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August 12, 2016

The Board of Commissioners of Public Utilities
Prince Charles Building
120 Torbay Road, P.O. Box 21040
St. John's, NL A1A 5B2

**Attention: Ms. Cheryl Blundon**
**Director Corporate Services & Board Secretary**

Dear Ms. Blundon:

**Re: The Board's Investigation and Hearing into Supply Issues and Power Outages on the Island Interconnected System – Phase Two – Filing of AMEC Report**

In January and February of 2016, Hydro experienced tube ruptures in the re-heater sections of Units 1 and 2 at the Holyrood Thermal Generating Station (Holyrood). Emergency repairs were completed immediately with more extensive tube replacements planned as part of the 2016 summer annual outage.

To mitigate the risk of further boiler tube failures over the remaining operating period of the Plant, Hydro determined that it would operate the boilers at lower pressures and therefore proposed that the units be de-rated while undertaking a further review. Hydro engaged engineering specialty firm, AMEC Foster Wheeler, to review the technical basis for this de-rate assessment and to apply alternative assessment methods to maximize unit load capability while maintaining acceptable reliability.

Because of the planned tube replacements, AMEC recommends continued normal operation of Unit 1 and 2 with regular monitoring. Based upon their calculations for Unit 3, AMEC recommends operating at 90% of the operating pressure and replacement of some tubes within the next year. Hydro has completed some preliminary non-destructive testing and to date has not observed deterioration of a level that would cause concern. Hydro intends to carry out further testing in the coming year when the opportunity arises. The report notes that a 10% de-rate in operating pressure will provide additional assurance for reliable operation in the short-term. In the event of a forced outage during the 2016/2017 winter season, Hydro will replace Unit 3 lost generation with existing emergency back-up generation while immediate repairs are made using in-stock spare tube materials.

Hydro is corresponding with its boiler regulator, Government Services Center, on this matter. Hydro accepts AMEC's recommendations with the earliest opportunity for planned tube replacement being Summer of 2017, after the 2016/2017 high demand winter season.

Should you have any questions, please contact the undersigned.

Yours truly,

***NEWFOUNDLAND AND LABRADOR HYDRO***

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August 8, 2016

Mr. Nelson Seymour
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Dear Mr. Seymour,

**RE: HOLYROOD TGS BOILER TUBE THINNING ASSESSMENT**

Nalcor has a need to potentially operate the three generating units at Holyrood TGS to 2021 with a high degree of reliability. A risk assessment conducted by Nalcor has identified boiler tube failures due to tube thinning as a reliability risk and has proposed de-rating the units as a means of mitigating this risk over the remaining operating period. Amec Foster Wheeler Nuclear Canada has been engaged to review the technical basis for this de-rate assessment, and to apply alternative assessment methods to maximise unit load capability while maintaining acceptable reliability. The initial Nalcor assessment was provided as a basis [1].

Following this review, Amec Foster Wheeler concurs with the overall approach taken in the original Nalcor de-rate technical basis. However, there were issues with the process for establishing the normal and emergency operating loads that created uncertainty in the outcomes and assessment of continued reliability.

Using design and operational data provided by Nalcor [2][3] (also tabulated in Appendix 1), ASME [4] code calculations were revisited while also exploring alternative assessment methods. Amec Foster Wheeler recommends a fitness-for-service approach be taken using B&W Plant Service Bulletin PSB-26 [5] for water-touched components and API 579-1/ASME FFS-1 [6] creep rupture calculations for steam-touched components. From the analysis, it is concluded that with planned replacements completed there is a low risk of boiler tube failures due to wall thinning on Units 1 and 2, operating at current pressures, with no de-rate, to 2021.



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The assessment for Unit 3 has concluded there is a high risk of tube failures due to wall thinning within the next year. A 10% de-rate in operating pressure is recommended in addition to monitoring and tube replacement.

If it is assumed that there is a linear relationship between operating pressure and unit load for load ranges being considered, the target loads for Units 1 and 2 are 175 MW (gross), and 135MW (gross) for Unit 3. Additional recommendations are provided below.

It needs to be noted that the above assessment is based on calculations conducted with the current ASME code allowable stress values and therefore represents a variance from the registered design. Concurrence from the boiler and pressure vessel jurisdictional authority is recommended. These conclusions also consider only boiler tube wall thinning, and do not address other potential reliability risks.

## 1.0 BACKGROUND

Holyrood TGS consists of three oil-fired conventional steam cycle generating units. The units have a maximum output rating of 175 MW for Units 1 and 2, and 150 MW for Unit 3. Units 1 and 2 (Stage 1) were commissioned in 1969/70, and Unit 3 (Stage 2) was commissioned in 1979. Units 1 and 2 were uprated in 1987 with modifications. Unit 3 has not been uprated but the material changes have been made and the reheater surface was modified (tubes removed) in 2001 to improve boiler performance.

The boiler tubing on all three units has experienced various forms of degradation that presents a reliability risk. The primary concerns were oil ash corrosion in the high temperature sections of the tubing and fireside corrosion and erosion in the low temperature tubing. A change in fuel is considered to have mitigated the impact of these degradation mechanisms. Pad-weld repairs or replacement of tube sections have been completed in all three units to address tube failures. Wall thickness surveys are also being conducted annually to monitor tube wall loss.

## 2.0 ASSESSMENT METHOD

The original assessment consisted of a re-calculation of design pressure for the lowest measured wall thickness observed over the period of 2010 to 2016, using ASME BPVC Section I rules (para PG-27.2.1) [4]. The original ASME minimum wall thickness was used to back-calculate the allowable stress. Where the original ASME minimum wall thickness was not available the supplied wall thickness was used.

The assessment was based on ASME code of construction allowable stresses (1968 for Units 1 and 2, and 1977 for Unit 3), and assumed uniform wall thickness. No other tube failure mechanisms were considered. In addition, adoption of the analysis results assumed no further wall thickness reductions over the remaining operating period.

The original assessment identified a new design pressure for each inspection location where the lowest measured thickness was less than the original ASME wall thickness. A revised load was estimated for locations where the new allowable pressure was less than the original operating pressure. The revised load reflected the percentage reduction in pressure adjusted for



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measurement at the turbine stop valve, assuming a linear relationship between steam pressure and unit load.

In the original assessment the average load for the target sections of tubing was identified as the Emergency Maximum Load. The Normal Maximum Load was based on the Emergency Maximum reduced by a further 10 MW to derive a target operating load.

Following the original assessment, Nalcor contracted Babcock & Wilcox (B&W) to evaluate the Unit 3 boiler superheater, reheater, and economizer tube metal temperatures. B&W generated ASME wall thickness and temperature maps for each tube length in the Unit 3 boiler, for an equivalent fuel and using the code of construction allowable stress values. The results of this study were documented in a report [3]. This action was undertaken to address potentially significant limitations in the original work where supplied wall thicknesses were used as the minimum. Note that the results presented in this letter are based on the materials and temperatures stated in the Revision 02 of this B&W report. If significant changes are made to this evaluation, or if any undocumented field modifications are identified, the analysis presented here should be revisited and revised if necessary.

The present analysis considers four alternative methods for evaluating Maximum Allowable Working Pressure (MAWP) as listed below. For Unit 3, the B&W analysis was used to identify tube metal temperatures and materials. The B&W analysis considered the impact of the reheater surface removal in 2001. For Units 1 and 2, the post up-rate conditions were used [2].

1) Application of the B&W Plant Service Bulletin PSB-26 [5]

   This bulletin provides guidance on limits for boiler tube wall loss tolerance based on supplied wall thickness, and takes advantage of manufacturing tolerances and design tolerances. For tubes satisfying this criteria, no change in operating pressure will be proposed.

2) Application of the current (2015) ASME code (Section I, PG-27.2.1) [4]

   The allowable stresses for ASME materials was increased in 1999 by reducing the factor of safety. This increase in allowable stress permits an increase in the allowable pressure for a given tube wall thickness. The MAWP is derived for each section for the lowest measured wall thickness using the same method applied in the initial analysis. The margin (difference) between the calculated MAWP and original operating pressure, and the margins for incremental pressure reductions are provided.

3) Application of the current (2015) ASME code (Section I, Appendix A, para A-317.2.1) [4]

   In addition to the increases in allowable stress in the current code, Appendix A, para A-317 provides a non-mandatory alternative for calculating wall thickness for boiler tubes and piping that further reduces the required tube wall thickness for a given pressure. Calculations similar to the method described above were completed to determine MAWP.



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4) Assessment of Tubing Operating in Creep Range (API 579-1/ASME FFS-1) [6]

For high temperature components, the creep life evaluation methods identified in API 579-1/ASME FFS-1 were applied. These methods are used for fitness-for-service assessments and are accepted in the National Board Inspection Code (NBIC) [7]. These evaluations result in estimated total life in operating hours for a given wall thickness, operating pressure, material, and temperature.

Assumptions

For the purpose of this wall thinning failure risk assessment, the following assumptions were applied. If any of these assumptions change, this assessment should be revisited.

- The station is required to operate in a manner consistent with current operations until 2021 in terms of cycles, hours, and operating temperatures.
- Over the next five years, the units will accumulate approximately 35,000 operating hours each (~80% operating factor per year).
- Currently, Unit 1 has approximately 193,000 total operating hours, Unit 2 has approximately 186,000 total operating hours, and Unit 3 has approximately 149,000 total operating hours.
- Wall thickness is uniform around the circumference and there is no further wall thinning.
- All tubing has been in-service since unit commissioning without accommodation for replaced tubing.
- The lowest wall thickness is representative of the tube bank for the respective area.
- Data supplied by the boiler manufacturer is correct; materials, minimum and supplied tube dimensions and temperatures.
- Allowable stresses and methods from the 2015 versions of the ASME Boiler and Pressure Vessel Code, Section I are applicable.
- Creep life calculations using lower bound Larson-Miller Parameter material properties are applicable.
- The set pressures for the closest upstream safety valves are taken as the maximum expected operating pressure for a given region.

## 3.0 RESULTS

The outcomes for the fitness-for-service methods described above are summarized in Table 1 and all analysis results are presented in detail in Appendix 1. These results provide a snapshot of current condition based on the inspection results and design documentation available at the time of this assessment.



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Note that for Units 1 and 2, results in Appendix 1 are presented for the reheater section being replaced in 2016. Appendix 1 also presents the results for the boiler floor tubes on Unit 3 that are planned to be restored in 2016. Discussion of these tubes are excluded from the comments below.

Acceptance Criteria

The following acceptance criteria were applied when evaluating the analysis results:

- B&W Plant Service Bulletin PSB-26: Current measured thickness greater than criteria is considered acceptable.
- ASME Code: Safety valve set pressure less than the code calculated MAWP using current tube wall thicknesses is considered acceptable.
- Creep Rupture: Calculated minimum creep life greater than 2x desired total life (projected total operating hours at 2021) is considered acceptable.
  - Unit 1 target: 456,000 hours
  - Unit 2 target: 442,000 hours
  - Unit 3 target: 368,000 hours
  - Tubes with calculated minimum creep life between the current number of operating hours and target number of operating hours are considered marginal and at medium risk of failure. Tubes with current operating hours exceeding the calculated minimum creep life are considered to be at high risk of failure.

## 3.1 Waterwall and Economiser Tubing

The waterwall and economiser tubing in all three units pass the PSB-26 criteria. This result indicates current operating pressures should not challenge the integrity of these tubes.

In Units 1 and 2, integrity of the economiser overhead bends at the 5th floor, and the Unit 3 economiser 6th floor lower tube wall bends are challenging ASME minimum wall thickness. Additionally, the waterwall upper rear tubes in Unit 2 were also found to be challenging ASME minimum wall thickness. However, these tubes currently still satisfy the PSB-26 criteria and are not anticipated to challenge creep life before end of operations. It is concluded these sections of tubing in all three units represents a low risk of failure due to tube wall thinning. Greater attention is required at these locations going forward to confirm and monitor wall thickness.

## 3.2 Superheater and Reheater Tubing

The steam tubing was assessed against the PSB-26 criteria, current ASME BPVC Section I (2015) code requirements, and evaluated for creep rupture life in accordance with API 579-1/ASME FFS-1.



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- Unit 1

  The steam tubing in Unit 1 does not satisfy the PSB-26 criteria in all cases, but satisfies all ASME Section I criteria using the current code and original operating pressure. Therefore the risk of tube failure due to thinning is considered low.

- Unit 2

  The limiting location for Unit 2 is the primary superheater 8th floor bend. This location fails both the PSB-26 criteria and the current code ASME requirements at original operating pressure. The lower bound creep rupture life at the assumed operating pressure is approximately 2.6 million hours. The major factors leading to this result are extensive wall loss and a material (SA-210 A1) operating at the upper end of the acceptable range.

  The results indicate this section of the primary superheater would require dropping operating pressure by approximately 10% to satisfy the current ASME code criteria. However, since the creep rupture life is shown to be extensive, it is concluded that the boiler can be operated for an additional five years at full operating pressure with low risk of tube failure due to thinning. Re-inspection of the area can confirm wall thickness, and replacement can be considered if the most severe damage is localised.

- Unit 3

  The Unit 3 steam tubing fails to satisfy the PSB-26 criteria and the ASME code requirements in several locations within the secondary superheater and reheater sections. Additional metallurgical concerns have also been identified with respect to the use of SA-213 T11 and T2 in the primary superheater.

  The limiting locations are in the 9th floor cavity in the reheater. With only 64% remaining wall thickness, the 9th floor overhead reheater bends do not satisfy the PSB-26 criteria for steam tubing, do not meet the current ASME code requirements at full pressure (or with a 20% pressure de-rate), and do not meet the remaining creep life criteria. Creep life exhaustion is also predicted for the SA-213 T11 tubing below feet. Although there may be some life remaining before creep rupture based on available inspection results (currently no evidence of creep damage), it should be noted that predicted creep life is on the same order of magnitude as the reheater tubing that failed in Unit 1 earlier in 2016. To provide additional assurance in the short-term (1 year), a 10% pressure de-rate is recommended until additional targeted inspections/repairs can be conducted.

  The main issue with the 9th floor cavity reheater tubes, in addition to wall thinning, is predicted metal temperatures at the upper limits of the allowable range. In this temperature range the ASME allowable stresses begin to drop significantly. Creep life is also highly dependent on temperature. This is illustrated where, although passing the PSB-26 thickness criteria, the SA-213 T11 spans are now challenging predicted creep life.



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Similarly, high predicted metal temperatures at the 10th floor primary superheater tubes are challenging predicted creep life, although still satisfying the PSB-26 criteria for wall thickness. This concern of elevated metal temperatures has also been identified in the B&W study [3]. Longer-term operation without mitigation (either through tube replacement or measures to decrease local temperatures) represents a reliability risk.

The Unit 3 reheater tubing at the 9th floor overhead south side bends and the 9th floor reheater T11 tubing below feet present a high risk of tube failure if mitigating action is not taken. The compromised primary superheating tubes should also be closely monitored. A 10% de-rate will provide additional assurance in the short-term (1 year), but selective, or bulk replacement of these tubes should be considered at the earliest opportunity followed by annual monitoring and replacement to ensure longer-term reliability.

## 4.0 SUMMARY AND RECOMMENDATIONS

The methods applied in the initial assessment by Nalcor for assessing boiler tube reliability associated with tube wall thinning are consistent with industry practice. Reductions in pressure for boiler component integrity management is common but acceptance from the local jurisdictional authority is typically required when operating outside of the original design configuration. Operating parameter changes to be applied over an extended period are consistent with direction in NBIC Section 3.4.1 "Re-Rating". The action can address the need to de-rate for integrity management, redefine ASME limitations using a more recent code, or up-rating.

The revised analysis completed by Amec Foster Wheeler presents options for establishing a load limit for the remaining operating period (2016 to 2021) that would mitigate boiler tube reliability concerns due to tube wall thinning.

The results of the analysis indicate that Nalcor has two options:

- Base the target loads on the 2015 ASME BPVC Section I Code para. A-317.2.1 requirements.
- Base the target loads on the B&W PSB-26 for water-touched tubing where the failure mechanism is controlled by overload, and based on creep rupture where failure is controlled by creep life (steam-touched tubing).

The first option is more consistent with the re-rate alteration process. The second approach is a fitness-for-service case. Margins on safety for the ASME case are based on limits on allowable stress. In the fitness-for-service case, the margins are based on extended life well in-excess of the requirements for creep, and manufacturing and design margins for PSB-26. It is also noted that PSB-26 is consistent with the recommended practice for erosion corrosion (FAC) in ASME B31.1 Appendix IV.

To support extended life, Amec Foster Wheeler recommends adoption of the fitness-for-service approach.



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Through application of the PSB-26 criteria and predicted remaining creep life calculations, the analysis performed using currently available data suggests that Units 1 and 2 can continue to operate at full pressure with low risk of boiler tube failures due to wall thinning, to 2021. Target loads can therefore be maintained at 175 MW (gross). This conclusion assumes minimal future wall loss, with ongoing monitoring and repair.

For Unit 3, creep life is exhausted for the 9th floor cavity reheater tubing, where predicted creep life values are now in the same order of magnitude as the reheater tubing that required replacement on Units 1 and 2. Creep life is also being challenged for tubing in the primary superheater (10th floor). A 10% de-rate will provide additional assurance for reliable operation in the short-term, but corrective action is recommended at the earliest opportunity (within 1 year) to avoid tube failures. Assuming a linear relationship between pressure and load, a target load of 135 MW (gross) is recommended.

A summary of the tubes challenging ASME minimum allowable wall thickness and/or creep life, with recommended actions (for 1- and 5-year time horizons) assuming adoption of the fitness-for-service approach, is provided in Table 1 below.



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## Table 1: Recommendations for Boiler Tubes of Concern

| Unit | Appendix 1 Row # | Compromised Tube Location | Fitness-for-Service Evaluation Criteria at 100% Operating Pressure[1] | | Immediate Action(s) (1 Year of Continued Operation) | | Longer-Term Action(s) (5 Years of Continued Operation) | |
|---|---|---|---|---|---|---|---|---|
| | | | **B&W PSB-26** | **Creep Life (Larson-Miller Parameter)** | **Recommended Action** | **Recommended Unit De-Rate** | **Recommended Action** | **Recommended Unit De-Rate** |
| 1 | 21 | Economizer, 5th Floor, Overhead (Bends) | **PASS** | *EXTENSIVE REMAINING LIFE* | Continue monitoring tube wall thinning. | None Required | Continue monitoring tube wall thinning. | None Required |
| 2 | 8 | Primary Superheater, 8th Floor (Bends) | *FAIL* | **EXTENSIVE REMAINING LIFE** | Continue monitoring tube wall thinning. | None Required | Continue monitoring tube wall thinning. | None Required |
| | 22 | Water Wall Upper Rear Tubes | **PASS** | *EXTENSIVE REMAINING LIFE* | | | | |
| | 23 | Economizer, 5th Floor, Overhead (Bends) | **PASS** | *EXTENSIVE REMAINING LIFE* | | | | |
| 3 | 1, 2 | Economizer Tubes, 6th Floor, Lower Tube Wall (North and South Bends) | **PASS** | *EXTENSIVE REMAINING LIFE* | Identify a suitable wall thickness for each zone and conduct inspection and selective replacement at the earliest opportunity (within 1 year). | 10% (15 MW) (risk of creep rupture may be reduced, but not eliminated with a reduced operating pressure) | Proactively replace tubing at or near end of creep life at the earliest opportunity, placing priority on the highest-risk tubing.<br><br>Continue monitoring tube wall thinning on other tubing. | 10% (15 MW) (risk of creep rupture may be reduced, but not eliminated with a reduced operating pressure)<br><br>Re-assess based on inspection and replacement results. |
| | **16, 17** | **Low Temperature Superheater, 10th Floor, Below Feet (Boiler Side) (Bends and Tubes)** | *PASS* | **MARGINAL – MEDIUM RISK** | | | | |
| | **18** | **Low Temperature Superheater, 10th Floor, Below Feet (Economizer Side) (Bends)** | *PASS* | **HIGH RISK** | | | | |
| | **19** | **Low Temperature Superheater, 10th Floor, Below Feet (Economizer Side) (Tubes)** | *PASS* | **MARGINAL – MEDIUM RISK** | | | | |
| | 20 | High Temperature Superheater, 8th Floor, Overhead (Bends) | *FAIL* | **EXTENSIVE REMAINING LIFE** | | | | |
| | 25, 26 | High Temperature Superheater, 8.5 Floor, Below Feet (Tubes and Bends) | *PASS* | **EXTENSIVE REMAINING LIFE** | | | | |
| | **29** | **Reheater Tubes, 9th Floor, Overhead (Bends)** | *FAIL* | **HIGH RISK** | | | | |
| | **30** | **Reheater Tubes, 9th Floor, Overhead (Tubes)** | *FAIL* | **MARGINAL – MEDIUM RISK** | | | | |
| | **31** | **Reheater Tubes, 9th Floor, Below Feet (Tubes, SA-213 T11)** | *PASS* | **HIGH RISK** | | | | |
| | **32** | **Reheater Tubes, 9th Floor, Below Feet (Tubes, SA-213 T22)** | *PASS* | **MARGINAL – MEDIUM RISK** | | | | |

[1]Most relevant evaluation criteria for a given tube (based on metal temperatures) are **bold**.



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Recommendations

The following recommendations are provided to support Nalcor in optimising load capability and mitigate the outage risk associated with boiler tube wall thinning:

1. It is recommended a fitness-for-service approach be applied to manage boiler tube integrity related to tube wall thinning. Limits for water-touched tubes should be based on the PSB-26 criteria, and for the steam-touched (high-temperature) tubes, based on predicted creep rupture life.

2. The results of this analysis should be reviewed with the local jurisdictional authority to assess regulatory requirements associated with implementation. It is expected that this discussion will confirm the feasibility of adopting the fitness-for-service approach.

3. It is recommended additional tube replacements be completed in the Unit 3 primary superheater and reheater at the earliest opportunity. The creep life analysis has determined that the primary superheater tubing on the 10th floor (below feet) and reheater tubing in the 9th floor cavity are approaching end of life. Creep life is predicted to be in the same order of magnitude as the reheater tubing in Units 1 and 2 that required replacement in 2016. A 10% (15 MW) de-rate is recommended in the interim period in order to regain margin and reduce the risk of creep rupture.

4. An assessment should be performed to determine minimum acceptable wall thickness for compromised areas to support inspection and selective replacement.

5. Conduct follow-up inspections in 2016 to confirm materials and wall thickness in limiting locations (extent of damage).

6. Continue with annual boiler tube wall thickness surveys to monitor damage accumulation rates and locations. If there is evidence of additional wall thinning, the re-rating needs to be revisited. The cause(s) of tube thinning on Unit 3 should be investigated and mitigated where possible in order to reduce the risk of early tube failure.

7. Other failure mechanisms beyond wall thinning, such as fatigue cracking, are outside this scope of this thickness-based analysis. Fatigue failures are due to pressure/temperature cycles, therefore it is recommended that stops/starts and load cycling be limited when possible.

8. Use of pressure for control of generator output is recommended over load control, due to potential non-linearity in the translation between the pressure and load at higher pressure reductions (i.e. >10%). Additionally, if a long-term de-rate is applied, a boiler performance assessment is recommended to evaluate other impacts.



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## REFERENCES

[1] Correspondence, "Holyrood TGS Condition Re-Rate Assessment Review", AmecFW File No. AM212/011/000001 R00, 2016-04-27.

[2] Report, "Uprating Holyrood Units 1 and 2 from 150 MW to 175 MW", File No. TIS 8536, 1990-10-01.

[3] Report, "Thermal Study – Superheater and Reheater Metal" B&W File No. TP900932 R02, 2016-07-05.

[4] ASME Boiler and Pressure Vessel Code Section I, 2015-07-01.

[5] B&W Plant Service Bulletin, "Tube Thickness Evaluation Repair or Replacement Guide", B&W File No. PSB-26, 1994-06-01.

[6] API 579-1/ASME FFS-1, "Fitness for Service", 2007-06-05.

[7] National Board Inspection Code (NBIC), Part 3 "Repairs and Alterations", NB-23 (2015).



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## APPENDIX 1

### Analysis Results

**Unit 1**

| # | Inspection Location | Physical Properties | | | | | B&W Plant Service Bulletin PSB-26 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lowest Measured Wall Thickness (inch) | Assumed 100% Operating Pressure (psi) | Material | Temp. (°F) | Tube OD (inches) | PSB-26 Requirement (t = specified wall) | Percent Remaining from Original | Required Wall (inches) | Margin at Design Pressure (inches) | Criteria Satisfied? |
| 1 | Water Wall Tubes at Buners | 0.204 | 2205 | SA210A1 | 701 | 2.5 | 70%t | 102% | 0.140 | 0.064 | YES |
| 2 | Economizer, 8th Floor, Below Feet | 0.202 | 2205 | SA192 | 704 | 2 | 70%t | 101% | 0.140 | 0.062 | YES |
| 3 | Boiler Floor Tubes | 0.174 | - | - | - | - | 70%t | 87% | 0.140 | 0.034 | YES |
| 4 | Primary Superheater, 10th Floor, Below Feet | 0.206 | 2055 | SA213T11 | 914 | 2 | 85%t | 114% | 0.153 | 0.053 | YES |
| 5 | Primary Superheater, 9th Floor, Overhead | 0.19 | 2055 | SA210A1 | 768 | 2 | 85%t | 106% | 0.153 | 0.037 | YES |
| 6 | Primary Superheater, 9th Floor, Below Feet | 0.183 | 2055 | SA210A1 | 751 | 2 | 85%t | 111% | 0.140 | 0.043 | YES |
| 7 | Primary Superheater, 8th Floor (Bend) | 0.153 | 2055 | SA210A1 | 732 | 2 | 85%t | 93% | 0.140 | 0.013 | YES |
| 8 | Primary Superheater, 8th Floor (Tube) | 0.173 | 2055 | SA210A1 | 732 | 2 | 85%t | 105% | 0.140 | 0.033 | YES |
| 9 | Secondary Superheater, 7th Floor, Overhead | 0.192 | 2055 | SA213TP321H | 993 | 2 | 85%t | 116% | 0.140 | 0.052 | YES |
| 10 | Secondary Superheater, 7th Floor, Below Feet | 0.215 | 2055 | SA213T22 | 875 | 2 | 85%t | 83% | 0.221 | -0.006 | NO |
| 11 | Secondary Superheater, 8th Floor, Below Feet | 0.197 | 2055 | SA213TP347H | 1160 | 2 | 85%t | 82% | 0.204 | -0.007 | NO |
| 12 | Secondary Superheater, 6th Floor (Overhead from Scaffold) | 0.193 | 2055 | SA213T22 | 959 | 2 | 85%t | 82% | 0.202 | -0.009 | NO |
| 13 | *Reheater, 8th Floor, Overhead*[2] | *0.061* | *532* | *SA213TP304H* | *1186* | *2.125* | *85%t* | *41%* | *0.126* | *-0.065* | *NO* |
| 14 | Reheater, 9th Floor, Below Feet (North Bend) | 0.14 | 532 | SA213T22 | 1060 | 2.125 | 85%t | 95% | 0.126 | 0.014 | YES |
| 15 | Reheater, 9th Floor, Below Feet (North Bend) | 0.182 | 532 | SA213T22 | 1060 | 2.125 | 85%t | 123% | 0.126 | 0.056 | YES |
| 16 | Reheater, 9th Floor, Below Feet (South Section of Tube) | 0.214 | 532 | SA213T9 | 1100 | 2.125 | 85%t | 105% | 0.173 | 0.041 | YES |

| # | Inspection Location | MAWP (ASME BPVC Section I, PG-27.2.1) | | | | | | | MAWP (ASME BPVC Section I, A-317.2.1) | | | | | | | Larson-Miller at 100% Operating Pressure | | Larson-Miller at 90% Operating Pressure | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | Minimum Predicted Life (hours) | *Mean Predicted Life (hours)* | Minimum Predicted Life (hours) | *Mean Predicted Life (hours)* |
| 1 | Water Wall Tubes at Buners | 2580 | 375 | 419 | 485 | 595 | 705 | 816 | 2770 | 565 | 609 | 675 | 786 | 896 | 1006 | 1.00E+08 | 8.35E+08 | 2.51E+08 | 2.02E+09 |
| 2 | Economizer, 8th Floor, Below Feet | 2505 | 400 | 444 | 510 | 620 | 730 | 841 | 2767 | 562 | 606 | 673 | 783 | 893 | 1003 | 9.05E+07 | 1.76E+08 | 2.07E+08 | 3.95E+08 |
| 3 | Boiler Floor Tubes | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | Primary Superheater, 10th Floor, Below Feet | 2694 | 639 | 680 | 741 | 844 | 947 | 1050 | 2859 | 804 | 846 | 907 | 1010 | 1113 | 1215 | 2.05E+06 | 1.28E+07 | 5.24E+06 | 3.03E+07 |
| 5 | Primary Superheater, 9th Floor, Overhead | 2415 | 360 | 401 | 463 | 565 | 668 | 771 | 2572 | 517 | 559 | 620 | 723 | 826 | 928 | 1.82E+07 | 1.31E+08 | 4.48E+07 | 2.72E+08 |
| 6 | Primary Superheater, 9th Floor, Below Feet | 2639 | 584 | 625 | 687 | 790 | 892 | 995 | 2817 | 762 | 803 | 864 | 967 | 1070 | 1173 | 9.68E+07 | 6.85E+08 | 2.22E+08 | 1.46E+09 |
| 7 | Primary Superheater, 8th Floor (Bend) | 2146 | 91 | 132 | 194 | 297 | 400 | 502 | 2314 | 259 | 300 | 362 | 465 | 567 | 670 | 1.87E+07 | 1.56E+08 | 4.59E+07 | 3.49E+08 |
| 8 | Primary Superheater, 8th Floor (Tube) | 2473 | 418 | 459 | 521 | 624 | 726 | 829 | 2647 | 592 | 633 | 695 | 798 | 900 | 1003 | 5.84E+07 | 4.33E+08 | 1.37E+08 | 9.38E+08 |
| 9 | Secondary Superheater, 7th Floor, Overhead | 3249 | 1194 | 1235 | 1297 | 1400 | 1502 | 1605 | 3460 | 1405 | 1446 | 1507 | 1610 | 1713 | 1816 | 1.85E+07 | 2.42E+08 | 3.46E+07 | 4.60E+08 |
| 10 | Secondary Superheater, 7th Floor, Below Feet | 2147 | 92 | 133 | 195 | 298 | 400 | 503 | 2275 | 220 | 262 | 323 | 426 | 529 | 631 | 8.43E+05 | 3.79E+06 | 1.63E+06 | 7.26E+06 |
| 11 | Secondary Superheater, 8th Floor, Below Feet | 2059 | 4 | 45 | 107 | 209 | 312 | 415 | 2190 | 135 | 176 | 237 | 340 | 443 | 546 | 8.06E+05 | 2.27E+06 | 1.34E+06 | 3.77E+06 |
| 12 | Secondary Superheater, 6th Floor (Overhead from Scaffold) | 2074 | 19 | 60 | 122 | 224 | 327 | 430 | 2208 | 153 | 194 | 256 | 358 | 461 | 564 | 7.38E+05 | 3.49E+06 | 1.49E+06 | 6.83E+06 |
| 13 | *Reheater, 8th Floor, Overhead*[2] | *318* | *-214* | *-203* | *-187* | *-161* | *-134* | *-108* | *387* | *-145* | *-134* | *-118* | *-92* | *-65* | *-38* | *1.23E+05* | *1.30E+06* | *2.26E+05* | *2.02E+06* |
| 14 | Reheater, 9th Floor, Below Feet (North Bend) | 690 | 158 | 168 | 184 | 211 | 238 | 264 | 751 | 220 | 230 | 246 | 273 | 299 | 326 | 1.82E+06 | 7.45E+06 | 4.48E+06 | 1.08E+07 |
| 15 | Reheater, 9th Floor, Below Feet (North Bend) | 933 | 401 | 412 | 428 | 455 | 481 | 508 | 1000 | 468 | 478 | 494 | 521 | 547 | 574 | 8.79E+06 | 1.86E+07 | 1.21E+07 | 2.41E+07 |
| 16 | Reheater, 9th Floor, Below Feet (South Section of Tube) | 699 | 167 | 177 | 193 | 220 | 246 | 273 | 741 | 210 | 221 | 237 | 263 | 290 | 317 | 2.56E+06 | 1.71E+07 | 4.17E+06 | 2.78E+07 |

[2] Tubes to be replaced in 2016.



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## APPENDIX 1
### Analysis Results

**Unit 1**

| # | Inspection Location | Physical Properties: Lowest Measured Wall Thickness (inch) | Physical Properties: Assumed 100% Operating Pressure (psi) | Physical Properties: Material | Physical Properties: Temp. (°F) | Physical Properties: Tube OD (inches) | B&W Plant Service Bulletin PSB-26: PSB-26 Requirement (t = specified wall) | B&W Plant Service Bulletin PSB-26: Percent Remaining from Original | B&W Plant Service Bulletin PSB-26: Required Wall (inches) | B&W Plant Service Bulletin PSB-26: Margin at Design Pressure (inches) | B&W Plant Service Bulletin PSB-26: Criteria Satisfied? |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | Reheater, 9th Floor, Below Feet (North Section of Tube) | 0.154 | 532 | SA213T22 | 1060 | 2.125 | 85%t | 104% | 0.126 | 0.028 | YES |
| 18 | Reheater, 9th Floor, Overhead | 0.165 | 532 | SA213T22 | 1060 | 2.5 | 85%t | 111% | 0.126 | 0.039 | YES |
| 19 | Reheater, 10th Floor, Below Feet | 0.137 | 532 | SA209T1 | 700 | 2.5 | 85%t | 102% | 0.134 | 0.003 | YES |
| 20 | Water Wall Knee Region | 0.211 | 2205 | SA210A1 | 701 | 2.5 | 70%t | 106% | 0.140 | 0.071 | YES |
| 21 | Economizer, 5th Floor, Overhead (Bend) | 0.143 | 2205 | SA192 | 704 | 2 | 70%t | 72% | 0.140 | 0.003 | YES |
| 22 | Economizer, 5th Floor, Overhead (Tube) | 0.183 | 2205 | SA192 | 704 | 2 | 70%t | 92% | 0.140 | 0.043 | YES |

| # | MAWP (ASME BPVC Section I, PG-27.2.1): MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) |
|---|---|---|---|---|---|---|---|
| 17 | 770 | 238 | 248 | 264 | 291 | 318 | 344 |
| 18 | 681 | 159 | 170 | 186 | 212 | 239 | 268 |
| 19 | 1646 | 1114 | 1124 | 1140 | 1167 | 1193 | 1220 |
| 20 | 2682 | 477 | 521 | 587 | 697 | 808 | 918 |
| 21 | 1747 | -458 | -414 | -347 | -237 | -127 | -17 |
| 22 | 2323 | 118 | 162 | 228 | 338 | 448 | 559 |

| # | MAWP (ASME BPVC Section I, A-317.2.1): MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | Larson-Miller at 100% Operating Pressure: Minimum Predicted Life (hours) | Larson-Miller at 100% Operating Pressure: Mean Predicted Life (hours) | Larson-Miller at 90% Operating Pressure: Minimum Predicted Life (hours) | Larson-Miller at 90% Operating Pressure: Mean Predicted Life (hours) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 833 | 301 | 312 | 328 | 354 | 381 | 407 | 4.43E+06 | 1.08E+07 | 6.71E+06 | 1.50E+07 |
| 18 | 753 | 221 | 232 | 248 | 274 | 301 | 328 | 2.84E+06 | 7.51E+06 | 4.32E+06 | 1.09E+07 |
| 19 | 1823 | 1291 | 1301 | 1317 | 1344 | 1370 | 1397 | 1.68E+12 | 3.78E+12 | 2.73E+12 | 9.40E+12 |
| 20 | 2875 | 670 | 714 | 780 | 890 | 1000 | 1111 | 1.39E+08 | 1.18E+09 | 3.44E+08 | 2.68E+09 |
| 21 | 1893 | -322 | -268 | -202 | -92 | 18 | 128 | 3.42E+06 | 7.41E+06 | 8.95E+06 | 1.87E+07 |
| 22 | 2479 | 274 | 318 | 384 | 494 | 605 | 715 | 3.69E+07 | 7.36E+07 | 8.71E+07 | 1.70E+08 |



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## APPENDIX 1

### Analysis Results

| Unit 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Inspection Location | Physical Properties | | | | | B&W Plant Service Bulletin PSB-26 | | | | | MAWP (ASME BPVC Section I, PG-27.2.1) | | | | | | | MAWP (ASME BPVC Section I, A-317.2.1) | | | | | | | Larson-Miller at 100% Operating Pressure | | Larson-Miller at 90% Operating Pressure | |
| | | Lowest Measured Wall Thickness (inch) | Assumed 100% Operating Pressure (psi) | Material | Temp. (°F) | Tube OD (inches) | PSB-26 Requirement (t = specified wall) | Percent Remaining from Original | Required Wall (inches) | Margin at Design Pressure (inches) | Criteria Satisfied? | MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | Minimum Predicted Life (hours) | *Mean Predicted Life (hours)* | Minimum Predicted Life (hours) | *Mean Predicted Life (hours)* |
| 1 | Water Wall Tubes at Buners | 0.171 | 2205 | SA210A1 | 701 | 2.5 | 70%t | 86% | 0.140 | 0.031 | YES | 2105 | -100 | -56 | 10 | 120 | 231 | 341 | 2287 | 81 | 126 | 252 | 303 | 413 | 523 | 1.68E+07 | 1.81E+08 | 4.37E+07 | 4.39E+08 |
| 2 | Economizer, 8th Floor, Below Feet | 0.209 | 2205 | SA182 | 704 | 2 | 70%t | 105% | 0.140 | 0.069 | YES | 2710 | 505 | 549 | 615 | 726 | 836 | 946 | 2871 | 670 | 714 | 781 | 891 | 1001 | 1111 | 1.23E+08 | 2.37E+08 | 2.77E+08 | 5.25E+08 |
| 3 | Boiler Floor Tubes | 0.177 | - | - | - | - | 70%t | 89% | 0.140 | 0.037 | YES | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | Primary Superheater, 10th Floor, Below Feet (Bend) | 0.163 | 2055 | SA213T11 | 914 | 2 | 85%t | 91% | 0.153 | 0.010 | YES | 2054 | -1 | 60 | 102 | 204 | 307 | 410 | 2206 | 151 | 182 | 253 | 356 | 459 | 562 | 6.61E+05 | 4.08E+06 | 1.05E+06 | 6.40E+06 |
| 5 | Primary Superheater, 10th Floor, Below Feet (Tube) | 0.168 | 2055 | SA213T11 | 914 | 2 | 85%t | 103% | 0.153 | 0.015 | YES | 2422 | 367 | 408 | 470 | 573 | 675 | 778 | 2582 | 527 | 568 | 629 | 732 | 835 | 938 | 1.31E+06 | 8.16E+06 | 2.07E+06 | 1.30E+07 |
| 6 | Primary Superheater, 9th Floor, Overhead | 0.191 | 2055 | SA210A1 | 768 | 2 | 85%t | 106% | 0.153 | 0.038 | YES | 2410 | 375 | 416 | 477 | 580 | 683 | 786 | 2588 | 533 | 574 | 635 | 738 | 841 | 944 | 2.12E+07 | 1.37E+08 | 4.68E+07 | 2.83E+08 |
| 7 | Primary Superheater, 9th Floor, Below Feet | 0.182 | 2055 | SA210A1 | 732 | 2 | 85%t | 110% | 0.140 | 0.042 | YES | 2623 | 568 | 609 | 670 | 773 | 876 | 979 | 2800 | 745 | 786 | 847 | 950 | 1053 | 1156 | 9.22E+07 | 6.55E+08 | 2.12E+08 | 1.40E+09 |
| 8 | Primary Superheater, 8th Floor (Bend) | 0.125 | 2055 | SA210A1 | 732 | 2 | 85%t | 76% | 0.140 | -0.015 | NO | 1700 | -355 | -315 | -252 | -149 | -46 | 56 | 1861 | -194 | -153 | -91 | 11 | 114 | 217 | 2.56E+06 | 2.68E+07 | 6.86E+06 | 6.39E+07 |
| 9 | Primary Superheater, 8th Floor (Tube) | 0.179 | 2055 | SA210A1 | 732 | 2 | 85%t | 108% | 0.140 | 0.039 | YES | 2573 | 518 | 559 | 620 | 723 | 826 | 929 | 2749 | 694 | 735 | 796 | 899 | 1002 | 1105 | 7.34E+07 | 5.72E+08 | 1.84E+08 | 1.23E+09 |
| 10 | Secondary Superheater, 7th Floor, Overhead | 0.192 | 2055 | SA213TP321H | 991 | 2 | 85%t | 116% | 0.140 | 0.052 | YES | 3249 | 1194 | 1235 | 1297 | 1400 | 1502 | 1605 | 3460 | 1405 | 1446 | 1507 | 1610 | 1713 | 1816 | 1.83E+07 | 2.42E+08 | 3.46E+07 | 4.60E+08 |
| 11 | Secondary Superheater, 7th Floor, Below Feet | 0.22 | 2055 | SA213T22 | 875 | 2 | 85%t | 85% | 0.221 | -0.001 | NO | 2206 | 151 | 192 | 253 | 356 | 459 | 562 | 2336 | 281 | 322 | 383 | 486 | 589 | 692 | 9.95E+05 | 4.40E+06 | 1.94E+06 | 8.51E+06 |
| 12 | Secondary Superheater, 8th Floor, Below Feet | 0.192 | 2055 | SA213TP347H | 1160 | 2 | 85%t | 80% | 0.204 | -0.012 | NO | 1998 | -57 | -16 | 46 | 149 | 251 | 354 | 2118 | 73 | 114 | 175 | 278 | 381 | 484 | 7.01E+05 | 1.96E+06 | 1.17E+06 | 3.28E+06 |
| 13 | Secondary Superheater, 6th Floor (Overhead from Scaffold) | 0.213 | 2055 | SA213T22 | 959 | 2 | 85%t | 89% | 0.202 | 0.011 | YES | 2326 | 271 | 312 | 374 | 477 | 579 | 682 | 2466 | 411 | 452 | 514 | 617 | 719 | 822 | 1.54E+06 | 7.07E+06 | 3.04E+06 | 1.37E+07 |
| 14 | *Reheater, 8th Floor, Overhead[3]* | *0.05* | *525* | *SA213TP304H* | *1186* | *2.125* | *85%t* | *34%* | *0.126* | *-0.076* | *NO* | *247* | *-278* | *-267* | *-252* | *-225* | *-199* | *-173* | *316* | *-209* | *-199* | *-183* | *-157* | *-131* | *-104* | *4.03E+04* | *3.81E+05* | *7.45E+04* | *6.66E+05* |
| 15 | Reheater, 9th Floor, Below Feet (South Bend) | 0.206 | 525 | SA213T9 | 1100 | 2.125 | 85%t | 101% | 0.173 | 0.033 | YES | 668 | 145 | 154 | 170 | 196 | 222 | 248 | 711 | 186 | 197 | 212 | 239 | 265 | 291 | 1.24E+06 | 1.30E+07 | 3.64E+06 | 2.43E+07 |
| 16 | Reheater, 9th Floor, Below Feet (South Bend) | 0.202 | 525 | SA213T9 | 1100 | 2.125 | 85%t | 100% | 0.173 | 0.029 | YES | 653 | 128 | 139 | 154 | 181 | 207 | 233 | 696 | 171 | 182 | 197 | 223 | 250 | 276 | 2.02E+06 | 1.35E+07 | 3.29E+06 | 2.19E+07 |
| 17 | Reheater, 9th Floor, Below Feet (South Section of Tube) | 0.225 | 525 | SA213T9 | 1100 | 2.125 | 85%t | 111% | 0.173 | 0.052 | YES | 741 | 216 | 226 | 242 | 268 | 294 | 321 | 785 | 260 | 271 | 287 | 313 | 339 | 365 | 1.51E+06 | 2.36E+07 | 3.75E+06 | 3.82E+07 |

[3] Tubes to be replaced in 2016.



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## APPENDIX 1

### Analysis Results

| Unit 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Inspection Location | Physical Properties | | | | | B&W Plant Service Bulletin PSB-26 | | | | | MAWP (ASME BPVC Section I, PG-27.2.1) | | | | | | | MAWP (ASME BPVC Section I, A-317.2.1) | | | | | | | Larson-Miller at 100% Operating Pressure | | Larson-Miller at 90% Operating Pressure | |
| | | Lowest Measured Wall Thickness (inch) | Assumed 100% Operating Pressure (psi) | Material | Temp. (°F) | Tube OD (inches) | PSB-26 Requirement (t = specified wall) | Percent Remaining from Original | Required Wall (inches) | Margin at Design Pressure (inches) | Criteria Satisfied? | MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | Minimum Predicted Life (hours) | Mean Predicted Life (hours) | Minimum Predicted Life (hours) | Mean Predicted Life (hours) |
| 18 | Reheater, 9th Floor, Below Feet (North Section of Tube) | 0.17 | 525 | SA213T22 | 1060 | 2.125 | 85%t | 115% | 0.116 | 0.044 | YES | 861 | 338 | 348 | 364 | 390 | 416 | 443 | 928 | 405 | 413 | 429 | 455 | 481 | 508 | 7.10E+06 | 1.57E+07 | 1.01E+07 | 2.08E+07 |
| 19 | Reheater, 9th Floor, Overhead | 0.159 | 525 | SA213T22 | 1060 | 2.5 | 85%t | 114% | 0.126 | 0.043 | YES | 711 | 186 | 196 | 212 | 238 | 264 | 291 | 773 | 248 | 258 | 274 | 300 | 327 | 353 | 3.39E+06 | 8.67E+06 | 5.29E+06 | 1.34E+07 |
| 20 | Reheater, 10th Floor, Below Feet | 0.133 | 525 | SA209T1 | 700 | 2.5 | 85%t | 99% | 0.114 | 0.018 | YES | 1590 | 1065 | 1076 | 1091 | 1118 | 1144 | 1170 | 1766 | 1241 | 1252 | 1267 | 1294 | 1320 | 1346 | 1.55E+12 | 3.31E+12 | 2.51E+12 | 8.65E+12 |
| 21 | Water Wall Knee Region | 0.216 | 2205 | SA210A1 | 701 | 2.5 | 70%t | 108% | 0.140 | 0.076 | YES | 2756 | 551 | 595 | 661 | 771 | 881 | 992 | 2950 | 745 | 789 | 855 | 965 | 1075 | 1186 | 1.74E+08 | 1.45E+09 | 4.27E+08 | 3.25E+09 |
| 22 | Water Wall Upper Rear Tubes | 0.15 | 2205 | SA210A1 | 701 | 2.5 | 70%t | 75% | 0.140 | 0.010 | YES | 1810 | -395 | -351 | -285 | -175 | -64 | 46 | 1988 | -217 | -173 | -107 | 3 | 113 | 224 | 4.08E+06 | 1.24E+07 | 1.19E+07 | 1.34E+08 |
| 23 | Economizer, 5th Floor, Overhead (Bend) | 0.155 | 2205 | SA192 | 704 | 2 | 70%t | 78% | 0.140 | 0.015 | YES | 1917 | -288 | -244 | -177 | -67 | 43 | 153 | 2065 | -140 | -95 | -29 | 81 | 191 | 301 | 7.62E+06 | 1.60E+07 | 1.92E+07 | 3.92E+07 |
| 24 | Economizer, 5th Floor, Overhead (Tube) | 0.184 | 2205 | SA192 | 704 | 2 | 70%t | 94% | 0.140 | 0.044 | YES | 2396 | 191 | 235 | 302 | 412 | 522 | 632 | 2554 | 349 | 393 | 459 | 570 | 680 | 790 | 4.72E+07 | 9.36E+07 | 1.10E+08 | 2.14E+08 |



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## APPENDIX 1

### Analysis Results

| Unit 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Inspection Location | Physical Properties | | | | | B&W Plant Service Bulletin PSB-26 | | | | | MAWP (ASME BPVC Section I, PG-27.2.1) | | | | | | | MAWP (ASME BPVC Section I, A-317.2.1) | | | | | | | Larson-Miller at 100% Operating Pressure | | Larson-Miller at 90% Operating Pressure | |
| | | Lowest Measured Wall Thickness (inch) | Assumed 100% Operating Pressure (psi) | Material | Temp. (°F) | Tube OD (inches) | PSB-26 Requirement (t = specified wall) | Percent Remaining from Original | Required Wall (inches) | Margin at Design Pressure (inches) | Criteria Satisfied? | MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | Minimum Predicted Life (hours) | Mean Predicted Life (hours) | Minimum Predicted Life (hours) | Mean Predicted Life (hours) |
| 1 | Economizer Tubes, 6th Floor, Lower Tube Wall (South Bend) | 0.153 | 2200 | SA210A1 | 700 | 2.5 | 70%t | 75% | 0.142 | 0.011 | YES | 1858 | -342 | -298 | -232 | -122 | -12 | 98 | 2037 | -163 | -119 | -53 | 57 | 167 | 277 | 5.49E+06 | 6.85E+07 | 1.38E+07 | 1.73E+08 |
| 2 | Economizer Tubes, 6th Floor, Lower Tube Wall (North Bend) | 0.155 | 2200 | SA210A1 | 700 | 2.5 | 70%t | 76% | 0.142 | 0.013 | YES | 1886 | -314 | -270 | -204 | -94 | 16 | 126 | 2065 | -135 | -91 | -25 | 85 | 195 | 305 | 6.33E+06 | 7.76E+07 | 1.81E+07 | 1.95E+08 |
| 3 | Economizer Tubes, 6th Floor, Lower Tube Wall (Tube) | 0.189 | 2200 | SA210A1 | 700 | 2.5 | 70%t | 93% | 0.142 | 0.047 | YES | 2370 | 170 | 214 | 280 | 390 | 500 | 610 | 2557 | 357 | 401 | 467 | 577 | 687 | 797 | 5.06E+07 | 4.85E+08 | 1.31E+08 | 1.13E+09 |
| 4 | Economizer Tubes, 8th Floor, Lower (Under Sootblower) | 0.178 | 2200 | SA210A1 | 700 | 2.5 | 70%t | 88% | 0.142 | 0.036 | YES | 2212 | 12 | 56 | 122 | 232 | 342 | 452 | 2396 | 196 | 240 | 306 | 416 | 526 | 636 | 1.75E+07 | 2.83E+08 | 7.33E+07 | 6.74E+08 |
| 5 | Economizer Tubes, 8th Floor, Lower (North Bend) | 0.218 | 2200 | SA210A1 | 700 | 2.5 | 70%t | 107% | 0.142 | 0.076 | YES | 2794 | 594 | 638 | 704 | 814 | 924 | 1034 | 2990 | 790 | 834 | 900 | 1010 | 1120 | 1230 | 1.05E+08 | 1.69E+09 | 5.01E+08 | 3.79E+09 |
| 6 | Economizer Tubes, 8th Floor, Lower (North Bend) | 0.186 | 2200 | SA210A1 | 700 | 2.5 | 70%t | 92% | 0.142 | 0.044 | YES | 2327 | 127 | 171 | 237 | 347 | 457 | 567 | 2513 | 313 | 357 | 423 | 533 | 643 | 753 | 6.31E+07 | 4.20E+08 | 1.13E+08 | 9.89E+08 |
| 7 | Economizer Tubes, 8th Floor, Upper (South Bend) | 0.171 | 2200 | SA210A1 | 700 | 2.5 | 70%t | 84% | 0.142 | 0.029 | YES | 2112 | -88 | -44 | 22 | 132 | 242 | 352 | 2295 | 95 | 139 | 205 | 315 | 425 | 535 | 1.81E+07 | 1.90E+08 | 4.93E+07 | 4.74E+08 |
| 8 | Economizer Tubes, 8th Floor, Upper (Tube) | 0.178 | 2200 | SA210A1 | 700 | 2.5 | 70%t | 88% | 0.142 | 0.036 | YES | 2212 | 12 | 56 | 122 | 232 | 342 | 452 | 2396 | 196 | 240 | 306 | 416 | 526 | 636 | 1.75E+07 | 2.83E+08 | 7.33E+07 | 6.74E+08 |
| 9 | Economizer Tubes, 8th Floor, Upper (North Bend) | 0.178 | 2200 | SA210A1 | 700 | 2.5 | 70%t | 88% | 0.142 | 0.036 | YES | 2212 | 12 | 56 | 122 | 232 | 342 | 452 | 2396 | 196 | 240 | 306 | 416 | 526 | 636 | 1.75E+07 | 2.83E+08 | 7.33E+07 | 6.74E+08 |
| 10 | Low Temperature Superheater, 8th Floor, Overhead (Bend) | 0.180 | 2010 | SA210A1 | 696 | 2.5 | 85%t | 89% | 0.173 | 0.007 | YES | 2258 | 248 | 288 | 348 | 449 | 549 | 650 | 2444 | 434 | 474 | 535 | 635 | 736 | 836 | 8.91E+07 | 8.29E+08 | 2.29E+08 | 1.92E+09 |
| 11 | Low Temperature Superheater, 8th Floor, Overhead (Tube) | 0.194 | 2010 | SA210A1 | 696 | 2.5 | 85%t | 96% | 0.173 | 0.021 | YES | 2461 | 451 | 491 | 551 | 652 | 753 | 853 | 2651 | 641 | 681 | 742 | 842 | 943 | 1043 | 1.85E+08 | 1.39E+09 | 4.60E+08 | 3.61E+09 |
| 12 | Low Temperature Superheater, 9th Floor, Below Feet (Bend) | 0.179 | 2010 | SA210A1 | 741 | 2.5 | 85%t | 88% | 0.173 | 0.006 | YES | 1922 | -88 | -48 | 12 | 113 | 213 | 314 | 2081 | 71 | 111 | 172 | 272 | 373 | 473 | 7.58E+06 | 6.53E+07 | 1.88E+07 | 1.47E+08 |
| 13 | Low Temperature Superheater, 9th Floor, Below Feet (Tube) | 0.218 | 2010 | SA210A1 | 741 | 2.5 | 85%t | 106% | 0.173 | 0.045 | YES | 2387 | 377 | 417 | 477 | 578 | 678 | 779 | 2555 | 545 | 585 | 645 | 746 | 846 | 947 | 4.25E+07 | 3.08E+08 | 9.91E+07 | 6.60E+08 |
| 14 | Low Temperature Superheater, 9th Floor, Overhead (Bend) | 0.170 | 2010 | SA209T1A | 766 | 2.5 | 85%t | 84% | 0.173 | -0.003 | NO | 2184 | 174 | 214 | 274 | 375 | 475 | 576 | 2374 | 364 | 404 | 465 | 565 | 666 | 766 | 2.75E+08 | 3.72E+08 | 4.37E+08 | 1.37E+09 |




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## APPENDIX 1
### Analysis Results

**Unit 3**

| # | Inspection Location | Physical Properties: Lowest Measured Wall Thickness (inch) | Physical Properties: Assumed 100% Operating Pressure (psi) | Physical Properties: Material | Physical Properties: Temp. (°F) | Physical Properties: Tube OD (inches) | B&W Plant Service Bulletin PSB-26: PSB-26 Requirement (t = specified wall) | B&W PSB-26: Percent Remaining from Original | B&W PSB-26: Required Wall (inches) | B&W PSB-26: Margin at Design Pressure (inches) | B&W PSB-26: Criteria Satisfied? |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | Low Temperature Superheater, 9th Floor, Overhead (Tube) | 0.210 | 2010 | SA209T1A | 756 | 2.5 | 85%t | 103% | 0.173 | 0.037 | YES |
| 16 | Low Temperature Superheater, 10th Floor, Below Feet (Boiler Side) (Bend) | 0.374 | 2010 | SA213T11 | 1019 | 2.5 | 85%t | 89% | 0.333 | 0.039 | YES |
| 17 | Low Temperature Superheater, 10th Floor, Below Feet (Boiler Side) (Tube) | 0.430 | 2010 | SA213T11 | 1019 | 2.5 | 85%t | 109% | 0.335 | 0.095 | YES |
| 18 | Low Temperature Superheater, 10th Floor, Below Feet (Economizer Side) (Bend) | 0.310 | 2010 | SA213T2 | 993 | 2.5 | 85%t | 92% | 0.287 | 0.023 | YES |
| 19 | Low Temperature Superheater, 10th Floor, Below Feet (Economizer Side) (Tube) | 0.347 | 2010 | SA213T2 | 993 | 2.5 | 85%t | 100% | 0.287 | 0.060 | YES |
| 20 | High Temperature Superheater, 8th Floor, Overhead (Bend) | 0.216 | 2010 | SA209T1A | 941 | 2.25 | 85%t | 66% | 0.278 | -0.062 | NO |
| 21 | High Temperature Superheater, 8th Floor, Overhead (Tube) | 0.228 | 2010 | SA209T1A | 941 | 2.25 | 85%t | 70% | 0.278 | -0.050 | NO |
| 22 | High Temperature Superheater, 8th Floor, Below Feet | 0.221 | 2010 | SA209T1A | 905 | 2.25 | 85%t | 78% | 0.242 | -0.021 | NO |
| 23 | High Temperature Superheater, 8.5 Floor, Overhead (Bend) | 0.275 | 2010 | SA213T22 | 1037 | 2 | 85%t | 84% | 0.278 | -0.003 | NO |
| 24 | High Temperature Superheater, 8.5 Floor, Overhead (Tube) | 0.283 | 2010 | SA213T22 | 1034 | 2 | 85%t | 87% | 0.274 | 0.009 | YES |
| 25 | High Temperature Superheater, 8.5 Floor, Below Feet (Bend) | 0.379 | 2010 | SA213T22 | 1021 | 2.25 | 85%t | 98% | 0.342 | 0.037 | YES |

| # | MAWP (ASME BPVC Section I, PG-27.2.1): MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | MAWP (ASME BPVC Section I, A-317.2.1): MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | Larson-Miller at 100% Operating Pressure: Minimum Predicted Life (hours) | Larson-Miller at 100% Operating Pressure: *Mean Predicted Life (hours)* | Larson-Miller at 90% Operating Pressure: Minimum Predicted Life (hours) | Larson-Miller at 90% Operating Pressure: *Mean Predicted Life (hours)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 2803 | 791 | *833* | *894* | *994* | *1095* | *1195* | 3005 | 995 | *1035* | *1096* | *1196* | *1297* | *1397* | 1.30E+09 | *4.09E+09* | *2.09E+09* | *6.45E+09* |
| 16 | 1860 | -150 | -110 | -49 | 51 | *152* | *252* | 1956 | -54 | -14 | 47 | *147* | *248* | *348* | 1.74E+05 | *9.75E+05* | 2.66E+05 | *1.50E+06* |
| 17 | 2206 | 196 | *236* | *297* | *397* | *498* | *598* | 2320 | 310 | *350* | *410* | *511* | *611* | *712* | 3.46E+05 | *1.56E+06* | 5.30E+05 | *3.01E+06* |
| 18 | 1719 | -291 | -251 | -191 | -90 | 10 | *111* | 1813 | -197 | -157 | -96 | 4 | *105* | *205* | 1.12E+05 | *2.85E+05* | 1.64E+05 | *4.33E+05* |
| 19 | 1965 | -45 | -4 | 56 | *156* | *257* | *357* | 2069 | 59 | *99* | *159* | *260* | *360* | *461* | 1.81E+05 | *4.77E+05* | 2.64E+05 | *7.01E+05* |
| 20 | 1840 | -170 | -130 | -69 | 31 | *132* | *232* | 1959 | -51 | -11 | 50 | *150* | *251* | *351* | 3.25E+05 | *8.75E+05* | 4.79E+05 | *1.30E+06* |
| 21 | 1959 | -51 | -10 | 50 | *150* | *251* | *351* | 2081 | 71 | *112* | *172* | *273* | *373* | *473* | 4.05E+05 | *1.10E+06* | 6.00E+05 | *1.63E+06* |
| 22 | 2704 | 694 | *734* | *794* | *895* | *995* | *1096* | 2876 | 866 | *906* | *967* | *1067* | *1168* | *1268* | 1.58E+06 | *4.66E+06* | *2.51E+06* | *7.00E+06* |
| 23 | 1924 | -86 | -46 | 14 | *115* | *215* | *316* | 2025 | 15 | *56* | *116* | *216* | *317* | *417* | 4.52E+05 | *1.79E+06* | *8.40E+05* | *3.09E+06* |
| 24 | 2035 | 25 | *65* | *125* | *226* | *326* | *427* | 2141 | 131 | *171* | *232* | *332* | *433* | *533* | 6.23E+05 | *2.38E+06* | *1.15E+06* | *4.17E+06* |
| 25 | 1900 | -110 | -70 | -9 | 91 | *192* | *292* | 2005 | -5 | 35 | *95* | *196* | *296* | *397* | 4.12E+05 | *1.70E+06* | *7.80E+05* | *3.10E+06* |




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## APPENDIX 1
### Analysis Results

| Unit 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # | Inspection Location | Physical Properties | | | | | B&W Plant Service Bulletin PSB-26 | | | | | MAWP (ASME BPVC Section I, PG-27.2.1) | | | | | | | MAWP (ASME BPVC Section I, A-317.2.1) | | | | | | | Larson-Miller at 100% Operating Pressure | | Larson-Miller at 90% Operating Pressure | |
| | | Lowest Measured Wall Thickness (inch) | Assumed 100% Operating Pressure (psi) | Material | Temp. (°F) | Tube OD (inches) | PSB-26 Requirement (t = specified wall) | Percent Remaining from Original | Required Wall (inches) | Margin at Design Pressure (inches) | Criteria Satisfied? | MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | MAWP (psi) | Max. Operating Pressure Margin (psi) | Margin with 2% pressure reduction (psi) | Margin with 5% pressure reduction (psi) | Margin with 10% pressure reduction (psi) | Margin with 15% pressure reduction (psi) | Margin with 20% pressure reduction (psi) | Minimum Predicted Life (hours) | *Mean Predicted Life (hours)* | Minimum Predicted Life (hours) | *Mean Predicted Life (hours)* |
| 26 | High Temperature Superheater, 8.5 Floor, Below Feet (Tube) | 0.273 | 2010 | SA213T22 | 1021 | 2.25 | 85%t | 96% | 0.242 | 0.031 | YES | 1968 | -142 | -102 | -41 | 59 | *160* | *260* | 1972 | -38 | 2 | *62* | *163* | *263* | *364* | 1.72E+05 | *1.54E+06* | *7.06E+05* | *2.82E+06* |
| 27 | Reheater Tubes, 7th Floor, Top of Scaffold (Bend) | 0.113 | 600 | SA213TP347H | 1017 | 2.25 | 85%t | 76% | 0.126 | -0.013 | NO | 1547 | 947 | *959* | *977* | *1007* | *1037* | *1067* | 1729 | 1129 | *1141* | *1159* | *1189* | *1219* | *1249* | 1.32E+09 | *3.76E+09* | *2.13E+09* | *6.55E+09* |
| 28 | Reheater Tubes, 7th Floor, Top of Scaffold (Tube) | 0.129 | 600 | SA213TP347H | 1017 | 2.25 | 85%t | 87% | 0.126 | 0.003 | YES | 1804 | 1204 | *1216* | *1234* | *1264* | *1294* | *1324* | 1989 | 1389 | *1401* | *1419* | *1449* | *1479* | *1509* | 2.56E+09 | *7.87E+09* | *4.47E+09* | *1.37E+10* |
| 29 | Reheater Tubes, 9th Floor, Overhead (Bend) | 0.116 | 600 | SA213T22 | 1107 | 2.25 | 85%t | 64% | 0.153 | -0.037 | NO | 352 | -248 | -236 | -218 | -188 | -158 | -128 | 392 | -208 | -196 | -178 | -148 | -118 | -88 | 6.53E+04 | *2.24E+05* | 1.16E+05 | *3.71E+05* |
| 30 | Reheater Tubes, 9th Floor, Overhead (Tube) | 0.140 | 600 | SA213T22 | 1107 | 2.25 | 85%t | 78% | 0.153 | -0.013 | NO | 437 | -163 | -151 | -133 | -103 | -73 | -43 | 479 | -121 | -109 | -91 | -61 | -31 | -1 | 1.89E+05 | *5.65E+05* | 3.19E+05 | *8.73E+05* |
| 31 | Reheater Tubes, 9th Floor, Below Feet (SA-213 T11) | 0.161 | 600 | SA213T11 | 1063 | 2.5 | 85%t | 88% | 0.153 | 0.008 | YES | 484 | -116 | -104 | -86 | -56 | -26 | 4 | 529 | -71 | -59 | -41 | -11 | 19 | *49* | 9.06E+04 | *4.89E+05* | 1.37E+05 | *7.42E+05* |
| 32 | Reheater Tubes, 9th Floor, Below Feet (SA-213 T22) | 0.160 | 600 | SA213T22 | 1058 | 2.5 | 85%t | 89% | 0.153 | 0.007 | YES | 486 | -114 | -102 | -84 | -54 | -24 | 6 | 531 | -69 | -57 | -39 | -9 | 21 | 51 | 3.09E+05 | *8.06E+05* | 5.18E+05 | *1.38E+06* |
| 33 | Boiler Roof Tubes (Boiler Side) | 0.188 | - | - | - | - | 70%t | 78% | 0.168 | 0.020 | YES | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 34 | Water Wall Knee Region | 0.213 | - | - | - | - | 70%t | 101% | 0.147 | 0.066 | YES | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 35 | *Boiler Floor Tubes*[4] | 0.110 | - | - | - | - | 70%t | 52% | 0.147 | -0.037 | *NO* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 36 | Water Wall at Buners (Elevation 1) | 0.169 | - | - | - | - | 70%t | 80% | 0.147 | 0.022 | YES | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 37 | Water Wall at Buners (Elevation 2) | 0.199 | - | - | - | - | 70%t | 95% | 0.147 | 0.052 | YES | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 38 | Water Wall at Buners (Elevation 3) | 0.181 | - | - | - | - | 70%t | 81% | 0.147 | 0.044 | YES | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

[4] Tubes to be restored in 2016.



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