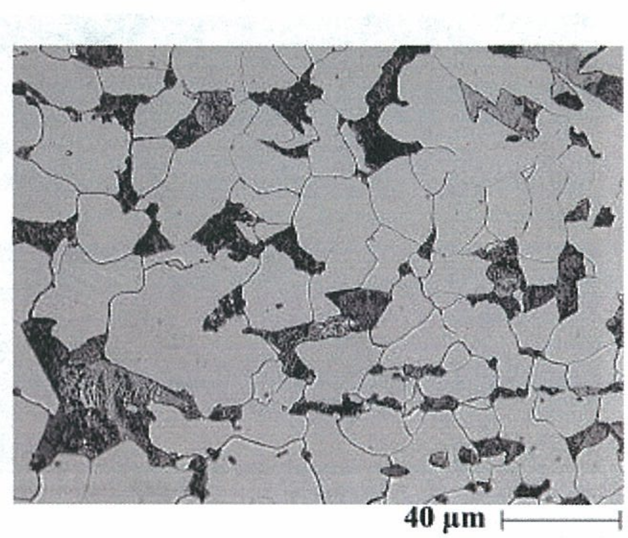


Figure 3. Documenting the Typical Condition of the Macrostructure and Microstructure on the Casing Side of the Tube at the Blister Elevation.

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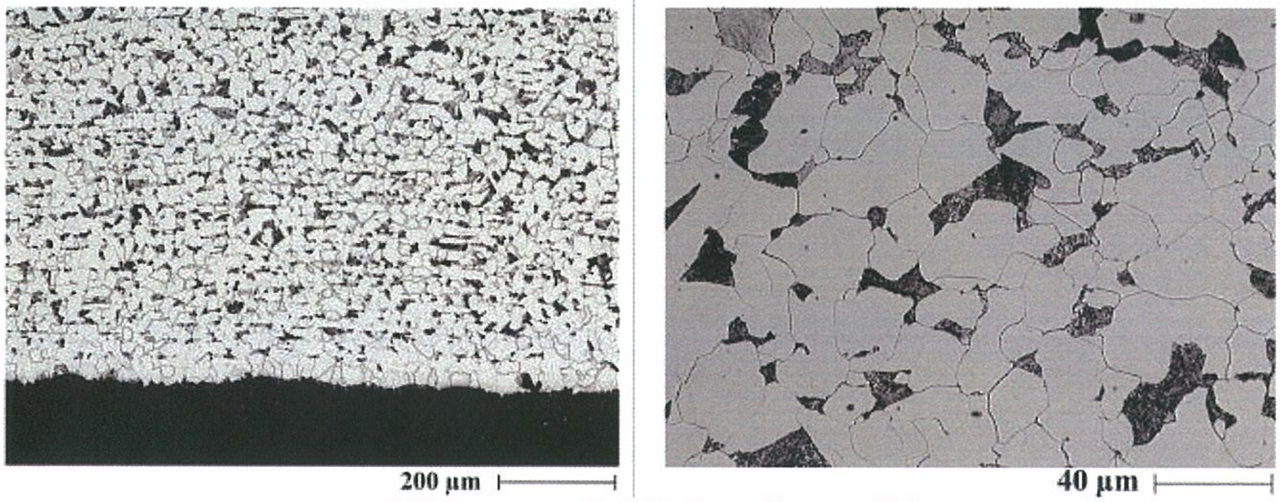
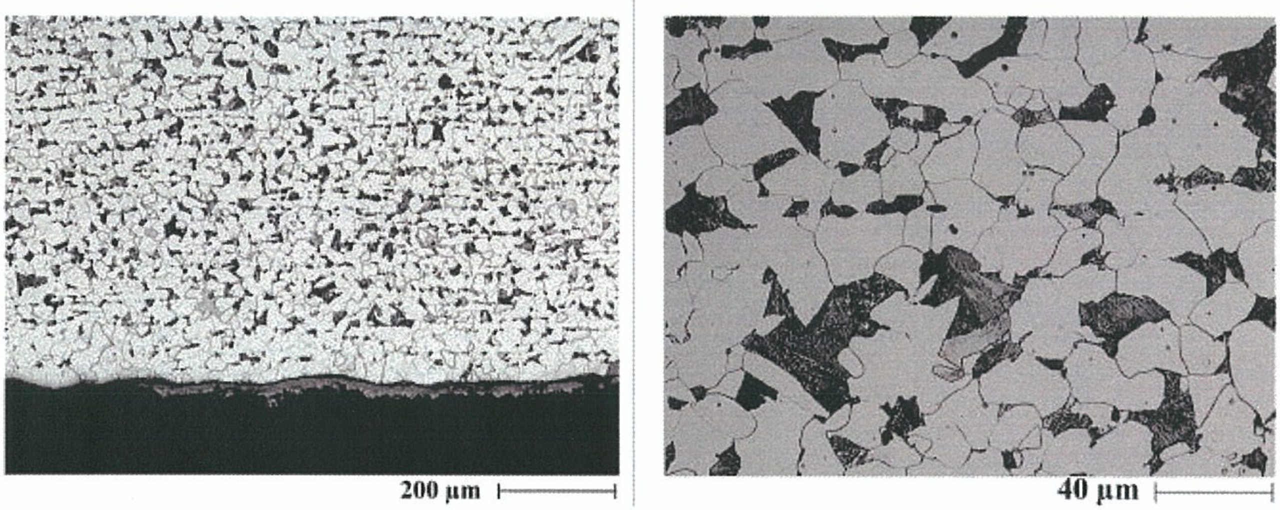


05276-A Nital Etch *Furnace Side*



05276-A Nital Etch *Casing Side*

Figure 4. Documenting the Typical Condition of the Microstructure on the Furnace and Casing Sides of the Tube at a Location away from the Blister.

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ALSTOM

Power Service

Newfoundland & Labrador Hydro February 6, 2006

Attention: Terry LeDrew
Manager,Thermal Generation

Further to our meeting at Hydro Place on February 1, 2006, ALSTOM was requested to comment on the risks and consequences of further tube failures as a result of the discussion and the action plan being instituted for unit #2. The plan includes a replacement of waterwall sections which will include the affected tubes. As this replacement will not occur for two months, a review of possible risks of additional tube failures in this two month window is outlined below.

Fire Side Tube Failures

The failure mechanism associated with the recent waterwall tube failures is overheating caused by internal deposits. These deposits insulate the tube from cooling, and combine with the heat flux from combustion to overheat the tube locally. It is important to note that not every tube is affected, as it has been seen that the majority of the tubes in the affected area show no signs of wall thinning. This failure mode can only occur on the fire side of the waterwall as it is driven by the heat flux of combustion. It can not occur on the casing side on the boiler.

The failure manifests itself either by forming a blister, which cracks and causes a leak, by thinning the wall of the tube through wastage to the point of producing a pressure failure, or by hydrogen attack caused by overheating together with the corrosive environment under the internal deposits on the fireside of the tube.

The recent inspection of the east wall found a total of 38 blisters. The failure which caused the most recent outage was due to hydrogen attack, and there were no tube failures due to wall thinning.

As it has been determined that the internal deposits range from "very difficult to virtually impossible" to remove chemically (Northland Consulting Ltd. Letter of January 26, 2006), the only way to reduce the risk of additional failures in the next two months is to reduce the heat flux to the affected wall area. Actions are being instituted which will accomplish this.

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With regard to the probability of another fireside tube failure occurring in the next two months, until the affected tubes are replaced, the potential still exits for another failure. However, recent and future actions will reduce this probability.

1. In the past three weeks an extensive inspection has been carried to isolate the boundaries of the damage and identify each tube that required repair/replacement. UT inspection, RT inspection, and internal boroscope inspection has resulted in a detailed mapping of the condition of each and every tube in the affected area. Although it is known that there are some tubes that remain with wall thickness less than 0.140" MWT, and it is possible that there are some tubes that may have hydrogen damage that was not detected, the thorough inspection has resulted in repairs and replacement of the blisters, cracks, and excessively thinned tubes (less than 0.100").
2. The predicted tube mid wall temperature is about 720°F, which is based on a clean tube. The damage that is being seen indicates that the metal temperature must be at least 900°F. This extra temperature is the result of the insulating effect of the internal scale. By operating the unit at 60MW or lower and reducing the drum operating pressure from 2050 psi to 1700 psi, the predicted metal temperature will reduce by 52°F. This reduction is due to a lower saturation temperature from the pressure reduction combined with a lower heat flux from the load reduction.
3. Another action that is being instituted is a change to the firing practice whereby only the lower elevation of burners would be placed in service and they will be placed in a downward tilt position. Also, multiple burners will be used. This action will further reduce the heat flux to the waterwall tubes in the affected area. This will result in a minor reduction of about 5°F in the tube temperature.
4. The combination of items 2 and 3 above will have a net affect of reducing the tube metal temperature by 57°F. This will provide an increased margin of protection as the ASME Code minimum wall requirement will drop from 0.191" MWT to 0.136" MWT based on the 2004 ASME Code. Thus, by reducing the tube temperature, the potential for further overheating failures is reduced.
5. Base on the ASME Code required wall thickness of 0.136" as indicated in item 4 above, 70% of this thickness is 0.095". There are currently no tubes that have a wall thickness below 0.100" .
6. The unit was recently subjected to two service pressure tests of 1885 psi. By reducing the operating pressure to 1700 psi, the waterwall tubing will be operating at a pressure about 10% below the successful service pressure test.

Although the above actions will not eliminate the risk of another fireside tube leak, this risk is reduced considerably by the detailed inspection/repair/replace actions and the limitations imposed on the future firing/operational practice.

In addressing the consequences of another leak, a couple of points need to be considered.

1. A fireside tube leak or failure does not affect personnel safety as the failure is completely contained inside of the boiler.
2. There have been two failure modes experienced from the overheating, cracks in blisters, and a blow out from hydrogen damage. To date there have been 38 blisters discovered and one (1) hydrogen blow out. The consequent of a blister crack occurring may not cause a unit outage if the crack is small enough not to affect the boiler operation. Of course, a large or multiple cracked blisters may cause an outage. A hydrogen blow out will definitely cause an outage.
3. The action plan also includes restricting access to this area, which will also provide safety assurances.

In summary, the worst case scenario would be a boiler outage and personnel safety is assured.

During our meeting, the possibility of adding refractory to the waterwall to reduce the tube metal temperature was discussed. Refractory has been added to waterwalls in the past to protect the walls from erosion and abrasion, and to act as a heat sink to retain the heat in the bottom of a bark fired industrial boiler for better combustion of moist fuel. The addition of refractory to protect waterwalls from overheating has not been done previously. As the current action plan provides for a replacement waterwall in two months, the practicality of the time and cost required to obtain the refractory material, and the time and cost required to install same for a two month operational period must be considered when weighing the risks. As noted above, the consequence of an additional failure will be a boiler outage which will require a tube replacement.

Casing Side Tube Failures

The recent tube failures, as described above, are isolated to the fireside exclusively. As there is no heat flux on the casing side, this type of failure can not happen on the outward side of the tube.

Failures that can occur on the casing side include corrosion fatigue, failures at points of attachments, original tube defects, pitting corrosion, etc. The risk of this type of failure occurring is no greater on this unit than any other 35 year old oil fired utility and the recent fireside failures do not increase this risk.

Membrane Failures

The membrane between two adjacent tubes is cooled by conduction from the tubing. Although some tubes have suffered from overheating, this is local to the crown of the tube, or close to the crown. The membrane is attached to the tube 90° away from the crown, where the tube midwall temperature is lower. Therefore the membrane should still have adequate cooling and will not experience elevated temperatures.

Therefore, there is no risk of a membrane failure caused by the same failure mechanism as the recent fireside failures.

John McMillan P.Eng.

John McMillan, P.Eng
Manager, Engineering

PUB 14 NLH
Attachment 3

Technical Services Report
Newfoundland & Labrador Hydro
Holyrood Unit 2
January 2006 - East Waterwall Tube Failures

March 6, 2006

ALSTOM | Power Service

1 About this report

This report documents the failure and subsequent repair of a waterwall tube in the East wall of the Holyrood Unit 2 boiler. Also discussed is the additional damage that was discovered and the associated inspections and repairs completed. The original tube failure occurred on January 6, 2006. Repairs were performed by ALSTOM personnel.

John Adams prepared this report.

2 Background

A tube failure occurred on January 6, 2006. The failure was on tube #56 from D corner on the east wall at 53′ elevation. It was a window-type failure as can be seen in the photograph in Section 8 of this report. This tube was removed and replaced with new material.

As part of the repair of this tube, the butt welds were examined by RT. The RT inspection revealed a longitudinal crack in the adjacent original material. As a result, further visual inspection was completed and several blisters were found on tubes in the general area of the failure. This led to a detailed investigation complete with scaffold erection and extensive inspections.

The original failure and one other tube (#42 at elevation 54′) were sent to the ALSTOM Material Technology Centre (MTC) for analysis.

Blisters have been reported before in this unit. In April 2005, the first three blisters were found in this boiler. There was one on each of the north, west, and east walls. In the fall of 2005, during the annual maintenance overhaul, a careful visual inspection was completed and five additional blisters were found. All were on the east wall. One of these was removed and sent to ALSTOM MTC for analysis (reference report MTC-05-376).

Note that all tubes in this report and attached documents were numbered from the burner nest and do not include the four tubes located in the nest. The burner nest tubes were included in previous inspections and reports. For example, tube 28 in this report would have been numbered 32 in my previous reports.

The waterwall tubes are 2-1/2″ OD by 0.200″ MWT. The material is SA-210-A1 carbon steel.

3 Inspections

The following is a summary of the inspections and tests completed.

1. UT survey of tube crown on all tubes with the following limits:
    - East wall – 48′ to 60′ elevation

- West wall – 53' to 57' elevation (49 to 57 from tubes 23 to 33)
- North wall – 53' to 57' elevation (51 to 57 from tubes 35 to 45)
- South wall – 53' to 57' elevation

2. UT survey adjacent to crown (both sides) on east wall from tubes 17 to 64 – 8 foot band
3. RT shot of east wall tubes 17 to 40 from elevation 49' to 52'
4. Boroscope inspection of 8 tubes on the east wall (while cut-out)
5. Boroscope inspection of 3 tubes on the west wall (windows cut for access). These were tubes 20, 28, and 50 from B corner. All access points were at 45' elevation and inspection was done up to about 62' elevation
6. Internal inspections of bottom sidewall headers
7. Burner yaw measurements and visual inspection
8. Service pressure test to 13,000 kPa.

4 Results and Conclusions

The following summarizes the results of the inspections.

East Wall Inspection

The defects listed below can be found on the map of the east wall (Attachment 9.1).

- 34 blisters total
- 2 cracks found by RT adjacent to butt welds – tubes 42 and 56
- cracks found during service pressure test – tubes 23, 35, and 38
- 8 tubes with UT measurements below 0.100"
- 19 additional tubes with UT measurements below 70% MWT

The UT measurements taken adjacent to the crown showed significant thinning. This data is included in Attachment 9.2.

For reliable operation of this unit, this wall section requires replacement as soon as possible.

West Wall Inspection

The results of the UT survey can be found in Attachment 9.3. All measurements were above 70% MWT. However, widespread thinning below 0.200" was observed. This may indicate that the condition of this wall is similar to the east wall but has not progressed to the same extent. Also, one blister has been repaired already on this wall, and deposits were noted during the boroscope inspections (see below). It is likely that this wall will require replacement in the near future. Detailed inspection is required to verify this.

North Wall Inspection

The results of the UT survey can be found in Attachment 9.4. One measurement was below 70% MWT. Most other measurements were above 0.200". However between tubes 34 and 46 there was some thinning observed. Again, with one blister already found on this wall (in the thin area), it is possible that a section of this wall might require replacement in the future. Detailed inspection is required.

South Wall Inspection

The results of the UT survey can be found in Attachment 9.5. All measurements were above 70% MWT. Most measurements were above 0.200" however between tubes 26 and 60 there was some thinning observed.

Header inspection

Considerable loose scale was found towards the south end of the east inlet header. This was removed.

RT examination

This was not effective for locating deposits or blisters. It was abandoned in favour of UT inspections.

Boroscope inspection

This helped to determine the extent of deposits and damage. In general, heavy deposits on the east wall were located between 43' and 58' elevations. The inspections of tubes 31, 39, and 46 on the east wall were completed with assistance from Afonso and were recorded.

Inspection of the west wall also revealed localized deposits although not as severe or as frequent as on the east wall. The previously repaired blister on Tube 28 was observed. Also observed was attack at the bottom weld in a pup piece in Tube 20. The origin of this pup was unknown. The inspections of the west tubes were completed with assistance from Afonso and were recorded.

Burner yaw measurements

At each corner except C, which was not accessible due to interference with the scaffold, a check of the burner yaw was completed. A pipe was held against the side of the top level fuel air nozzle to use as a straight-edge. Then the distance between the centre of the pipe and three separate wall tubes was measured. These measurements would give an indication of the angle of the pipe (and consequently the burner) relative to the side wall. As can be seen in the table below, the measurements demonstrated that the alignment of the D corner burner was consistent with the other two burners.

Tube (from corner)	A Corner	B Corner	D Corner
3	10-5/8"	10-5/8"	10-7/8"
8	22-1/2"	22-1/2"	22-1/2"
15	41-1/2"	39-3/4"	40-3/4"

Service pressure test

A service pressure test was first conducted on January 23rd. At that time four through–wall cracks were found – two on tube 38 (close together) and the others on tubes 35 and 23. These tubes were included in the RT shot previously conducted but the cracks were found just above where the film was placed.

After repairing the four cracks, a successful pressure test was completed on January 25th. The test pressure was 13,000 kPa and this test was witnessed by the AI.

5 Repairs

Nine cut-outs were completed. These removed 11 identified blisters. The location of the cut-outs is shown in Attachment 9.1. The cut-outs were done for the following reasons:

- 1 to remove the original failure
- 1 to remove a particularly bad tube (many blisters)
- 6 to remove tubes with UT measurements under 0.100"
- 1 "good tube" for confirmation purposes.

In addition to the cut-outs there were 32 pad weld repairs completed for the following reasons. The locations of all are shown on Attachment 9.1 except the last one, which is shown on Attachment 9.4.

- 23 additional blisters
- 2 welds on cracks found by RT adjacent to butt welds
- 3 welds on 4 cracks found during service pressure test (two cracks on #38 done together)
- 3 locations under 0.100" found adjacent to the crown
- 1 location on the north wall that measured 0.124".

Three windows were cut in west wall tubes to allow for boroscope inspection. These were cut at the 45' elevation in tubes 20, 28 and 50 from B corner.

Three handhole caps were removed for header inspection. These were the north cap on the west bottom header and the north and south caps on the east bottom header.

Three thermocouples were installed to measure waterwall temperature. The locations are shown in the table below.

Wall	Location
West	Between tubes 42 and 43 from B-Corner
East	Between tubes 50 and 51 from D-corner
East	Between tubes 85 and 86 from D-corner

6 Engineering Review

ALSTOM Engineering was asked to review the findings and to provide comments and recommendations. The attached two letters from ALSTOM's Engineering Manager document this work (see Attachment 9.6).

Two tube samples were sent to the ALSTOM Materials Test Centre for evaluation. This included the original failed tube. The final report was pending at the time this report was written. However, the lab had confirmed verbally that the original blow-out failure was a result of hydrogen attack and that hydrogen damage was found on both tubes over the entire length of the fire-side. A small (previously unidentified crack) was found in the second sample and this was also caused by hydrogen attack.

ALSTOM has a UT technique that has been proven to be effective in locating hydrogen damage. This technique, which has been in use for many years, makes use of the dampening effect of hydrogen damage on the ultrasonic waves. This, in conjunction with more conventional UT, would identify cracking, thinning, and hydrogen damage.

7 Recommendations

1. Proceed with chemical clean of this unit and Unit 1during next maintenance outage.

2. Replace damaged wall sections in east wall during next maintenance outage. Proposed cut lines have been determined.

3. Perform specialized UT inspection to look for cracks, thinning, and hydrogen damage in Unit 1and in remaining three walls in Unit 2 during next maintenance outage. Include an inspection of the arch as this is predicted to have the highest heat flux.

4. Support the UT inspection above with boroscope inspections and tube samples during next maintenance outage.

5. During the next maintenance outage of Unit 1 and Unit 2, install additional thermocouples on the waterwalls as required to evaluate the heat flux distribution. Note that at the time this report was completed, the unit had not been operated and no conclusions could be drawn from the thermocouples already installed.

6. Keep loading on the unit as low as practical until the east wall panels are replaced. Also, with the low loads, keep drum pressure as low as practical. This will reduce stresses in the tubes and will have the added benefit of lowering the tube temperatures.

7. Budget for partial replacement of the other waterwalls in this unit. Based on the previous blisters on the north and west walls, the deposits and thinning seen on the west wall tubes, and the likelihood that the deposits can not be removed, it is almost certain that additional panel replacements will be required in the future. This should be planned for the near future. Partial replacement of the east wall is now required just eight months after discovery of the first blister. We can't predict how fast the other walls might deteriorate.

8 Photographs

Figure 1. Original tube failure - Tube 56 from D corner 53' elevation

9 Attachments

9.1 Map of East Wall UT results showing blister, crack and cut-out locations

9.2 Map of East Wall UT results showing measurements taken adjacent to the crown

9.3 Map of West Wall UT results

9.4 Map of North Wall UT results

9.5 Map of South Wall UT results

9.6 Engineering Evaluation Summary (two letters)

ALSTOM

NFLD Hydro
January, 2006
Unit # 2
East Waterwall

Tube Number

Elev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Elev.
60'	N/A	N/A	0.210	0.215	0.215	0.210	0.210	0.215	0.215	0.220	0.220	0.217	0.220	0.225	0.220	0.223	0.220	0.210	0.217	0.221	0.212	0.211	0.218	0.223	0.200	0.205	0.207	0.214	0.210	0.214	0.214	0.217	60'
59'	N/A	N/A	0.212	0.200	0.222	0.200	0.222	0.223	0.208	0.218	0.212	0.212	0.208	0.224	0.227	0.227	0.217	0.205	0.213	0.215	0.203	0.200	0.217	0.210	0.200	0.220	0.208	0.200	0.200	0.196	**0.199**	0.200	59'
58'	N/A	N/A	0.220	0.205	0.225	0.207	0.220	0.217	0.216	0.212	0.216	0.207	0.204	0.220	0.210	0.220	0.219	0.200	0.205	0.208	0.196	0.207	0.200	0.213	0.198	0.209	0.200	0.200	0.200	0.198	**0.173**	0.198	58'
57'	N/A	N/A	0.220	0.210	0.225	0.212	0.222	0.215	0.212	0.220	0.210	0.200	0.201	0.218	0.227	0.211	0.213	0.200	0.205	0.167	0.196	0.209	0.203	0.211	0.189	0.214	0.194	0.205	0.205	0.180	**0.175**	0.202	57'
56'	N/A	N/A	0.209	0.214	0.217	0.218	0.218	0.215	0.212	0.218	0.212	0.200	0.200	0.200	0.222	0.207	0.221	0.211	0.195	0.202	0.180	0.210	0.207	0.210	0.184	0.202	0.173	0.200	0.205	0.200	**0.200**	0.198	56'
55'	N/A	N/A	0.200	0.205	0.200	0.214	0.218	0.210	0.204	0.213	0.218	0.196	0.197	0.220	0.220	0.207	0.211	0.208	0.192	0.202	0.184	0.204	0.190	0.207	0.185	0.215	0.180	0.200	0.202	0.210	**0.197**	0.204	55'
54'	N/A	N/A	0.225	0.196	0.200	0.137	0.213	0.217	0.208	0.215	0.211	0.207	0.195	0.223	0.197	0.200	0.209	0.212	0.190	0.210	0.190	0.161	0.169	0.197	0.193	0.210	0.202	0.205	0.209	0.200	**0.165**	0.206	54'
53'	N/A	N/A	0.219	0.210	0.223	0.210	0.217	0.227	0.219	0.222	0.227	0.199	0.212	0.209	0.224	0.212	0.221	0.219	0.216	0.215	0.206	0.203	0.194	0.206	0.186	0.219	0.211	0.195	0.209	0.207	**0.205**	0.214	53'
52'	N/A	N/A	0.225	0.215	0.228	0.213	0.184	0.221	0.205	0.218	0.227	0.211	0.209	0.221	0.223	0.199	0.185	0.197	0.219	0.209	0.198	0.199	0.177	0.208	0.196	0.209	0.176	0.192	0.202	0.200	**0.195**	0.198	52'
51'	N/A	N/A	0.226	0.206	0.219	0.219	0.188	0.211	0.210	0.217	0.223	0.203	0.199	0.213	0.192	0.188	0.194	0.186	0.198	0.199	0.198	0.195	0.202	0.198	0.193	0.188	0.200	0.187	0.205	0.192	**0.200**	0.192	51'
50'	N/A	N/A	0.231	0.208	0.196	0.216	0.208	0.211	0.208	0.217	0.220	0.200	0.196	0.216	0.212	0.195	0.193	0.183	0.208	0.197	0.193	0.184	0.205	0.200	0.183	0.178	0.193	0.175	0.198	0.196	**0.194**	0.195	50'
49'	N/A	N/A	0.250	0.240	0.237	0.217	0.247	0.230	0.225	0.228	0.233	0.235	0.229	0.241	0.250	0.218	0.197	0.197	0.188	0.205	0.196	0.200	0.203	0.208	0.193	0.207	0.205	0.195	0.204	0.202	**0.198**	0.208	49'
48'	N/A	N/A																															48'
																															V		

Tube Number

Elev.	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	Elev.
60'	0.208	0.215	0.212	0.210	0.210	0.217	0.215	0.209	0.200	0.200	0.200	0.210	0.208	0.217	0.205	0.212	0.205	0.192	0.210	0.212	0.204	0.210	0.220	0.204	0.208	0.210	0.210	0.207	0.207	0.212	0.210	0.205	60'
59'	0.198	0.200	0.198	0.202	0.204	0.200	0.200	0.197	0.185	0.210	0.207	0.204	0.206	0.195	0.190	0.200	0.185	0.188	0.200	0.193	0.197	0.197	0.193	0.177	0.195	0.188	0.195	0.188	0.194	0.197	0.195	0.187	59'
58'	0.290	0.195	0.202	0.196	0.198	0.200	0.160	0.192	0.185	0.190	0.210	0.198	0.185	0.200	0.195	0.187	0.182	0.184	0.215	0.200	0.190	0.191	0.189	0.162	0.192	0.185	0.188	0.184	0.203	0.200	0.195	0.188	58'
57'	0.298	0.200	0.197	0.198	0.198	0.207	0.160	0.197	0.188	0.210	0.213	0.200	0.210	0.199	0.190	0.200	0.185	0.189	0.200	0.202	0.197	0.189	0.178	0.162	0.200	0.161	0.196	0.193	0.198	0.205	0.190	0.193	57'
56'	0.295	0.200	0.205	0.199	0.200	0.200	**0.190**	0.200	0.196	**0.205**	0.208	0.202	0.187	0.198	0.203	0.196	0.195	0.195	0.198	0.144	0.187	0.109	0.123	0.162	0.187	0.142	0.195	**0.200**	0.200	0.203	0.188	0.162	56'
55'	0.195	0.202	0.205	0.197	0.217	0.206	**0.135**	0.150	0.190	**0.165**	0.208	0.207	0.197	0.195	0.200	0.204	0.198	0.200	0.195	0.140	0.195	0.100	0.162	**0.210**	0.186	0.137	0.184	0.093	0.195	0.153	0.195	0.113	55'
54'	0.200	0.205	0.205	0.132	0.229	0.208	**0.200**	0.190	0.195	**0.170**	0.200	0.160	0.197	0.190	0.200	0.205	0.193	0.192	0.192	0.124	0.179	0.201	0.140	**0.210**	0.190	0.140	0.175	0.088	0.185	0.192	0.187	0.142	54'
53'	0.206	0.209	0.209	0.201	0.247	0.209	**0.196**	0.208	0.212	**N/A**	0.200	0.199	0.193	0.199	0.179	0.210	0.197	0.194	0.201	0.204	0.189	0.180	0.197	**0.237**	0.198	0.183	0.212	**0.191**	0.203	0.210	0.207	0.195	53'
52'	0.202	0.194	0.195	0.195	0.186	0.203	**0.191**	0.194	0.222	0.199	0.213	0.190	0.194	0.207	0.211	0.204	0.194	0.191	0.204	0.207	0.196	0.204	0.199	**0.214**	0.202	0.199	0.207	0.198	0.209	0.212	0.202	0.197	52'
51'	0.198	0.196	0.197	0.199	0.204	0.202	**0.197**	0.183	0.211	0.196	0.225	0.204	0.189	0.200	0.203	0.203	0.193	0.191	0.207	0.187	0.199	0.203	0.204	0.195	0.206	0.174	0.204	0.194	0.205	0.218	0.201	0.194	51'
50'	0.196	0.206	0.185	0.196	0.198	0.205	**0.196**	0.197	0.204	0.200	0.229	0.209	0.194	0.211	0.202	0.207	0.199	0.196	0.213	0.186	0.204	0.199	0.199	0.210	0.209	0.199	0.209	0.197	0.204	0.220	0.206	0.199	50'
49'	0.202	0.193	0.196	0.203	0.202	0.204	**0.204**	0.208	0.202	0.208	0.219	0.209	0.206	0.214	0.203	0.214	0.206	0.214	0.211	0.199	0.207	0.204	0.200	0.193	0.214	0.194	0.215	0.199	0.201	0.220	0.217	0.199	49'
48'																																	48'
							V																										

ALSTOM

NFLD Hydro
January, 2006
Unit # 2
East Waterwall

Tube Number

Elev.	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	Elev.
60'	0.210	0.215	0.208	0.215	0.210	0.210	0.208	0.215	0.210	0.200	0.210	0.205	0.210	0.205	0.205	0.206	0.205	0.215	0.210	0.220	0.220	0.210	0.215	0.218	0.225	0.210	0.215	0.215	0.217	0.220	0.225	0.215	60'
59'	0.202	0.206	0.185	0.198	0.192	0.190	0.190	0.200	0.186	0.200	0.200	0.195	0.185	0.185	0.185	0.190	0.190	0.209	0.200	0.210	0.197	0.176	0.200	0.189	0.191	0.190	0.188	0.192	0.188	0.200	0.200	0.187	59'
58'	0.198	0.189	0.189	0.189	0.179	0.190	0.179	0.198	0.190	0.196	0.195	0.195	0.180	0.187	0.187	0.193	0.186	0.200	0.190	0.200	0.198	0.180	0.202	0.186	0.173	0.180	0.180	0.190	0.183	0.201	0.204	0.184	58'
57'	0.210	0.188	0.191	0.185	0.200	0.191	0.190	0.210	0.180	0.197	0.190	0.190	0.190	0.186	0.186	0.183	0.182	0.203	0.204	0.137	0.203	0.135	0.204	0.144	0.194	0.135	0.185	0.186	0.183	0.192	0.199	0.190	57'
56'	0.203	0.192	0.189	0.182	0.197	0.185	0.194	0.186	0.188	0.190	0.185	0.181	0.180	0.180	0.180	**0.160**	0.127	0.200	0.186	0.187	0.195	0.196	0.189	0.118	0.194	0.195	0.188	0.189	0.178	0.166	0.194	0.184	56'
55'	0.198	0.189	0.188	0.199	0.144	0.185	0.185	0.189	0.188	0.183	0.190	0.190	0.186	0.170	0.170	**0.090**	0.160	0.195	0.190	0.200	0.205	0.181	0.192	0.107	0.127	0.190	0.186	0.195	0.180	0.194	0.197	0.189	55'
54'	0.196	0.184	0.180	0.189	0.202	0.197	0.170	0.205	0.189	0.188	0.142	0.184	0.181	0.195	0.195	**0.085**	0.103	0.135	0.203	0.197	0.210	0.136	0.135	0.192	0.140	0.180	0.186	0.192	0.179	0.207	0.206	0.193	54'
53'	0.196	0.207	0.196	0.186	0.219	0.209	0.195	0.209	0.205	0.209	0.207	0.204	0.201	0.206	0.208	**0.191**	0.210	0.203	0.212	0.216	0.210	0.199	0.215	0.204	0.206	0.192	0.199	0.204	0.204	0.209	0.210	0.199	53'
52'	0.216	0.199	0.203	0.197	0.212	0.209	0.196	0.197	0.193	0.208	0.208	0.195	0.204	0.202	0.207	0.197	0.212	0.208	0.214	0.218	0.209	0.205	0.210	0.199	0.194	0.195	0.191	0.194	0.188	0.210	0.204	0.197	52'
51'	0.212	0.196	0.205	0.193	0.194	0.205	0.188	0.205	0.201	0.203	0.190	0.199	0.207	0.199	0.194	0.195	0.206	0.210	0.213	0.208	0.210	0.207	0.205	0.199	0.195	0.188	0.188	0.193	0.190	0.206	0.204	0.193	51'
50'	0.204	0.206	0.192	0.186	0.202	0.206	0.187	0.197	0.204	0.204	0.199	0.209	0.202	0.190	0.197	0.199	0.204	0.194	0.213	0.202	0.203	0.208	0.208	0.196	0.204	0.197	0.194	0.199	0.194	0.206	0.210	0.199	50'
49'	0.212	0.200	0.206	0.197	0.213	0.211	0.201	0.209	0.207	0.208	0.208	0.204	0.199	0.197	0.203	0.212	0.208	0.209	0.210	0.210	0.214	0.207	0.215	0.198	0.208	0.192	0.197	0.207	0.200	0.212	0.209	0.207	49'
48'																																	48'

Tube Number

Elev.	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	Elev.
60'	0.208	0.215	0.208	0.220	0.205	0.220	0.205	0.220	0.215	0.215	0.215	0.205	0.215	0.210	0.215	0.220	0.212	0.200	0.212	0.217	0.222	0.217	0.205	0.214	0.210	0.208	0.214	0.217	N/A	N/A	N/A	N/A	60'
59'	0.180	0.178	0.182	0.186	**0.180**	0.183	**0.181**	0.192	0.200	0.203	0.179	0.182	0.183	0.190	0.196	0.189	0.178	0.163	0.200	0.195	0.200	0.200	0.188	0.183	0.193	0.182	0.205	0.205	N/A	N/A	N/A	N/A	59'
58'	0.176	0.178	0.176	0.160	**0.088**	0.126	**0.078**	0.193	0.184	0.190	0.180	0.175	0.180	0.182	0.190	0.180	0.187	0.168	0.192	0.182	0.186	0.195	0.177	0.185	0.185	0.184	0.192	0.209	N/A	N/A	N/A	N/A	58'
57'	0.174	0.184	0.173	0.179	**0.083**	0.162	**0.189**	0.185	0.188	0.187	0.188	0.176	0.181	0.186	0.189	0.190	0.176	0.164	0.195	0.189	0.190	0.195	0.175	0.190	0.190	0.193	0.185	0.201	N/A	N/A	N/A	N/A	57'
56'	0.178	0.172	0.182	0.187	**0.190**	0.205	**0.097**	0.194	0.195	0.176	0.187	0.180	0.186	0.181	0.184	0.190	0.190	0.168	0.175	0.190	0.187	0.192	0.180	0.180	0.180	0.182	0.189	0.205	N/A	N/A	N/A	N/A	56'
55'	0.110	0.182	0.130	0.189	**0.182**	0.200	**0.172**	0.183	0.132	0.185	0.190	0.185	0.176	0.188	0.187	0.188	0.175	0.160	0.175	0.180	0.198	0.194	0.188	0.192	0.196	0.178	0.181	0.188	N/A	N/A	N/A	N/A	55'
54'	0.175	0.184	0.180	0.194	0.186	0.195	0.195	0.189	0.204	0.196	0.195	0.190	0.184	0.180	0.190	0.180	0.180	0.160	0.180	0.176	0.187	0.199	0.177	0.186	0.186	0.185	0.190	0.190	N/A	N/A	N/A	N/A	54'
53'	0.205	0.206	0.199	0.208	0.198	0.205	0.204	0.190	0.199	0.207	0.202	0.198	0.197	0.195	0.199	0.204	0.203	0.194	0.194	0.203	0.208	0.205	0.195	0.204	0.208	0.204	0.206	0.208	N/A	N/A	N/A	N/A	53'
52'	0.193	0.195	0.195	0.205	0.195	0.207	0.203	0.198	0.204	0.199	0.193	0.199	0.209	0.198	0.198	0.198	0.206	0.195	0.200	0.206	0.205	0.210	0.194	0.197	0.200	0.204	0.202	0.204	N/A	N/A	N/A	N/A	52'
51'	0.194	0.199	0.195	0.206	0.193	0.209	0.206	0.205	0.202	0.208	0.205	0.196	0.196	0.199	0.199	0.202	0.208	0.192	0.196	0.209	0.210	0.208	0.209	0.208	0.199	0.209	0.209	0.207	N/A	N/A	N/A	N/A	51'
50'	0.193	0.192	0.194	0.209	0.194	0.208	0.207	0.199	0.205	0.205	0.199	0.198	0.193	0.187	0.206	0.206	0.205	0.194	0.195	0.208	0.200	0.212	0.205	0.205	0.208	0.209	0.205	0.212	N/A	N/A	N/A	N/A	50'
49'	0.197	0.193	0.196	0.208	0.198	0.207	0.209	0.204	0.206	0.199	0.202	0.207	0.206	0.195	0.209	0.212	0.201	0.195	0.205	0.213	0.208	0.200	0.204	0.209	0.205	0.204	0.208	0.207	N/A	N/A	N/A	N/A	49'
48'																													N/A	N/A	N/A	N/A	48'

Denotes tube replacement. Note: Tube 31 is 15'-6" long. Tube 39 is 11'-0" long. Tube 46 was a 'good' tube removed for internal inspection.
Denotes blister on tube - all repaired by pad welding
Denotes tube below 70% MWT - not repaired
Denotes repair of crack noted in RT film or found during pressure test
Denotes pad welding of tube less than 0.100" based on supplimentary UT measurements taken adjacent to the tube crown

Summary:
All locations less than 0.100" removed or repaired.
All blisters and cracks repaired
Nine tubes removed
Thirty-two pad welds - note 3 blisters repaired at tube #18 - 51' elevation

ALSTOM

NFLD Hydro
11 January, 2006
Unit # 2
East Waterwall

Tube Number

Elev.	17N	17S	18N	18S	19N	19S	20N	20S	21N	21S	22N	22S	23N	23S	24N	24S	25N	25S	26N	26S	27N	27S	28N	28S	29N	29S	30N	30S	31N	31S	32N	32S	Elev.
58'	212	197	209	190	205	201	203	198	205	184	206	203	201	199	200	205	199	203	207	205	199	206	183	195	195	182	192	188			195	198	58'
57'	214	202	197	191	206	202	202	198	205	192	209	205	205	196	190	208	184	199	211	205	202	202	176	198	194	187	187	193			195	196	57'
56'	212	202	205	191	200	204	202	199	192	198	210	196	196	198	192	204	182	199	211	207	192	198	182	190	192	198	195	185			195	197	56'
55'	214	202	203	194	204	204	208	203	195	196	208	202	190	190	188	197	174	192	200	208	198	197	187	189	186	192	189	188			194	198	55'
54'	210	158	162	156	150	167	167	149	135	149	156	153	145	150	146	132	152	153	170	149	161	154	154	145	154	145	146	156			159	159	54'
53'	208	168	169	153	168	151	157	147	137	149	149	150	136	150	141	167	133	163	170	127	137	138	118	140	151	148	152	167			150	139	53'
52'	169	155	149	148	160	148	169	157	130	142	147	147	159	152	144	167	136	147	160	164	149	135	138	149	150	143	139	157			160	177	52'
51'	167	159	159	154	161	151	160	150	150	138	143	153	160	143	150	160	140	155	167	143	150	153	146	161	152	149	154	160			156	200	51'

Tube Number

Elev.	33N	33S	34N	34S	35N	35S	36N	36S	37N	37S	38N	38S	39N	39S	40N	40S	41N	41S	42N	42S	43N	43S	44N	44S	45N	45S	46N	46S	47N	47S	48N	48S	Elev.
58'	198	197	170	160	166	165	160	160	170	160	178	172	175	165	175	158	144	173	186	170	174	170	168	169	165	153	160	170	163	166	170	158	58'
57'	195	192	168	168	168	160	155	165	168	159	174	173	170	167	168	154	150	155	190	165	165	160	160	171	170	166	165	168	159	162	172	159	57'
56'	193	192	169	163	167	160	155	160	176	162	173	171	167	163	170	165	175	168	181	165	177	164	172	171	159	173	170	167	160	169	175	165	56'
55'	186	195	164	168	170	162	159	154	170	162	178	168	175	187	169	155	172	160	182	175	173	173	166	165	179	172	170	160	168	169	170	160	55'
54'	136	160	164	156	135	103	126	153	195	193	152	160	200	190	149	155	170	152	165	177	177	164	151	162	161	143	160	165	148	170	170	154	54'
53'	158	137	130	165	149	145	153	150	164	152	152	165	210	189	140	158	163	150	137	172	157	159	163	154	156	130	165	160	147	156	165	150	53'
52'	153	155	150	160	130	156	160	148	170	167	160	157	190	194	150	147	150	157	137	160	180	172	149	153	148	126	166	162	143	157	161	155	52'
51'	155	131	124	152	126	149	154	149	190	161	167	163	190	200	175	170	170	158	160	166	175	163	154	163	158	146	180	155	169	167	170	165	51'

Tube Number

Elev.	49N	49S	50N	50S	51N	51S	52N	52S	53N	53S	54N	54S	55N	55S	56N	56S	57N	57S	58N	58S	59N	59S	60N	60S	61N	61S	62N	62S	63N	63S	64N	64S	Elev.
58'	170	154	160	148	160	167	159	159	158	164	153	154	155	155	149	161	178	153	145	173	155	161	203	153	164	163	157	168	163	163	219	162	58'
57'	168	154	157	144	160	162	165	161	156	163	159	153	160	163	159	161	171	150	147	178	159	165	155	158	169	155	157	173	159	166	213	162	57'
56'	168	168	158	152	162	170	178	160	157	176	165	165	165	174	159	161	173	152	166	180	163	166	167	168	172	164	159	171	158	168	200	162	56'
55'	157	162	158	162	164	180	170	173	159	174	165	165	166	160	168	168	175	155	150	183	170	160	167	168	163	168	162	177	153	167	175	168	55'
54'	155	154	170	155	151	158	162	183	141	162	140	160	137	160	176	184	165	144	145	173	183	155	188	170	182	176	190	170	188	173	167	167	54'
53'	143	148	140	143	155	156	115	160	140	150	119	143	95	152	142	156	155	142	133	159	155	176	169	159	195	162	162	174	160	161	155	165	53'
52'	160	143	164	145	154	155	156	158	150	151	148	147	160	160	100	153	157	151	119	154	157	169	182	160	164	171	169	175	180	160	154	168	52'
51'	154	140	155	149	167	169	132	117	154	166	167	160	78	163	170	170	170	158	146	156	169	173	195	155	199	169	181	183	200	170	204	172	51'

ALSTOM

NFLD Hydro
13 January, 2006
Unit # 2
West Waterwall

Tube Number

Elev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Elev.
60'																																	60'
59'																																	59'
58'																																	58'
57'	0.202	0.193	0.196	0.181	0.200	0.174	0.195	0.184	0.180	0.192	0.184	0.178	0.184	0.189	0.178	0.187	0.182	0.179	0.187	0.189	0.191	0.189	0.193	0.184	0.188	0.192	0.191	0.188	0.187	0.185	0.174	0.189	57'
56'	0.210	0.185	0.202	0.189	0.195	0.174	0.196	0.180	0.178	0.190	0.184	0.180	0.180	0.190	0.182	0.185	0.184	0.178	0.189	0.188	0.188	0.187	0.191	0.186	0.184	0.192	0.189	0.186	0.185	0.182	0.179	0.189	56'
55'	0.206	0.189	0.200	0.175	0.196	0.170	0.185	0.183	0.180	0.191	0.182	0.179	0.179	0.185	0.176	0.180	0.179	0.173	0.184	0.182	0.188	0.184	0.187	0.183	0.180	0.192	0.187	0.186	0.184	0.186	0.175	0.189	55'
54'	0.195	0.184	0.204	0.179	0.200	0.175	0.188	0.186	0.182	0.190	0.185	0.179	0.175	0.182	0.170	0.175	0.179	0.174	0.186	0.186	0.186	0.186	0.186	0.182	0.182	0.188	0.187	0.180	0.184	0.180	0.170	0.185	54'
53'																							0.190	0.189	0.184	0.190	0.194	0.183	0.178	0.186	0.171	0.192	53'
52'																							0.189	0.198	0.186	0.194	0.200	0.189	0.185	0.188	0.176	0.191	52'
51'																							0.189	0.202	0.188	0.196	0.199	0.192	0.185	0.193	0.176	0.201	51'
50'																							0.195	0.204	0.200	0.201	0.204	0.197	0.182	0.199	0.183	0.200	50'
49'																																	49'
48'																																	48'

Tube Number

Elev.	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	Elev.
60'																																	60'
59'																																	59'
58'																																	58'
57'	0.178	0.176	0.181	0.183	0.177	0.189	0.181	0.184	0.177	0.189	0.186	0.174	0.193	0.180	0.184	0.170	0.176	0.180	0.183	0.179	0.182	0.182	0.178	0.187	0.177	0.184	0.184	0.191	0.197	0.186	0.176	0.176	57'
56'	0.175	0.174	0.178	0.182	0.178	0.185	0.183	0.186	0.175	0.186	0.189	0.176	0.192	0.182	0.181	0.163	0.178	0.180	0.182	0.184	0.184	0.183	0.179	0.186	0.175	0.182	0.180	0.192	0.195	0.189	0.178	0.180	56'
55'	0.177	0.173	0.179	0.179	0.174	0.189	0.179	0.182	0.175	0.189	0.182	0.182	0.195	0.182	0.179	0.170	0.178	0.185	0.182	0.178	0.184	0.183	0.181	0.186	0.176	0.183	0.183	0.192	0.197	0.188	0.179	0.175	55'
54'	0.182	0.176	0.181	0.181	0.174	0.197	0.175	0.189	0.180	0.187	0.198	0.178	0.186	0.193	0.180	0.175	0.180	0.182	0.184	0.177	0.183	0.185	0.176	0.188	0.178	0.186	0.182	0.193	0.195	0.194	0.180	0.178	54'
53'	0.176																																53'
52'	0.180																																52'
51'	0.185																																51'
50'	0.188																																50'
49'																																	49'
48'																																	48'

NFLD Hydro
13 January, 2006
Unit # 2
West Waterwall

Tube Number

ALSTOM

Elev.	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	Elev.
60'																																	60'
59'																																	59'
58'																																	58'
57'	0.192	0.186	0.186	0.186	0.191	0.201	0.192	0.182	0.184	0.189	0.171	0.195	0.189	0.184	0.184	0.189	0.182	0.184	0.171	0.180	0.184	0.174	0.179	0.181	0.188	0.178	0.187	0.178	0.173	0.193	0.180	0.170	57'
56'	0.187	0.183	0.188	0.184	0.193	0.198	0.186	0.179	0.186	0.190	0.171	0.193	0.189	0.181	0.189	0.184	0.184	0.189	0.175	0.182	0.187	0.180	0.181	0.182	0.184	0.177	0.183	0.176	0.175	0.184	0.178	0.172	56'
55'	0.189	0.185	0.184	0.184	0.186	0.199	0.187	0.191	0.187	0.194	0.174	0.192	0.189	0.184	0.191	0.188	0.186	0.191	0.169	0.186	0.190	0.180	0.180	0.182	0.185	0.175	0.184	0.178	0.175	0.191	0.183	0.172	55'
54'	0.191	0.184	0.187	0.182	0.184	0.199	0.187	0.183	0.189	0.192	0.172	0.196	0.183	0.179	0.188	0.192	0.183	0.188	0.167	0.185	0.188	0.180	0.178	0.178	0.185	0.186	0.184	0.176	0.179	0.195	0.188	0.178	54'
53'																																	53'
52'																																	52'
51'																																	51'
50'																																	50'
49'																																	49'
48'																																	48'

Tube Number

Elev.	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	Elev.
60'																																	60'
59'																																	59'
58'																																	58'
57'	0.183	0.186	0.186	0.185	0.182	0.179	0.174	0.179	0.178	0.177	0.173	0.184	0.175	0.160	0.181	0.175	0.179	0.175	0.183	0.188	0.182	0.185	0.190	0.190	0.183	0.198							57'
56'	0.184	0.182	0.184	0.189	0.181	0.181	0.178	0.184	0.180	0.172	0.178	0.187	0.173	0.162	0.179	0.176	0.182	0.185	0.179	0.189	0.183	0.200	0.197	0.185	0.185	0.202							56'
55'	0.182	0.181	0.189	0.187	0.182	0.180	0.178	0.181	0.177	0.172	0.176	0.188	0.175	0.169	0.178	0.177	0.182	0.176	0.184	0.188	0.182	0.193	0.193	0.188	0.182	0.207							55'
54'	0.182	0.184	0.190	0.191	0.187	0.181	0.179	0.183	0.179	0.178	0.175	0.184	0.181	0.170	0.180	0.183	0.178	0.181	0.186	0.199	0.182	0.192	0.200	0.191	0.179	0.210							54'
53'																																	53'
52'																																	52'
51'																																	51'
50'																																	50'
49'																																	49'
48'																																	48'

ALSTOM

NFLD Hydro
13 January, 2006
Unit # 2
North Waterwall

															Tube Number																	
Elev.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**Elev.**
60'																																	**60'**
59'																																	**59'**
58'																																	**58'**
57'	N/A	0.220	0.220	0.239	0.227	0.210	0.215	0.219	0.206	0.213	0.226	0.208	0.210	0.205	0.229	0.210	0.205	0.225	0.213	0.215	0.216	0.205	0.208	0.222	0.210	0.207	0.213	0.210	0.195	0.215	0.200	0.208	**57'**
56'	N/A	0.237	0.225	0.216	0.224	0.207	0.124	0.214	0.209	0.215	0.225	0.214	0.212	0.205	0.218	0.212	0.200	0.220	0.215	0.209	0.210	0.200	0.214	0.200	0.205	0.205	0.225	0.203	0.196	0.202	0.204	0.218	**56'**
55'	N/A	0.226	N/A	0.208	0.235	0.217	0.210	0.217	0.210	0.210	0.232	0.221	0.208	0.203	0.200	0.213	0.200	0.216	0.215	0.215	0.207	0.200	0.194	0.198	0.205	0.198	0.216	0.209	0.208	0.197	0.210	0.210	**55'**
54'	N/A	N/A	N/A	0.220	0.230	0.220	0.205	0.222	0.216	0.219	0.235	0.215	0.214	0.213	0.215	0.215	0.204	0.215	0.219	0.209	0.210	0.200	0.212	0.195	0.200	0.220	0.217	0.210	0.205	0.195	0.205	0.220	**54'**
53'																																	**53'**
52'																																	**52'**
51'																																	**51'**
50'																																	**50'**
49'																																	**49'**
48'																																	**48'**

															Tube Number																	
Elev.	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**Elev.**
60'																																	**60'**
59'																																	**59'**
58'																																	**58'**
57'	0.210	0.195	0.209	0.197	0.203	0.210	0.205	0.206	0.190	0.194	0.190	0.187	0.202	0.190	0.214	0.200	0.200	0.200	0.215	0.197	0.215	0.214	0.205	0.197	0.217	0.194	0.200	0.218	0.210	0.200	0.217	0.205	**57'**
56'	0.214	0.197	0.205	0.190	0.200	0.219	0.210	0.209	0.185	0.194	0.180	0.180	0.196	0.185	0.208	0.200	0.196	0.213	0.210	0.203	0.216	0.189	0.203	0.200	0.204	0.199	0.166	0.214	0.218	0.205	0.214	0.195	**56'**
55'	0.200	0.190	0.193	0.189	0.185	0.208	0.197	0.204	0.184	0.197	0.181	0.177	0.197	0.190	0.209	0.202	0.195	0.215	0.210	0.205	0.222	0.205	0.210	0.204	0.207	0.203	0.213	0.213	0.197	0.202	0.219	0.193	**55'**
54'	0.210	0.183	0.187	0.190	0.180	0.215	0.204	0.220	0.191	0.194	0.196	0.200	0.207	0.185	0.210	0.195	0.204	0.215	0.215	0.212	0.228	0.203	0.211	0.195	0.205	0.208	0.215	0.215	0.204	0.200	0.200	0.196	**54'**
53'			0.195	0.184	0.177	0.215	0.189	0.210	0.190	0.190	0.189	0.190	0.207																				**53'**
52'			0.205	0.198	0.217	0.208	0.210	0.167	0.184	0.190	0.194	0.191	0.215																				**52'**
51'																																	**51'**
50'																																	**50'**
49'																																	**49'**
48'																																	**48'**

Denotes tube below 70% MWT

NFLD Hydro
13 January, 2006
Unit # 2
North Waterwall

Tube Number

Elev.	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	Elev.
60'																																	60'
59'																																	59'
58'																																	58'
57'	0.210	0.205	0.210	0.209	0.208	0.200	0.213	0.210	0.225	0.208	0.195	0.203	0.209	0.189	0.208	0.206	0.218	0.217	0.220	0.214	0.214	0.210	0.205	0.210	0.217	0.218	0.212	0.212	0.204	0.206	0.205	0.205	57'
56'	0.210	0.205	0.212	0.208	0.205	0.198	0.210	0.202	0.223	0.205	0.200	0.204	0.209	0.200	0.207	0.209	0.220	0.213	0.225	0.222	0.217	0.212	0.213	0.212	0.215	0.217	0.211	0.210	0.205	0.200	0.208	0.207	56'
55'	0.204	0.209	0.215	0.207	0.210	0.200	0.212	0.204	0.228	0.200	0.204	0.210	0.205	0.197	0.210	0.207	0.210	0.212	0.226	0.221	0.215	0.204	0.220	0.211	0.216	0.218	0.210	0.207	0.210	0.198	0.207	0.210	55'
54'	0.208	0.208	0.210	0.213	0.208	0.205	0.212	0.208	0.220	0.217	0.204	0.214	0.210	0.195	0.208	0.210	0.205	0.212	0.222	0.214	0.212	0.205	0.206	0.217	0.220	0.221	0.208	0.217	0.208	0.205	0.212	0.209	54'
53'																																	53'
52'																																	52'
51'																																	51'
50'																																	50'
49'																																	49'
48'																																	48'

Tube Number

Elev.	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	Elev.
60'																																	60'
59'																																	59'
58'																																	58'
57'	0.215	0.205	0.212	0.205	0.189	0.210	0.215	0.208	0.246	0.260	0.211	0.200	0.203	0.204	0.203	0.205	0.203	0.216	0.221														57'
56'	0.215	0.210	0.210	0.205	0.190	0.212	0.212	0.198	0.200	0.212	0.210	0.205	0.204	0.206	0.200	0.198	0.210	0.210	N/A														56'
55'	0.212	0.217	0.213	0.211	0.193	0.212	0.213	0.204	0.205	0.212	0.213	0.195	0.204	0.210	0.200	0.202	0.207	0.206	0.218														55'
54'	0.205	0.217	0.218	0.208	0.194	0.206	0.211	0.196	0.198	0.219	0.207	0.193	0.202	0.205	0.200	0.200	0.207	0.210	N/A														54'
53'																																	53'
52'																																	52'
51'																																	51'
50'																																	50'
49'																																	49'
48'																																	48'

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NFLD Hydro
13 January, 2006
Unit # 2
South Waterwall

Tube Number

Elev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Elev.
60'																																	60'
59'																																	59'
58'																																	58'
57'	N/A	N/A	N/A	0.210	0.207	0.193	0.198	0.190	0.197	0.209	0.205	0.208	0.208	0.209	N/A	0.199	0.209	0.200	0.198	0.204	0.206	0.209	0.199	0.204	0.206	0.199	0.202	0.200	0.192	0.199	0.202	0.202	57'
56'	N/A	N/A	N/A	0.212	0.200	0.189	0.195	0.200	0.194	0.204	0.209	0.206	0.210	0.211	0.208	0.202	0.210	0.202	0.191	0.212	0.207	0.208	0.200	0.202	0.205	0.194	0.199	0.199	0.192	0.194	0.199	0.199	56'
55'	N/A	N/A	N/A	0.212	0.197	0.200	0.195	0.206	0.193	0.198	0.206	0.209	0.209	0.211	0.206	0.203	0.202	0.208	0.196	0.208	0.205	0.209	0.190	0.202	0.208	0.200	0.205	0.199	0.199	0.198	0.201	0.204	55'
54'	N/A	N/A	N/A	0.214	0.195	0.194	0.190	0.197	0.197	0.203	0.206	0.212	0.209	0.211	0.209	0.208	0.201	0.210	0.201	0.210	0.212	0.209	0.204	0.206	0.212	0.205	0.210	0.200	0.200	0.200	0.208	0.205	54'
53'																																	53'
52'																																	52'
51'																																	51'
50'																																	50'
49'																																	49'
48'																																	48'

Tube Number

Elev.	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	Elev.
60'																																	60'
59'																																	59'
58'																																	58'
57'	0.204	0.201	0.194	0.195	0.208	0.207	0.210	0.200	0.208	0.207	0.207	0.206	0.207	0.206	0.209	0.208	0.210	0.195	0.212	0.195	0.202	0.207	0.210	0.199	0.197	0.198	0.207	0.190	0.212	0.208	0.212	0.203	57'
56'	0.200	0.203	0.198	0.200	0.204	0.205	0.208	0.196	0.205	0.208	0.208	0.208	0.203	0.206	0.204	0.206	0.212	0.199	0.212	0.192	0.190	0.200	0.212	0.200	0.197	0.198	0.206	0.194	0.215	0.199	0.215	0.206	56'
55'	0.199	0.201	0.202	0.205	0.208	0.204	0.195	0.193	0.207	0.207	0.212	0.203	0.205	0.203	0.208	0.206	0.212	0.192	0.210	0.184	0.198	0.195	0.212	0.201	0.198	0.192	0.204	0.190	0.214	0.200	0.214	0.206	55'
54'	0.204	0.208	0.210	0.208	0.209	0.210	0.202	0.202	0.209	0.200	0.212	0.207	0.203	0.207	0.210	0.208	0.214	0.198	0.212	0.185	0.195	0.199	0.208	0.197	0.199	0.201	0.208	0.192	0.212	0.203	0.215	0.202	54'
53'																																	53'
52'																																	52'
51'																																	51'
50'																																	50'
49'																																	49'
48'																																	48'

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NFLD Hydro
13 January, 2006
Unit # 2
South Waterwall

Tube Number

Elev.	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	Elev.
60'																																	60'
59'																																	59'
58'																																	58'
57'	0.202	0.205	0.208	0.209	0.210	0.210	0.208	0.208	0.201	0.202	0.212	0.208	0.214	0.212	0.211	0.214	0.214	0.216	0.205	0.190	0.208	0.209	0.211	0.211	0.212	0.211	0.211	0.212	0.210	0.212	0.215	0.215	57'
56'	0.203	0.199	0.201	0.205	0.215	0.211	0.206	0.212	0.205	0.209	0.210	0.202	0.212	0.214	0.212	0.214	0.211	0.211	0.201	0.187	0.210	0.208	0.211	0.209	0.205	0.209	0.211	0.212	0.209	0.214	0.214	0.215	56'
55'	0.202	0.198	0.205	0.202	0.209	0.212	0.209	0.208	0.201	0.206	0.212	0.205	0.208	0.212	0.218	0.215	0.210	0.212	0.208	0.186	0.207	0.212	0.210	0.208	0.209	0.205	0.213	0.215	0.209	0.215	0.212	0.214	55'
54'	0.206	0.206	0.202	0.210	0.212	0.205	0.205	0.212	0.207	0.212	0.208	0.214	0.215	0.210	0.215	0.214	0.217	0.216	0.214	0.200	0.212	0.212	0.212	0.214	0.212	0.214	0.210	0.210	0.204	0.214	0.214	0.212	54'
53'																																	53'
52'																																	52'
51'																																	51'
50'																																	50'
49'																																	49'
48'																																	48'

Tube Number

Elev.	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	Elev.
60'																																	60'
59'																																	59'
58'																																	58'
57'	0.214	0.216	0.215	0.214	0.216	0.206	0.207	0.210	0.212	0.215	0.212	0.218	0.211	0.215	0.204	0.211	0.215	0.210	0.216														57'
56'	0.218	0.216	0.218	0.216	0.211	0.199	0.208	0.214	0.215	0.216	0.216	0.205	0.210	0.214	0.203	0.215	0.219	0.209	0.217														56'
55'	0.216	0.215	0.209	0.219	0.208	0.201	0.205	0.214	0.216	0.214	0.210	0.214	0.202	0.214	0.207	0.214	0.217	0.208	0.218														55'
54'	0.215	0.216	0.210	0.218	0.211	0.211	0.208	0.218	0.220	0.211	0.204	0.214	0.210	0.216	0.207	0.210	0.211	0.210	0.222														54'
53'																																	53'
52'																																	52'
51'																																	51'
50'																																	50'
49'																																	49'
48'																																	48'

ALSTOM

Power Service

Newfoundland & Labrador Hydro

January 26, 2006

Attention: Terry LeDrew:

We have reviewed the recent failures and damage found in the east sidewall of Holyrood Unit 2. Our conclusions and recommendations are discussed below.

The damage clearly is related to the fouling identified on the inside surfaces of the tube. The overheating patterns (isolated and spotty) are consistent with an internal problem rather than an external one such as flame impingement. Flame impingement would be expected to cause larger regions of consistent overheating damage.

The east and west sidewall are identical and therefore have the same circulation patterns. This should result in equal internal deposit loading on both walls. Perhaps the pending tube analysis will provide some insight into this.

Our standards predict that the highest heat zone in the waterwalls would be located near the centre at about the top of the windbox (at approximately 56' elevation). Thus the elevation of the damage observed makes sense. However, the models do not explain why the damage is essentially confined to the east wall.

Boiler blowdown on start-up (to control drum levels) was considered as a possible explanation. It was reported that the east side is the one that is nearly always used. However, the blowdown comes off of the central header, which in tern feeds the side headers. Thus it is unlikely that this would have a significant impact on the east wall. The same is true for the continuous blowdown that comes off the steam drum. This take-off for this blowdown is balanced inside the drum.

The current practice at Holyrood is to open fuel air dampers on an opposite corner basis. That is, when a burner is put in service, the fuel air damper for that burner and the one directly across from it open together. While this is not consistent with our current recommendation for only opening the fuel air dampers for the guns in service, there does not appear to be a connection between this firing pattern and the east wall damage.

Other firing practices can result in hot spots in the furnace. Our recommendations to avoid this are as follows:

- Avoid firing one burner in an elevation
- Fire burners in opposite pairs when ever possible
- Use as many burners as possible to spread out the heat flux as much as possible, especially at low loads when the circulation is not as strong
- Regularly rotate corners in service, especially at low loads

It may be possible that preferential use of the D corner burner at the 3rd elevation has lead to this failure location. This is difficult to substantiate however. When the unit is returned to service, it may also be possible to utilize the recently installed thermocouples to determine the effect of different firing patterns on the temperature of the east and west walls.

Another possible explanation for the accelerated failure on the east wall might be a shift in the fireball towards the east wall. This could occur if the auxiliary air dampers are not opening equally at all corners (in

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this case more on the west side than on the east). This should be investigated when the unit is returned to service.

The burner tip might play a roll as well. We understand that Holyrood currently uses 70 degree tips and that 90 degree tips may have been used at some time in the past. Smaller angle tips are also available (60 and 40 degree) and could be tried, possibly in conjunction with waterwall temperature measurements.

The low circulation as a result of recent low loading on the unit should not be an issue. At low loads, the circulation is less strong, but the heat flux to the wall also is lower. Also, the highest heat flux is to the arch and not the walls. Therefore it would be expected that any circulation problems would be manifested at this location. There has been no damage found on the arch. Firing at low loads does however make the boiler more susceptible to hot spots caused by firing few guns at high capacity and not rotating these guns. Our recommendations as described above should be followed.

Limiting load (and pressure) could bring the required thickness by ASME rules down to the point where the required minimum thickness is equal to 0.140 " compared to the current 0.200". Limiting pressure has the added benefit of reducing the saturation temperature and consequently would result in cooler tubes as well.

It seems reasonable to presume that the rapid deterioration of the east wall might be related to the pressure wash completed during the maintenance outage. Prior to the pressure wash, the tubes were insulated on the inside by the scale loading and also insulated on the outside by the slag coating. The slag was helping to counteract the effect of the internal deposits. When this slag was removed, the counteractive effect was also removed and this might have contributed to the accelerated failure rate observed since the unit was started after the overhaul. Conversely, the suggestion that was raised to apply refractory inside the furnace over the damaged wall area, might be effective in reducing future failure rates.

With respect to safety and personnel protection against injury from future failures, it is important to qualify the mechanism which caused the failures. The internal deposits, which insulate the tubes from cooling, combine with the high heat flux from the combustion, thereby creating local overheating in the tubes. The failure mode can be 1) blistering, or creep rupture from overheating, 2) wall thinning from wastage to a point where the internal pressure ruptures the tube, or 3) hydrogen attack caused by overheating together with the corrosive environment generated beneath the internal deposits on the furnace side of the tube. All three of these failure modes require a high heat flux. This heat flux is only present on the interior of the boiler(i.e. the furnace side of the waterwall tubes). Based on this fact, failures similar to the one experienced in January should not occur on the cold side of the tubes. This however does not guarantee that cold side (casing side) failures from other mechanisms will not occur. These other mechanisms could include corrosion fatigue, failures at points of attachments, original tube defects, pitting corrosion during layup, etc. This is a 35 year old unit which probably has a lot of the ills associated with a typical oil fired utility of this vintage and which it is now known to require chemical cleaning.

There is a high probability that there will be additional failures on the hot side of the tubes similar to previous ones until such time as the unit is chemically cleaned and the affected walls are replaced. Although Alstom Canada Inc. is not aware of any injury as a direct result of a hot side tube failure, restricting access to the affected area can be implemented to prevent unauthorized access.

To summarize, with the information available, we can not determine why the east wall has failed prematurely. We can only offer suggested explanations. Some may be verified once the unit returns to service. We have provided recommendations that should be followed to minimize the formation of hot spots in the furnace.

John McMillan P.Eng.

John McMillan P.Eng
Manager ,Engineering

ALSTOM

Power Service

Newfoundland & Labrador Hydro February 6, 2006

Attention: Terry LeDrew
Manager,Thermal Generation

Further to our meeting at Hydro Place on February 1, 2006, ALSTOM was requested to comment on the risks and consequences of further tube failures as a result of the discussion and the action plan being instituted for unit #2. The plan includes a replacement of waterwall sections which will include the affected tubes. As this replacement will not occur for two months, a review of possible risks of additional tube failures in this two month window is outlined below.

Fire Side Tube Failures

The failure mechanism associated with the recent waterwall tube failures is overheating caused by internal deposits. These deposits insulate the tube from cooling, and combine with the heat flux from combustion to overheat the tube locally. It is important to note that not every tube is affected, as it has been seen that the majority of the tubes in the affected area show no signs of wall thinning. This failure mode can only occur on the fire side of the waterwall as it is driven by the heat flux of combustion. It can not occur on the casing side on the boiler.

The failure manifests itself either by forming a blister, which cracks and causes a leak, by thinning the wall of the tube through wastage to the point of producing a pressure failure, or by hydrogen attack caused by overheating together with the corrosive environment under the internal deposits on the fireside of the tube.

The recent inspection of the east wall found a total of 38 blisters. The failure which caused the most recent outage was due to hydrogen attack, and there were no tube failures due to wall thinning.

As it has been determined that the internal deposits range from "very difficult to virtually impossible" to remove chemically (Northland Consulting Ltd. Letter of January 26, 2006), the only way to reduce the risk of additional failures in the next two months is to reduce the heat flux to the affected wall area. Actions are being instituted which will accomplish this.

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With regard to the probability of another fireside tube failure occurring in the next two months, until the affected tubes are replaced, the potential still exits for another failure. However, recent and future actions will reduce this probability.

1. In the past three weeks an extensive inspection has been carried to isolate the boundaries of the damage and identify each tube that required repair/replacement. UT inspection, RT inspection, and internal boroscope inspection has resulted in a detailed mapping of the condition of each and every tube in the affected area. Although it is known that there are some tubes that remain with wall thickness less than 0.140" MWT, and it is possible that there are some tubes that may have hydrogen damage that was not detected, the thorough inspection has resulted in repairs and replacement of the blisters, cracks, and excessively thinned tubes (less than 0.100").
2. The predicted tube mid wall temperature is about 720°F, which is based on a clean tube. The damage that is being seen indicates that the metal temperature must be at least 900°F. This extra temperature is the result of the insulating effect of the internal scale. By operating the unit at 60MW or lower and reducing the drum operating pressure from 2050 psi to 1700 psi, the predicted metal temperature will reduce by 52°F. This reduction is due to a lower saturation temperature from the pressure reduction combined with a lower heat flux from the load reduction.
3. Another action that is being instituted is a change to the firing practice whereby only the lower elevation of burners would be placed in service and they will be placed in a downward tilt position. Also, multiple burners will be used. This action will further reduce the heat flux to the waterwall tubes in the affected area. This will result in a minor reduction of about 5°F in the tube temperature.
4. The combination of items 2 and 3 above will have a net affect of reducing the tube metal temperature by 57°F. This will provide an increased margin of protection as the ASME Code minimum wall requirement will drop from 0.191" MWT to 0.136" MWT based on the 2004 ASME Code. Thus, by reducing the tube temperature, the potential for further overheating failures is reduced.
5. Base on the ASME Code required wall thickness of 0.136" as indicated in item 4 above, 70% of this thickness is 0.095". There are currently no tubes that have a wall thickness below 0.100" .
6. The unit was recently subjected to two service pressure tests of 1885 psi. By reducing the operating pressure to 1700 psi, the waterwall tubing will be operating at a pressure about 10% below the successful service pressure test.

Although the above actions will not eliminate the risk of another fireside tube leak, this risk is reduced considerably by the detailed inspection/repair/replace actions and the limitations imposed on the future firing/operational practice.

In addressing the consequences of another leak, a couple of points need to be considered.

1. A fireside tube leak or failure does not affect personnel safety as the failure is completely contained inside of the boiler.
2. There have been two failure modes experienced from the overheating, cracks in blisters, and a blow out from hydrogen damage. To date there have been 38 blisters discovered and one (1) hydrogen blow out. The consequent of a blister crack occurring may not cause a unit outage if the crack is small enough not to affect the boiler operation. Of course, a large or multiple cracked blisters may cause an outage. A hydrogen blow out will definitely cause an outage.
3. The action plan also includes restricting access to this area, which will also provide safety assurances.

In summary, the worst case scenario would be a boiler outage and personnel safety is assured.

During our meeting, the possibility of adding refractory to the waterwall to reduce the tube metal temperature was discussed. Refractory has been added to waterwalls in the past to protect the walls from erosion and abrasion, and to act as a heat sink to retain the heat in the bottom of a bark fired industrial boiler for better combustion of moist fuel. The addition of refractory to protect waterwalls from overheating has not been done previously. As the current action plan provides for a replacement waterwall in two months, the practicality of the time and cost required to obtain the refractory material, and the time and cost required to install same for a two month operational period must be considered when weighing the risks. As noted above, the consequence of an additional failure will be a boiler outage which will require a tube replacement.

Casing Side Tube Failures

The recent tube failures, as described above, are isolated to the fireside exclusively. As there is no heat flux on the casing side, this type of failure can not happen on the outward side of the tube.

Failures that can occur on the casing side include corrosion fatigue, failures at points of attachments, original tube defects, pitting corrosion, etc. The risk of this type of failure occurring is no greater on this unit than any other 35 year old oil fired utility and the recent fireside failures do not increase this risk.

Membrane Failures

The membrane between two adjacent tubes is cooled by conduction from the tubing. Although some tubes have suffered from overheating, this is local to the crown of the tube, or close to the crown. The membrane is attached to the tube 90° away from the crown, where the tube midwall temperature is lower. Therefore the membrane should still have adequate cooling and will not experience elevated temperatures.

Therefore, there is no risk of a membrane failure caused by the same failure mechanism as the recent fireside failures.

John McMillan P.Eng.

John McMillan, P.Eng
Manager, Engineering

ALSTOM

METALLURGICAL REPORT

March 8, 2006

EVALUATION OF WATERWALL TUBING

NEWFOUNDLAND AND LABRADOR HYDRO
HOLYROOD GENERATING STATION
UNIT NUMBER 2
CONTRACT NO. C-E 4968
PSA - 85818/LN-06A062
MTC-06-069

PREPARED FOR:

NEWFOUNDLAND AND LABRADOR HYDRO

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EXECUTIVE SUMMARY

Two failed sections of waterwall tubing removed from Unit 2 at Holyrood Generating Station were submitted to the Materials Technology Center (MTC) for destructive analysis. One of the tube sections, removed from east wall tube 56, failed from a relatively thick-lipped, window-type rupture, while the other tube section, removed from east wall tube 42, failed from a small pinhole opening that formed at the dome of a blister on the tube. It was noted that plant engineers were unaware of tube 42 having leaked in service prior to its submission to the laboratory. At the time of failure, both tube sections had been in service for more than 30 years.

The destructive examination of the samples established that both tubes failed as a result of severe hydrogen attack, a form of damage that occurs when the internal surfaces of tubing in high-pressure boilers undergo accelerated acidic corrosion under densely-packed internal deposits. The corrosion reaction at the ID surface of the tube liberates atomic hydrogen, which then diffuses into the remaining intact portions of the tube wall. There the hydrogen combines with the carbon present in the steel to form methane gas (CH_4). The resulting volume expansion of the methane gas causes fissuring of the grain boundaries, and in the case of these samples, eventual failure. In addition to the hydrogen attack, the blistering in tube 42 suggests that this failure had been influence by localized overheating related to the insulating effects of heavy deposits. A subsequent laboratory analysis showed these deposits to be in excess of 134 mg/cm^2 on the front side of the tube.

In an effort to identify the corrodants responsible for the hydrogen attack, a chemical analysis was made of the deposits using Energy Dispersive Spectroscopy (EDS), but none were found. This was not entirely surprising, however, given that most of the potential contaminants, particularly chlorides and acid sulfur species, are highly soluble in water.

In order to minimize the risk of additional failures in the waterwall tubing, it is recommended that a nondestructive inspection of the furnace walls be conducted to determine the extent and severity of the internal corrosion and hydrogen attack. The inspection initially should focus on the highest heat flux areas of the unit but should extend further if damage is found up to the limits of that area. Selected samples should be destructively evaluated to confirm the accuracy of the NDE so that, once the extent of the damage is known, decisions then can be made regarding tubing replacements. In addition, it is also recommended that a review of the water treatment practice for this unit be conducted in an effort to identify the source(s) of the contamination that instigated the internal corrosion and to ensure that optimum cycle chemistry is maintained during all phases of unit operation.

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March 8, 2006

METALLURGICAL REPORT:

Evaluation of Waterwall Tubing
Newfoundland and Labrador Hydro
Holyrood Generating Station, Unit 2
PSA-85818/LN-06A062
Contract No. C-E 4968
MTC-06-069

1.0 INTRODUCTION

Two sections of waterwall tubing removed from Unit 2 at Newfoundland and Labrador Hydro's Holyrood Generating Station were submitted to the Materials Technology Center (MTC) for destructive analysis. The samples, shown in Figure 1 as they appeared when received from the field, were removed from east wall tubes 56 and 42 at an approximate elevation of 54'. As shown, tube 56 failed from a large window-type failure, while tube 42 failed from a pinhole opening. It was noted that at the time the samples were submitted for examination, plant engineers were unaware of tube 42 having leaked in service.

According to information provided with the samples, the tubing was specified to be 2.5" OD x 0.200" MWT, SA-210 Grade A1 material. At the time of their removal, the tubing had been in service for more than 30 years.

Steam for Unit 2 at Holyrood Generating Station is supplied by an oil-fired natural circulation boiler that was designed and manufactured for Newfoundland and Labrador Hydro by Combustion Engineering (C-E) under the terms of contract 4968. The unit is rated for a steam flow of 1,167,500 lbs/hr MCR and a drum pressure of 2055 psi. The operating SH and RH outlet pressure are 1955 psi and 462 psi, respectively, both at an outlet temperature of 1005°F.

The assessment of the cause(s) of failure in the samples has been made based on information obtained through a program of testing that included a visual examination, dimensional measurements, chemical analysis, and metallography.

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2.0 RESULTS

2.1 Visual Examination

Both samples were inspected visually with the aid of a stereomicroscope in order to characterize the overall appearance of the failure sites and to detect any evidence of secondary distress, such as swelling, cracking, or abnormal wastage that might shed light on the cause(s) of the damage.

As shown in Figure 1, the failure in tube 56 involved a window-type failure that initiated near the membrane weld on the furnace side of the tube. The window developed under the influence of the reaction forces induced by the failure event, when a large flap of the tube wall peeled back away from the weld creating a nearly 6" hole in the tube wall. Apart from the rupture, the outer surface of the tube was covered by a moderate layer of ash and high temperature scale, beneath which was no evidence of any obvious wastage.

Examination of the outer surface of tube 42 revealed a thick layer of ash and high temperature scale on the furnace side of the tube. As indicated in Figure 1, the failure in this sample was an axial split that formed at the dome of one of three bulges that were visible on the furnace side of the tube.

When tube 42 was split longitudinally to facilitate inspection of the ID surface of the tube, local heavy deposits were observed along the furnace side of the tube, particularly in the areas between the blisters. Beneath the deposits, severe gouging, indicative of on-load corrosion caused by some upset in boiler water chemistry, was observed on the furnace side of the tube.

2.2 Chemistry Results

2.2.1 Tube Material:

Specimens of the tubing material were removed from the samples and chemically analyzed in order to verify that the correct material type had been installed in the unit and to determine whether there were any compositional anomalies that could have affected the service performance of the tubing. The results of the analysis, which are presented in Table 1, were compared to the requirements established by ASME for SA-210, Grade A1 tubing. As shown, the composition of the tubing was satisfactory with respect to all specified elements. In addition, all non-specified and residual elements were found to be at levels where their presence would have no significant impact on the long-term serviceability of the tubing.

2.2.2 ID Deposits:

An analysis of the ID deposits was performed using Energy Dispersive Spectrometry (EDS), and the results are presented in Table 2. As shown, the internal deposits were

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comprised mainly iron oxide, with lesser amounts of species containing magnesium, phosphorus, calcium, zinc, and copper also present. No traces of chlorides or acidic sulfur species were detected in the deposit, but since these species are highly soluble in water, their absence at detectable levels cannot be construed as proof that they never existed. The significant amounts of copper- and zinc-containing species in the deposits suggest the likeliness of corrosion activity in the pre-boiler circuit.

The quantity of deposit on tube 42 was measured using procedures outlined in ASTM specification D-3483 (Test Method A – Mechanical Removal). The results indicated that the quantity of ID deposits on the furnace side of the tube was heavy, measuring as much as 134.4 mg/cm^2. Given the heavy accumulation of deposits in these samples, it should be emphasized that the deposits provide an effective concentrating mechanism for any corrosive species that may be present in the boiler water.

2.3 Metallography

Based on the results of the visual examination, specimens for metallographic evaluation were removed from selected locations on the samples so that the macrostructural and microstructural features of the damage could be evaluated. These specimens were polished and etched in order to permit examination of the macrostructure and microstructure using light microscopy.

The damage at the rupture site on tube 56 is documented in Figure 2. As shown in the macrograph at the top of the figure, the rupture initiated in an area of severe internal gouging, but the edges of the fracture were relatively thick-lipped. On the ID surface of the tube in the vicinity of the fracture, evidence of extensive intergranular fissuring could be seen initiating from the ID surface of the tube, and the carbides within the pearlite colonies had been largely consumed, a damage feature indicative of hydrogen attack.

A similar mode of damage was observed in tube 42, but in this case the heavy internal deposits had disrupted the heat transfer through the tubing, causing localized overheating. This, in turn, had led to the formation of blisters in addition to the extensive hydrogen damage. As shown in Figure 4, tube 42 failed at the crown of one of three bulges that were present along the length of the sample.

The condition of the microstructure on the side of the tubing opposite the failures was found to be normal, consisting mainly of pearlite colonies in a ferrite matrix. Typical views of the microstructure in this area of the tubing are presented in Figure 3 and 5.

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3.0 CONCLUSIONS

The destructive examination of the samples established that both tubes failed as a result of severe hydrogen attack, a form of damage that occurs when the internal surfaces of tubing in high-pressure boilers undergo accelerated acidic corrosion under densely-packed internal deposits. The corrosion reaction at the ID surface of the tube liberates atomic hydrogen, which then diffuses into the remaining intact portions of the tube wall. There the hydrogen combines with the carbon present in the steel to form methane gas (CH_4). The resulting volume expansion of the methane gas causes fissuring of the grain boundaries, and in the case of these samples, eventual failure. In addition to the hydrogen attack, the blistering in tube 42 suggests that this failure had been influence by localized overheating related to the insulating effects of heavy deposits. A subsequent laboratory analysis showed these deposits to be in excess of 134 mg/cm^2 on the front side of the tube.

In an effort to identify the corrodants responsible for the hydrogen attack, a chemical analysis was made of the deposits using Energy Dispersive Spectroscopy (EDS), but none were found. This was not entirely surprising, however, given that most of the potential contaminants, particularly chlorides and acid sulfur species, are highly soluble in water.

4.0 RECOMMENDATIONS

In order to minimize the risk of additional failures in the waterwall tubing, it is recommended that a nondestructive inspection of the furnace walls be conducted to determine the extent and severity of the internal corrosion and hydrogen attack. The inspection initially should focus on the highest heat flux areas of the unit but should extend further if damage is found up to the limits of that area. Selected samples should be destructively evaluated to confirm the accuracy of the NDE so that, once the extent of the damage is known, decisions then can be made regarding tubing replacements. In addition, it is also recommended that a review of the water treatment practice for this unit be conducted in an effort to identify the source(s) of the contamination that instigated the internal corrosion and to ensure that optimum cycle chemistry is maintained during all phases of unit operation.

Paul VanKooten

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Table 1. Chemistry Results

Chemical Composition (Weight Percent)			
Element	***WW-56***	***WW-42***	***ASME SPEC. SA-210, GRADE A1***
Carbon	0.18	0.21	0.27 (max.)
Manganese	0.61	0.63	0.93 (max.)
Phosphorus	0.010	0.015	0.035 (max.)
Sulfur	0.009	0.010	0.035 (max.)
Silicon	0.25	0.25	0.10 (min.)
Nickel	0.02	0.02	---
Chromium	0.01	0.01	---
Molybdenum	<0.01	<0.01	---
Vanadium	0.004	0.004	----
Columbium	<0.001	<0.001	----
Titanium	0.001	0.001	---
Cobalt	0.008	0.008	----
Copper	0.03	0.03	---
Aluminum	0.013	0.004	----
Boron	<0.001	<0.001	---
Tungsten	<0.01	<0.01	----
Arsenic	0.006	0.006	----
Tin	0.002	0.002	----
Zirconium	<0.001	0.001	----

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Table 2. Chemistry Results – Deposit Analysis

Chemical Composition (Weight Percent)	
Element	***WW-42***
Oxygen	25.80
Sodium	1.43
Magnesium	0.52
Aluminum	0.38
Silicon	0.33
Phosphorus	1.37
Sulfur	0.15
Calcium	0.84
Manganese	0.76
Iron	64.63
Nickel	3.39
Copper	0.42
Deposit Accumulation mg/cm^2	134.4

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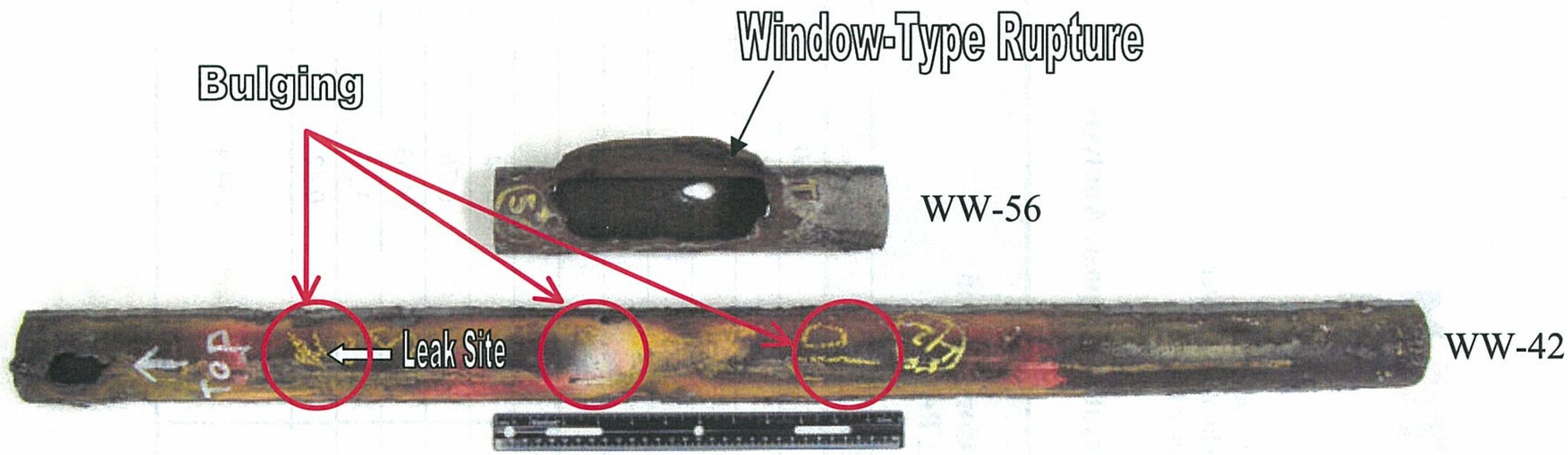

Figure 1. Documenting The Waterwall Tubes As They Appeared When Received From Unit 2 at Newfoundland and Labrador Hydro's Holyrood Generating Station. Also Indicating the Approximate Locations of the Failures and Bulging.

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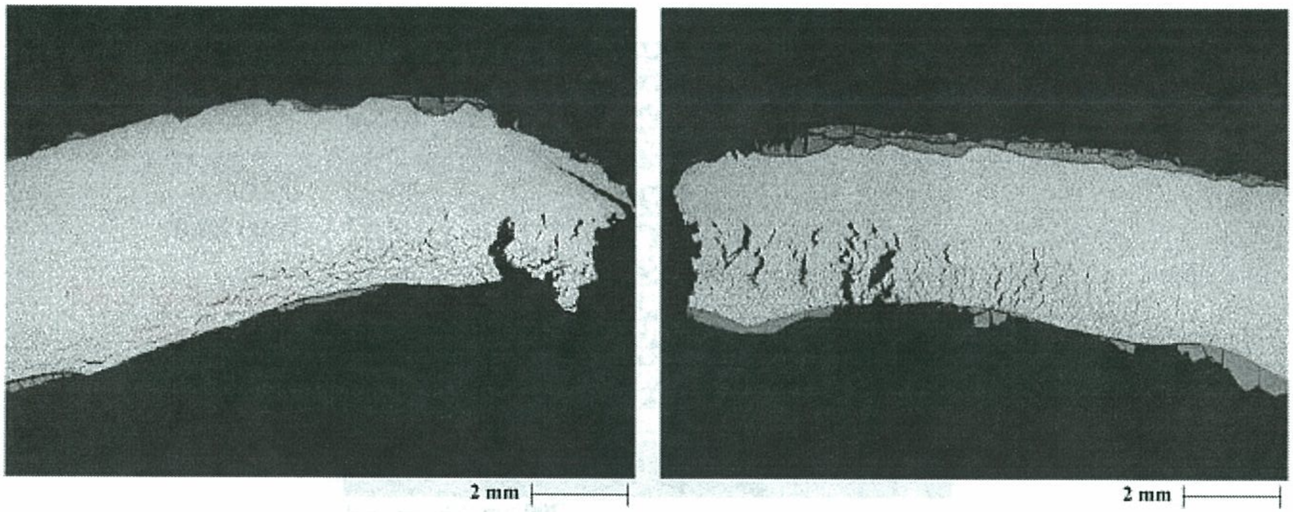
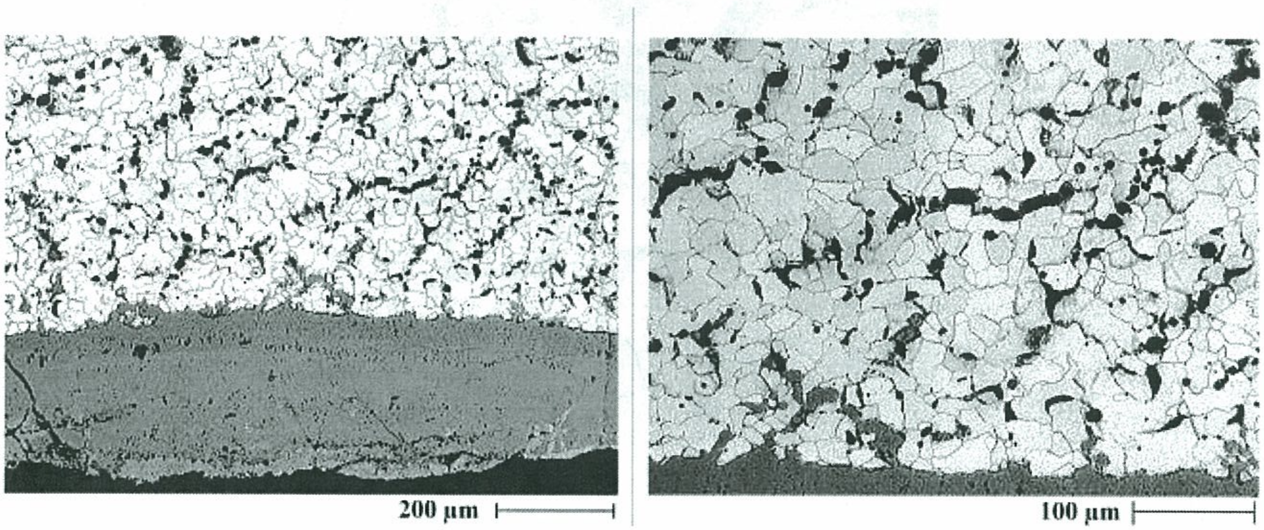


06030-A *Furnace Side* Nital Etch



06030-A *Furnace Side* Nital Etch

Figure 2. Documenting the Condition of the Macrostructure and Microstructure at the Failure Site on Tube 56.

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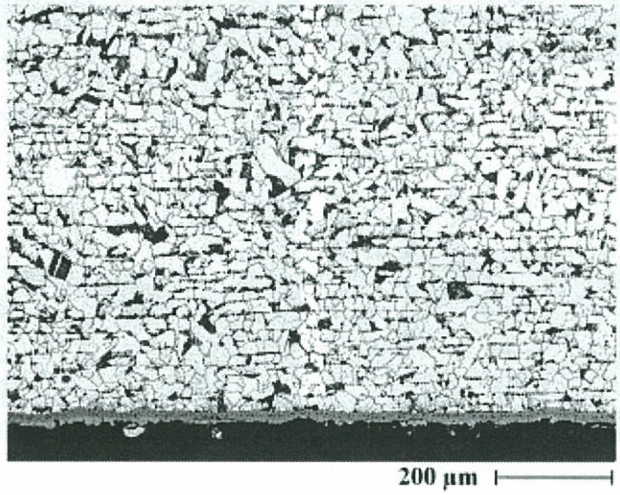
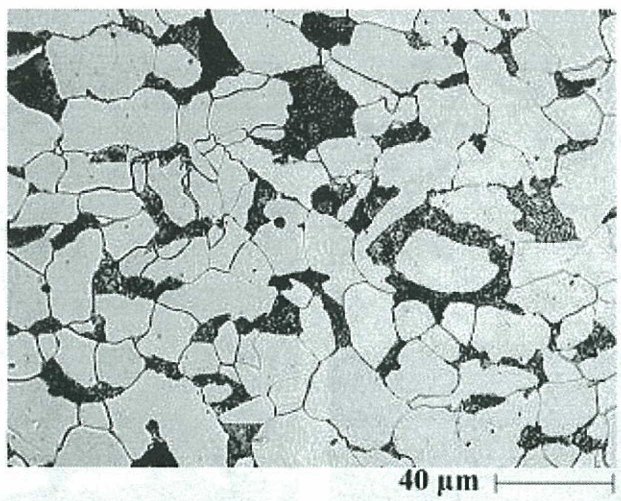


06030-A
Nital Etch

Casing Side - 180°
From Failure



06030-A
Nital Etch

Casing Side - 180°
From Failure

Figure 3. Documenting the Typical Condition of the Microstructure in Areas Away From the Failure on Tube 56.

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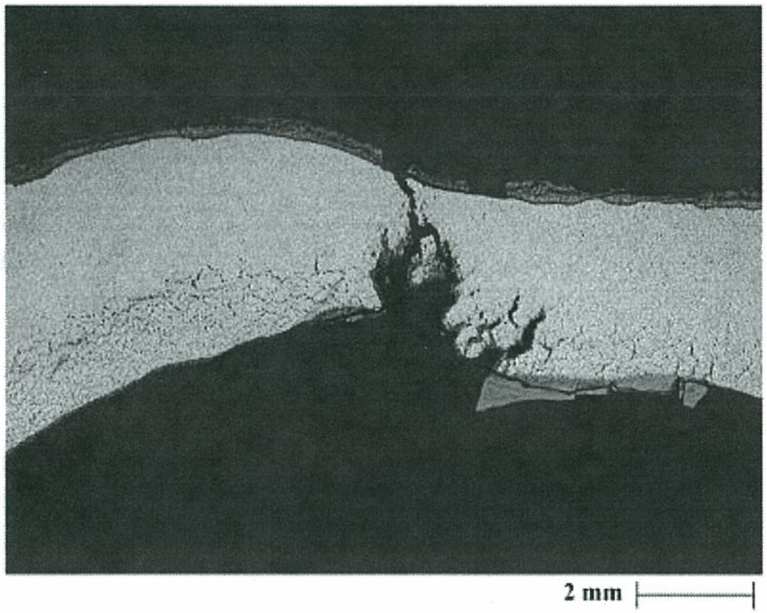
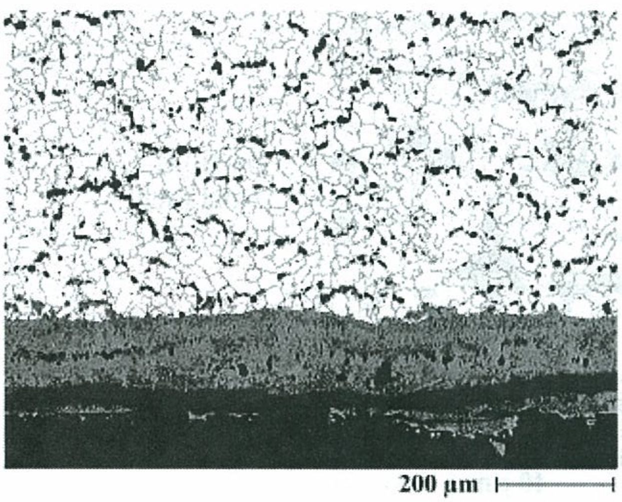
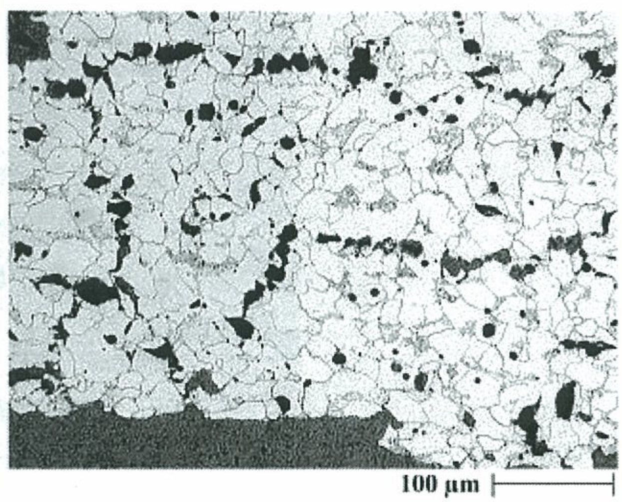


06030-B
Nital Etch

Furnace Side





06030-B *Furnace Side* Nital Etch

Figure 4. Documenting the Condition of the Macrostructure and Microstructure at the Failure Site on Tube-42.

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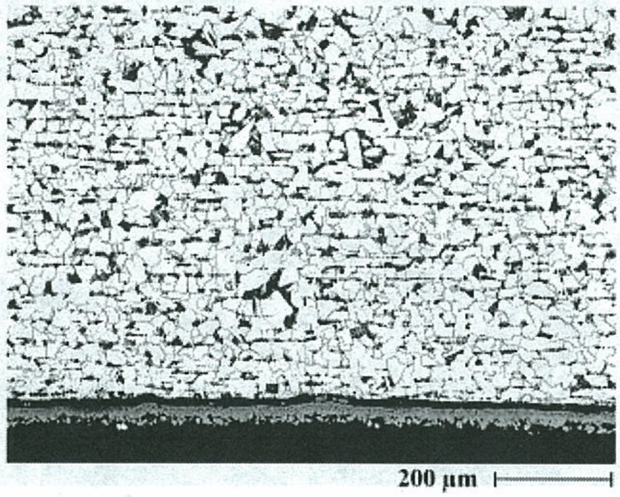
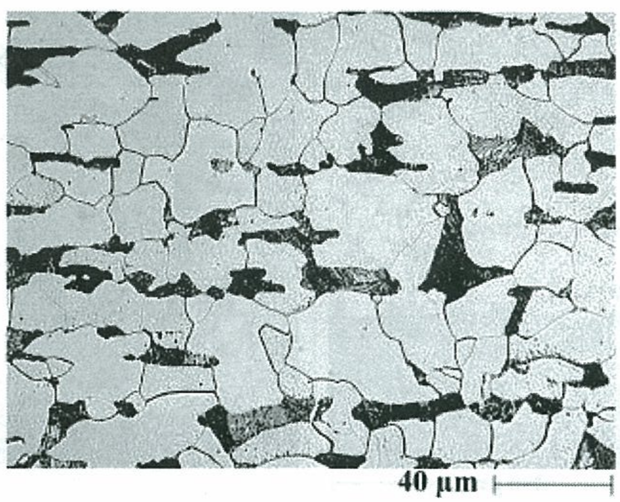


06030-B
Nital Etch

Casing Side - 180° From Failure



06030-B
Nital Etch

Casing Side - 180° From Failure

Figure 5. Documenting the Typical Condition of the Microstructure in Areas Away From the Failure on Tube 42.

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Condition Assessment Site Visit Report

Date Submitted:	4/30/06	Plant Person for Contact:	**John Adams Alstom**
Company Name:	**Newfoundland and Labrador Power**	Phone # Plant Contact:	
Location and Unit #:	**Holyrood #2**		
Date of Visit:	**4/25/06**	Name of Company work is being done for:	**Newfoundland and Labrador Power**
Name of Lead Inspector:	**David Overton**		
Phone # Lead Inspector:	**423-580-0130**	Project Manager (Condition Assessment):	**Michael Gilmore**
Proposal #:	**06-CAS-036**	Location work is being done:	**Holyrood, Newfoundland**
PSA #:		OEM Contract # :	**CA 68119**
UNIT SERVICE HOURS:			

PROPOSED LIST of COMPONENTS BEING INSPECTED (TESTED):									
List of Components	Description of Types of Inspection Work by Component								
	Vis	Dim	Electro magnet	UT		video	tube	STATS	Photo
Waterwall inspection (3 walls)	yes		yes	yes					yes

All changes to the scope of work are to be documented. Reasons for all changes are to be recorded on this form in that section of the form.

CHANGES in LIST of COMPONENTS INSPECTED (TESTED):										
List of Components	Description of Types of Inspection Work by Component									
	Vis	Dim	WFMT	AUT	Rep	Hard	video	tube	STATS	Photo

Reasons for Changes in Work Scope:
1.

INSPECTION FINDINGS

There should be a Findings Section for each component inspected.

Findings (section name):	Waterwall Inspections
Section Description:	Generally area to be inspected begins at the middle of burners (~45') and extends upward for 20'. LFET used on these wall follows up by UT of certain areas for checking findings. Left Sidewall 133 tubes each 2.5" OD x 0.200" MWT SA-210-A1 elevation 45' to 65' Right Sidewall 133 tubes each 2.5" OD x 0.200" MWT SA-210-A1 elevation 45' to 65' rear wall 127 tubes each 2.5" OD x 0.200" MWT SA-210-A1 elevation 45' to 80' (includes the arch). Probably some checking on the East wall tubes that are being removed and replaced during this outage

Findings:

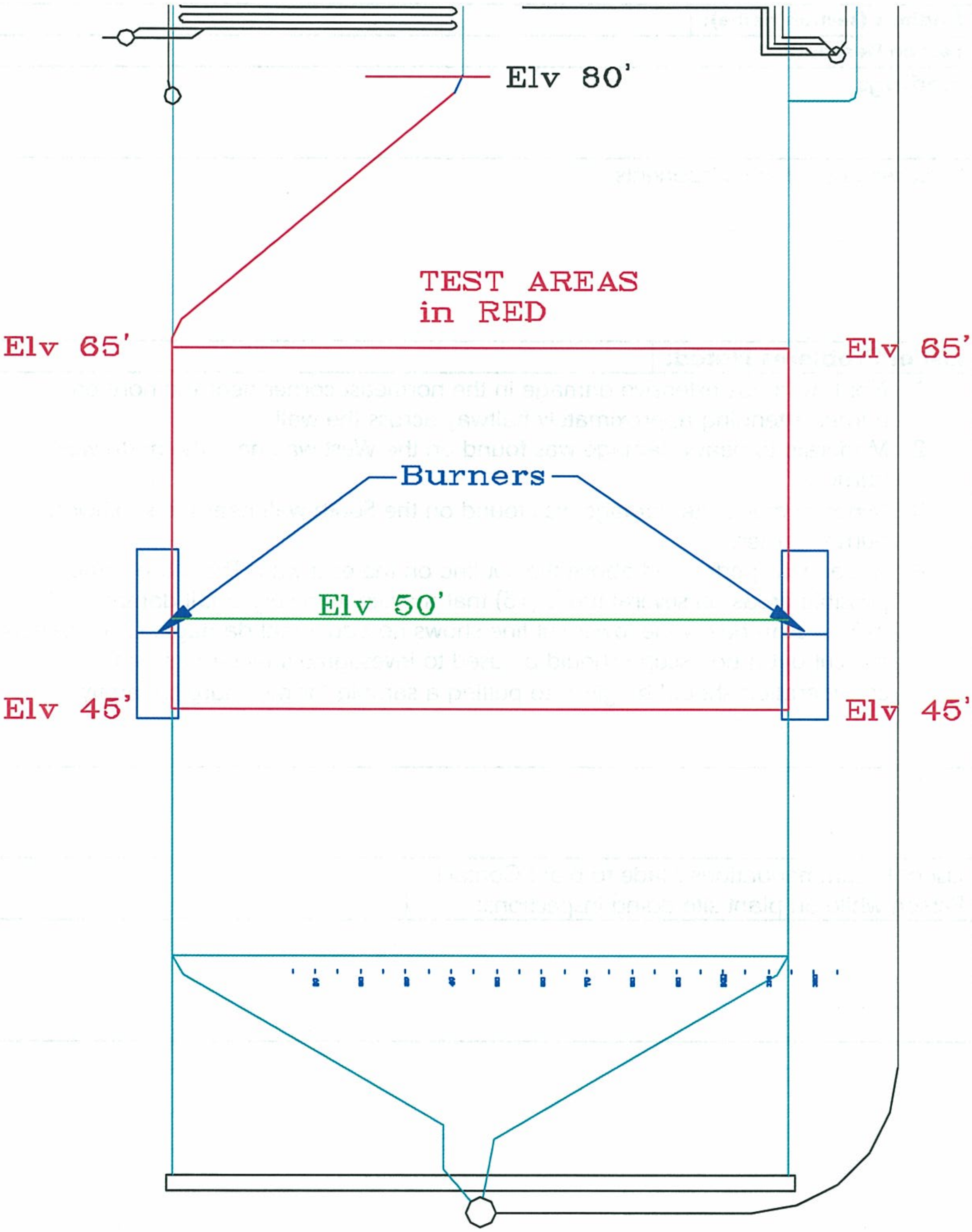
1. Left Sidewall (West Wall) A few spot indications indicative of Hydrogen damage were found in this wall. Specifically Tube numbers 5,6,8,11,12,13,31,49. Heavey damage was observed on tubes 5 remaining wall of 0.159" 8 remaining wall 0.140" 11 remaining wall 148 and 12 remaining wall of 0.126". All of these locations were near the middle and lower sections of the burner zone.

2. Front wall (South Wall) A few spot indications indicative of hydrogen damage were found in this wall. Specifically tubes 13,15,17,21,23,24,and 25. Tube number 24 shows a remaining wall of 0.140". All locations are in the middle burner zone.

3. Rear Wall (North Wall) Seveare damage was found on this wall in the north east corner extending from the burner to approximately midwall. The following tubes show damage indicative of hydrogen damage. Tube numbers 7,8,9,10,11,12,13,14,15,16,18,19,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,40,43,44,48,50,51,52,56,59,72 show varying degrees of damage from a low of tube 12 at 0.107" to minor damage of >.200". All locations are in the lower to upper burner zone with the highest concentration in the middle burner zone.

Note all tubing is numbered right to left facing each wall from inside the furnace

Sketches of section components.


Elv 80'
TEST AREAS
in RED
Elv 65'
Elv 65'
Burners
Elv 50'
Elv 45'
Elv 45'

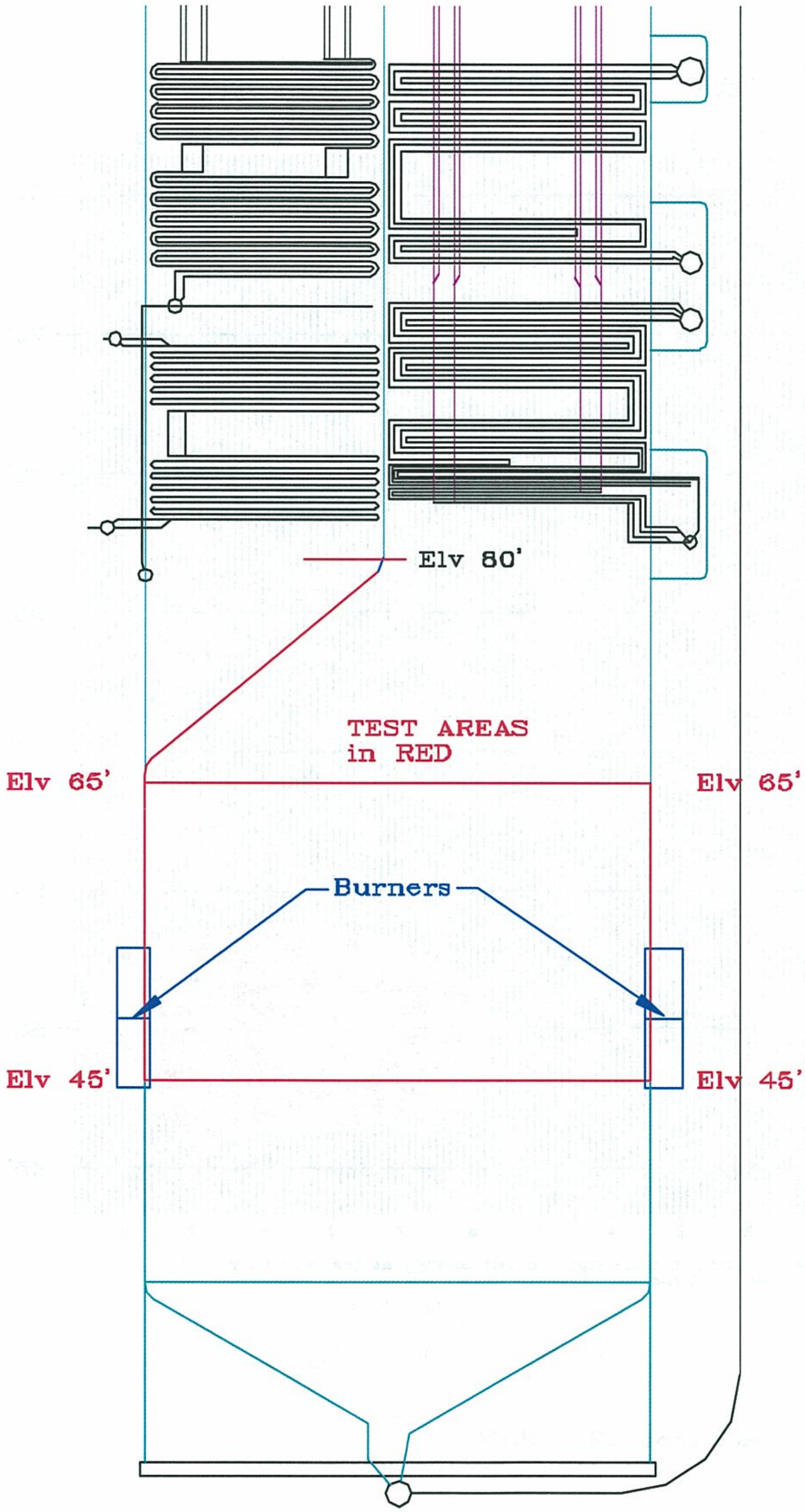
Findings (section name):	
Section Description:	

Findings:

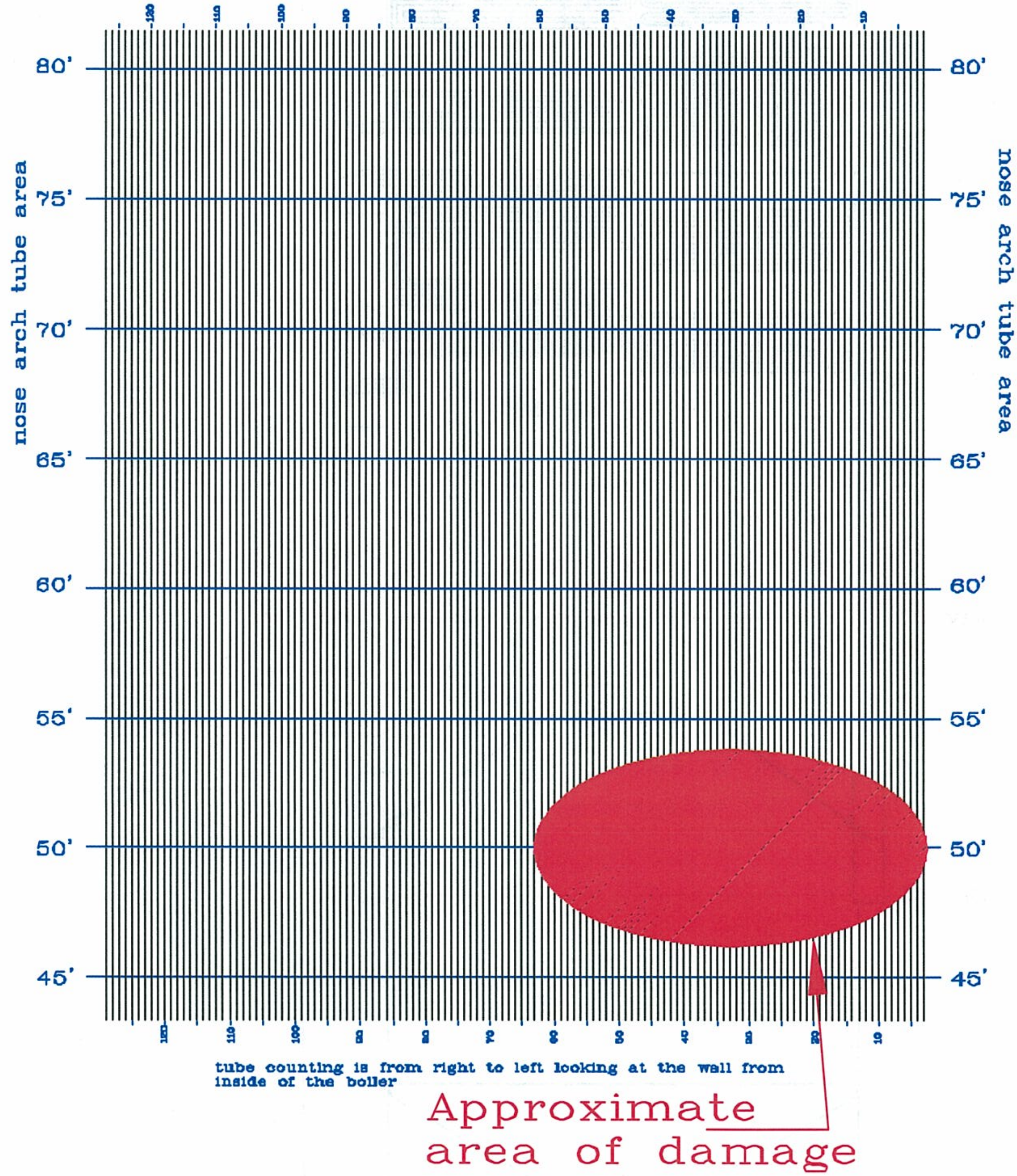
Sketches of section components.

List of Problems Noted:
1. North wall has extensive damage in the northeast corner near the northeast burner extending approximately halfway across the wall. 2. Moderate to heavy damage was found on the West wall near the north west burner. 3. Minor to moderate damage was found on the South wall near the southwest burner corner. 4. A scan was performed above the cut line on the east wall. There are some possible areas on several tubes (15) that may contain very small damage 10-20 mils. A scan below the lower cut line shows no additional damage. Once panels are cut out a borescope should be used to investigate those areas and consideration should be given to pulling a sample for metallurgical analysis.

List of Recommendations Made to plant Contact Person while on plant site doing inspections:	

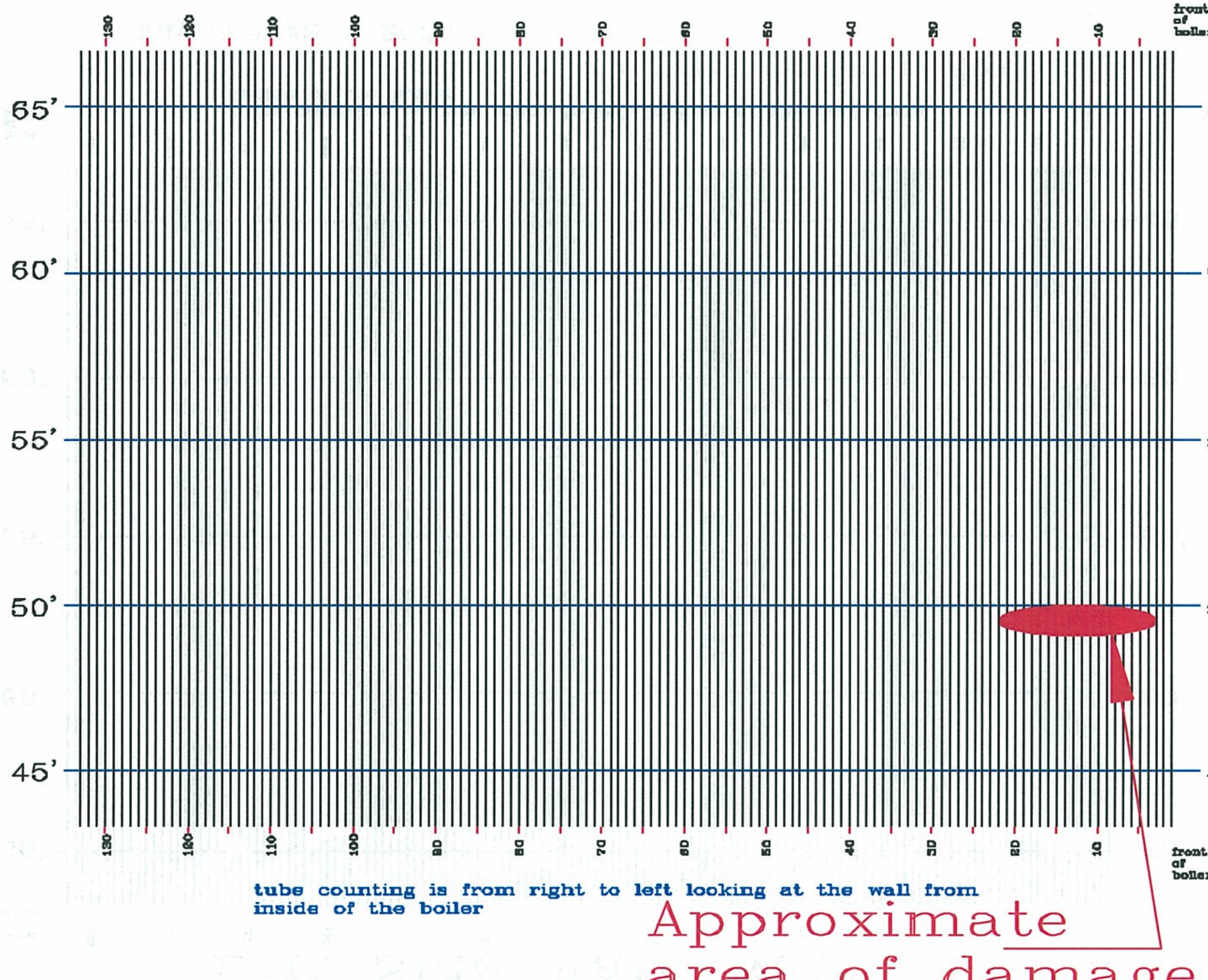

Elv 80'
TEST AREAS
in RED
Elv 65'
Elv 65'
Burners
Elv 45'
Elv 45'

Rear Waterwall



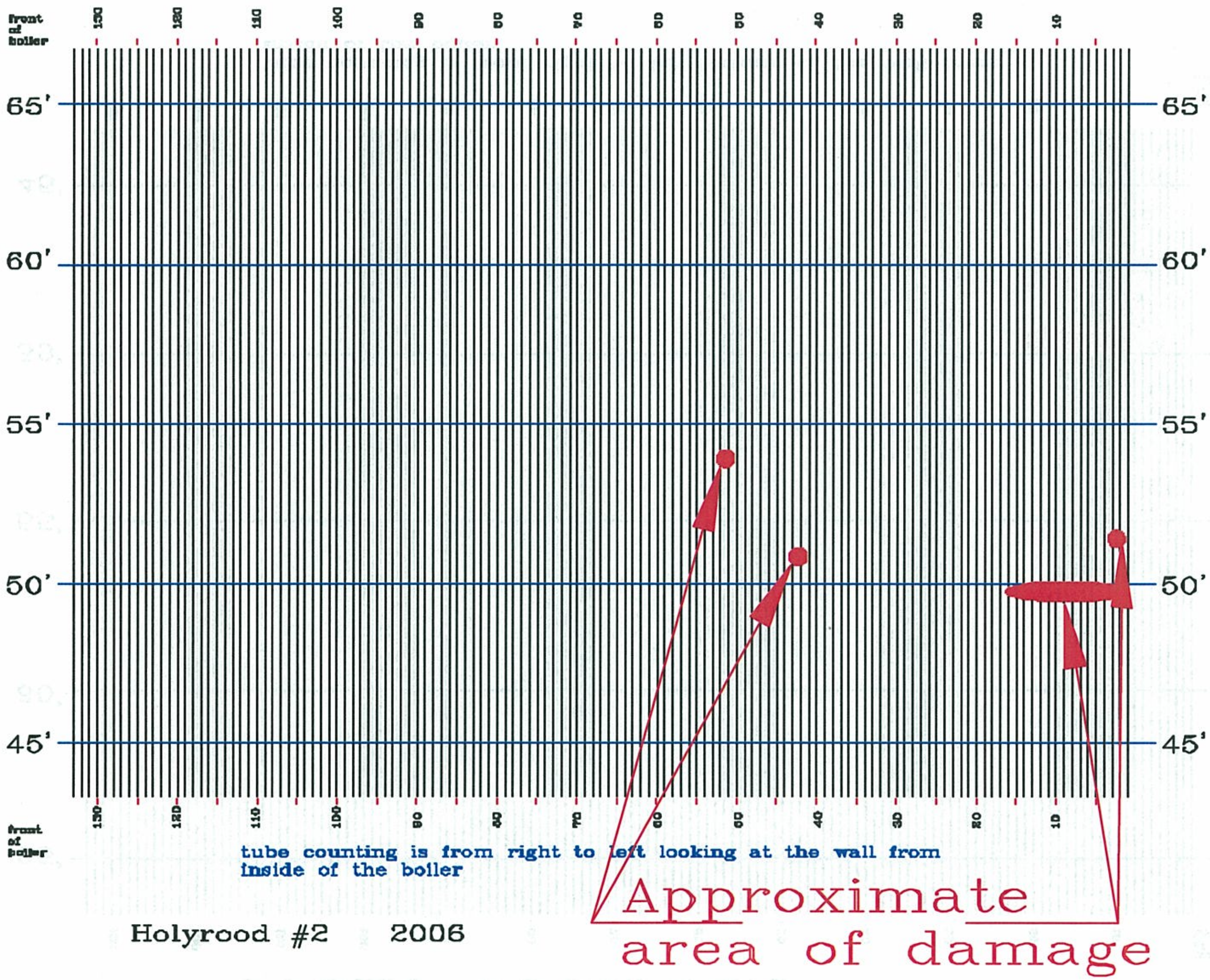
Holyrood #2 2006

Front Waterwall



Holyrood #2 2006

Left Side Waterwall



Holyrood #2 2006


North wall

South wall

West wall