STP
Nuclear Operating Company
South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

July 31, 2014
NOC-AE-14003135
10 CFR 54
File: G25

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

South Texas Project
Units 1 and 2
Docket Nos. STN 50-498, STN 50-499
Response to Requests for Additional Information for the
Review of the South Texas Project, Units 1 and 2,
License Renewal Application – Set 26 (TAC Nos. ME4936 and ME4937)

References:
1. Letter from G. T. Powell, STP, to NRC Document Control Desk, "License Renewal Application", dated October 25, 2010 (NOC-AE-10002607) (ML103010257)
2. Letter from NRC to STP, "Requests for Additional Information for the Review of the South Texas Project, Units 1 and 2, License Renewal Application – Set 26", dated December 18, 2012, (TAC Nos. ME4936 and ME4937) (AE-NOC-14002493) (ML12333A227)
3. Letter from D.W. Rencurrel, STP, to NRC Document Control Desk, "Supplement 2 to Request for NRC Staff to Suspend Safety Review of South Texas Project License Renewal Application", dated January 10, 2013, (TAC Nos. ME4936 and ME4937) (NOC-AE-13002943) (ML13024A413)
4. Letter from G.T. Powell, STP, to NRC Document Control Desk, "Response to Requests for Additional Information for the Review of the South Texas Project, Units 1 and 2, License Renewal Application – Set 26 Date Extension", dated March 20, 2014, (TAC Nos. ME4936 and ME4937) (NOC-AE-14003090) (ML14098A420)

By Reference 1, STP Nuclear Operating Company (STP) submitted a License Renewal Application (LRA) for South Texas Project Units 1 and 2. By Reference 2, the NRC staff requested additional information for their review of the STP LRA. STP temporarily suspended license renewal activities and committed in Reference 3 to provide a response to Reference 2 by February 28, 2014. Reference 4 requested an additional date extension until July 31, 2014, for the Reference 2 submittal. STP's response to Reference 2 requests is provided in Enclosure 1 to this letter. Changes to LRA pages described in Enclosure 1 are depicted as line-in/line-out pages provided in Enclosure 2.

STI: 33874692

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NRR

There are two revised regulatory commitments, one deleted commitment, and one completed regulatory commitment added to Table A4-1 of the LRA and are provided in Enclosure 3 to this letter. There are no other regulatory commitments in this letter.

Should you have any questions regarding this letter, please contact either Arden Aldridge, STP License Renewal Project Lead, at (361) 972-8243 or Rafael Gonzales, STP License Renewal Project regulatory point-of-contact, at (361) 972-4779.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 7-31-2014
Date

G. T. Powell

G. T. Powell
Site Vice President

RJG

Enclosures:
1. STP Response to Requests for Additional Information
2. STP LRA Changes with Line-in/Line-out Annotations
3. Regulatory Commitments

cc:
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Enclosure 1

STP Response to Requests for Additional Information

Attachment A: List of susceptible components, broken down by size

Attachment B: Calculation AES-C-1964-4, "Evaluation of 6-Inch Flange Test", APTECH Project AES 93061964-1Q (June 3, 1994).

Attachment C: Table reflecting leaking components that have occurred since July 28, 2011

Attachment D: CREE 12-29261-95, "STP evaluation methodology and associated analyses calculating the critical bending stresses for the four flaw cases"

Attachment E: Commitment No. 46, in response to RAI B2.1.37-4 Issue 5, Summary of the results of the leak rate analysis

SOUTH TEXAS PROJECT, UNITS 1 AND 2
REQUEST FOR ADDITIONAL INFORMATION, SET 26
(TAC NOS. ME4936 AND ME4937)

RAI B2.1.37-5

Background:

The staff has completed its evaluation of the response to request for additional information (RAI) B2.1.37-4 related to the Selective Leaching of Aluminum Bronze plant-specific aging management program (AMP). As a result of this review, there are several open questions.

Issue:

a) The wording of the commitments (i.e., 39, 44, and 45), the updated final safety analysis report (UFSAR) Supplement, and the aging management program (AMP) is not clear in relation to testing and inspection of removed components (e.g., Commitment No. 45, states that fracture toughness testing will be conducted but it does not discuss pressure and bend testing; Commitment Nos. 39 and 45, overlap in their descriptions of examinations). The staff believes that the intent of the proposed testing and inspections is as follows:

- **Profile Exam (PE) -removed leaking components will be tested/inspected for chemical composition (including aluminum content), mechanical properties, microstructure, degree of dealloying and cracking in order to establish the progression of dealloying, its impact on structural integrity, and to confirm the acceptability of using the existing correlation of observed outside diameter (OD) crack angle to project internal degradation.**

- **Analysis Confirmatory Test (ACT) -removed leaking components will be pressure tested and bend tested to confirm the results of the analytical methodology used to demonstrate structural integrity. In addition, samples will be tested/inspected for chemical composition (including aluminum content), mechanical properties, microstructure, degree of dealloying, and cracking.**

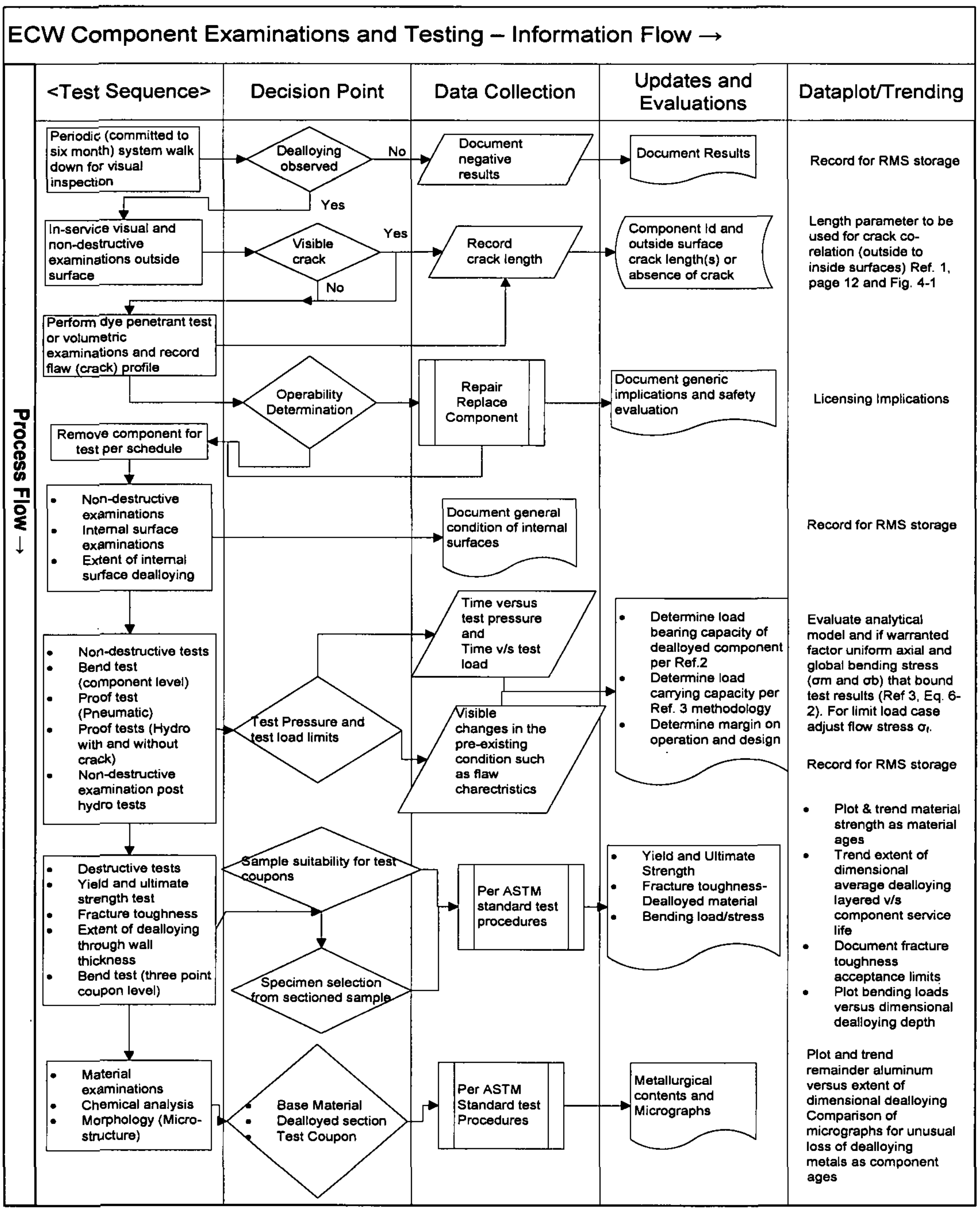
The staff recognizes that different terminology might be established for the above tests and inspections in order to best communicate the program requirements. However, given the currently proposed language in the AMP, UFSAR Supplement, and Commitments, the staff does not believe that testing and inspection requirements will be correctly interpreted in the future.

Request:

a) Revise the AMP, UFSAR Supplement, and Commitments to clearly state the intent of each test and the parameters that will be inspected or tested.

STP Response:

STP Program procedure 0PGP04-ZA-0148 rev.0, "Aluminum Bronze Dealloying Management Program" has been developed and includes the following flow chart documenting the Essential Cooling Water (ECW) Component Examinations and Testing:



Flow Chart References:

1. APTECH Project AES 93061964-1Q, Document AES-C-1964-5, titled 'Evaluation of the Significance of Dealloying and Subsurface Cracks on Flaw Evaluation Method', dated 1/23/1995; STP Record no. ST-7R-HS-090006, PFN MO5.02.02
2. APTECH Project AES 93061964-1Q, Document AES-C-1964-4, titled 'Evaluation of 6-Inch Flange Test', dated 6/3/1994; STP Record no. ST-7R-HS-090003, PFN MO5.02.02
3. APTECH Project AES 93061964-1Q, Document AES-C-1964-1, titled 'Calculation of Critical Bending Stress for Dealloyed Aluminum-Bronze Castings in the ECW System', dated 1/21/1994; STP Record no. ST-7R-HS-090002, PFN MO5.02.02

LRA Appendices A1.37 and B2.1.37, Commitments 39, and 44 in Table A4.1, and LRA Basis Document PSALBZ (B2.1.37) are revised to reflect the intent of each test as defined below:

- Analysis Confirmatory Test (ACT) - Removed leaking components that are pressure tested and bend tested.

The ACT results (pressure and bending moment) support the analytical methodology. The Linear Elastic Fracture Mechanics (LEFM)/Limit Load curves that provide the critical bending stress are based on crack angle use in the correlation of outer diameter (OD) to internal degradation (flaw/crack) angle for predicting internal degradation (APTECH Calc. AES-C-1964-5). The ACT confirms that the analytical methodology used to calculate the load carrying capacity and structural integrity of the leaking components is conservative.

Leaking components are removed and are non-destructively examined for the presence of any visual crack identifications (inside/outside surfaces). This Profile Examination (PE) is then followed by destructive examinations for: microstructure; degree of dealloying (percent dealloying through component cross section); percent of dealloying through-wall thickness; and chemical composition (including aluminum content). When sufficient material is available for the preparation of a test coupon, mechanical properties (ultimate strength, yield strength, and/or fracture toughness) are obtained. The PE results provide the physical, metallurgical and mechanical properties used to trend the progression of dealloying and to confirm the acceptability of using the existing correlation of observed OD crack angle as the means by which STP projects internal degradation.

Enclosure 2 provides the line-in/line-out revision to LRA Appendices A1.37 and B2.1.37.

Enclosure 3 provides the line-in/line-out revision to LRA Table A4-1 for LRA Commitments 39 and 44 and completed LRA Commitment 46.

Issue:

b) Subsequent to the public meeting conducted on August 27, 2012, the staff determined that an additional 14 PEs and 8 ACTs would be required to establish a reasonable basis that a susceptible component would be able to perform its intended function throughout the period of extended operation (PEO). The additional 14 PEs will result in a total of 22 PEs being conducted; including those conducted in 1994 (reference AES-C-1964-5, "Evaluation of the Significance of Dealloying and Subsurface Cracks on Flaw Evaluation Method"). The staff's position is that the ACTs should include a sufficiently wide range of component sizes and internal crack angles to validate the analytical methodology.

Specifically, a minimum of 3 component sizes, with 3 tests in each size, is recommended. The staff recognizes that a six-inch fitting was subjected to an ACT in 1994.

The number of tests described above is based on the test outcomes supporting current design documents, such as calculation output curves that provide the critical bending stress versus crack angle and the correlation of OD crack angle to internal degradation. If any of these tests do not support the pertinent design output documents, further testing will be required. This testing to establish reasonable assurance will have to be completed and submitted to the staff prior to issuance of the final SER.

The staff also believes that continuing confirmation testing will need to be conducted through the end of the PEO in order to either (a) demonstrate that the nature (e.g., plug-like versus layer-like) and rate of degradation continue as they have in the past and therefore can be managed by the program, or (b) demonstrate, through trending, the need to replace the susceptible components prior to signs of external leakage. In its consideration of this continuing testing, the staff noted the long period of time before the renewed license will expire, the importance of the essential cooling water system, and the fact that further degradation will continue to occur. The staff's position is that, for PEs, 100% of leaking components should be tested/inspected until the end of PEO. In regard to ACTs and following completion of the above-mentioned 9 ACTs, 20% of future leaking components should be tested until the end of PEO.

<u>Request:</u>

b) Amend the AMP, UFSAR Supplement, and Commitments to reflect the recommended number of continuing confirmation tests discussed above, or provide a statistical or engineering judgment basis for using an alternative number of tests.

<u>STP Response:</u>

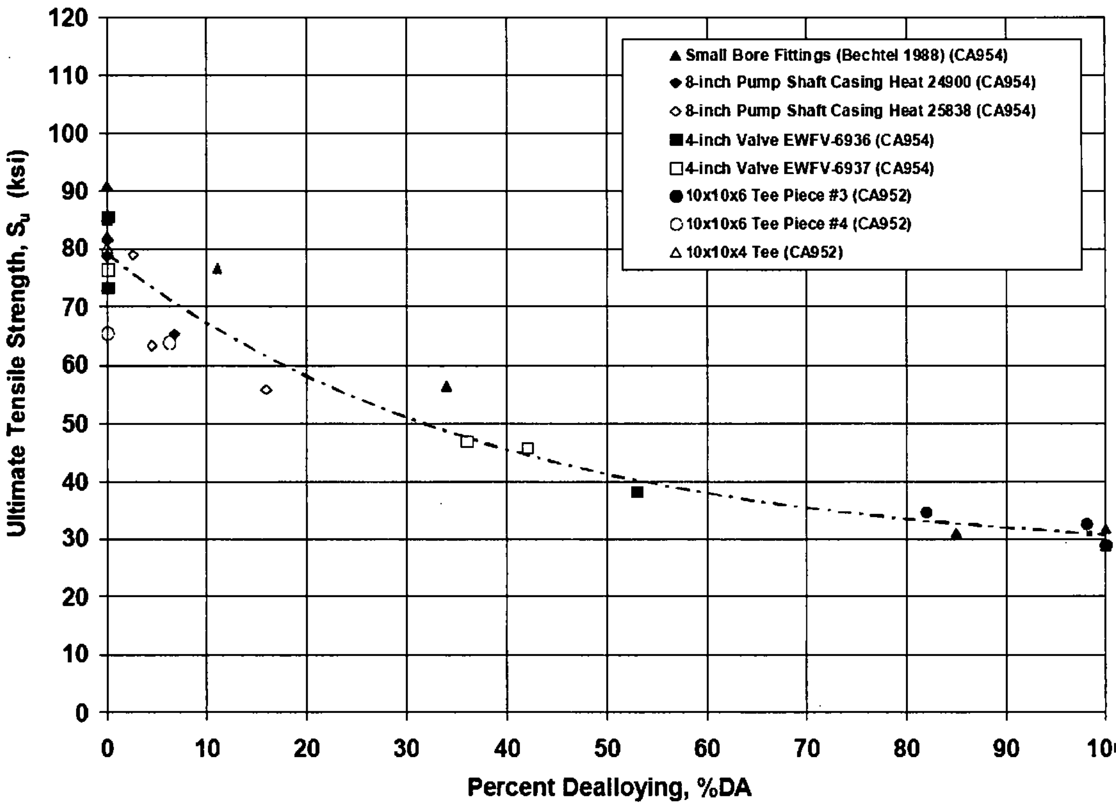
As of February 2014, STP has performed the following additional tests:

- STP has removed 18 in-service cast components that are likely candidates for dealloying. These components were selected because 1) the same component in another train had previously dealloyed; and 2) these components have higher potential to crack (stress considerations). STP did not identify any new leaking components or leaking valves, during this scope of work.
- One leaking flange, previously identified at ECW cross connect piping (ACTs and PEs performed)
- Twelve additional non-leaking components, selected based on a potential of finding dealloying (e.g., same component in a different train had dealloyed previously; located in stagnant flow region). The degree of dealloying on the 12 additional non-leaking components was determined to be insignificant based on 4 profile exams and visual exams of the inner and outer diameters.

- Performed 3 additional ACTs (total of 4 ACTs). These tests include: 2 - 4" valves, 1- 10" flange, and 1 - 6" flange (all tested in 1994).
- Performed 7 additional PE tests in 2013 (total of 15 PEs including 8 previous tests from 1994).
- Performed 15 additional tensile tests from recently removed components (total of 22 tensile tests including 7 previously conducted tests from 1994).
- Performed 14 additional Crack Tip Opening Displacement (CTOD) tests on the recently removed components (total of 18 fracture toughness tests including 4 previously conducted CTODs from 1994).

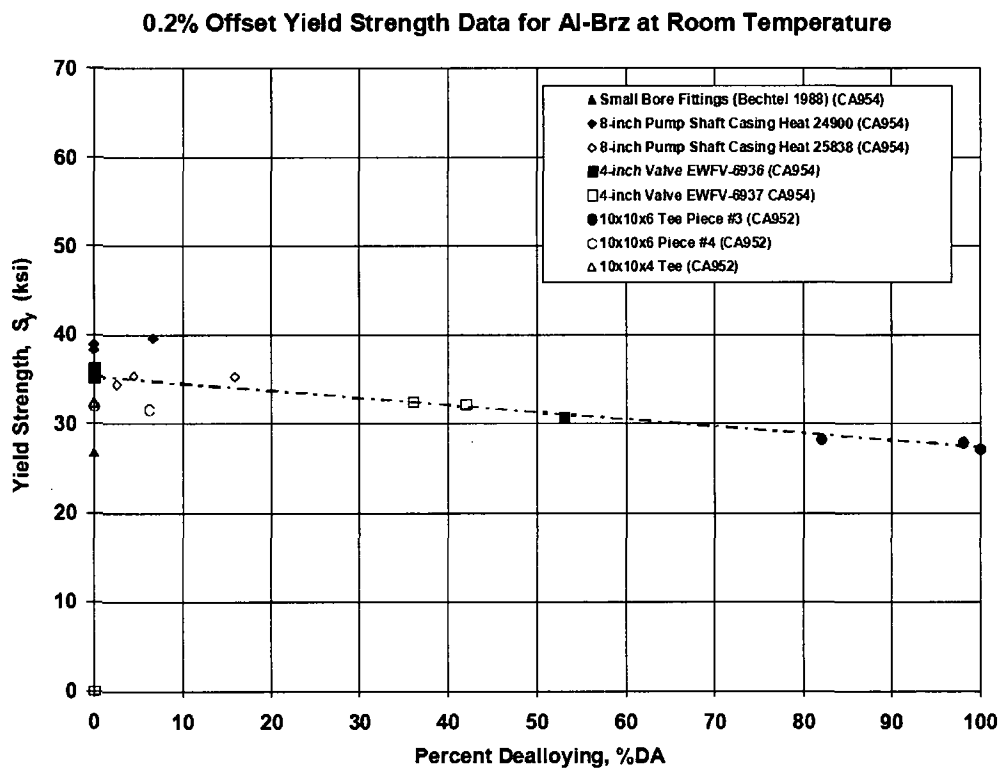
The following graphs display material properties (ultimate strength, yield strength, and fracture toughness), as trended from the above listed PE tests and pertinent STP observations.

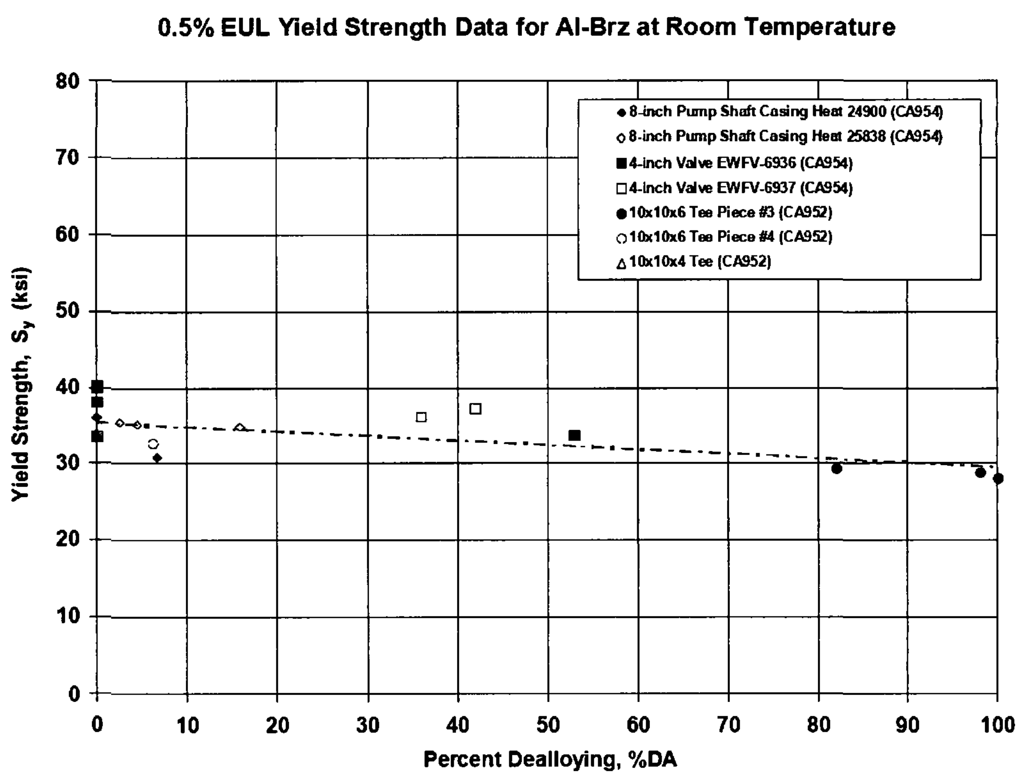
Ultimate Tensile Strength Data for Al-Brz Castings at Room Temperature



STP Observation:

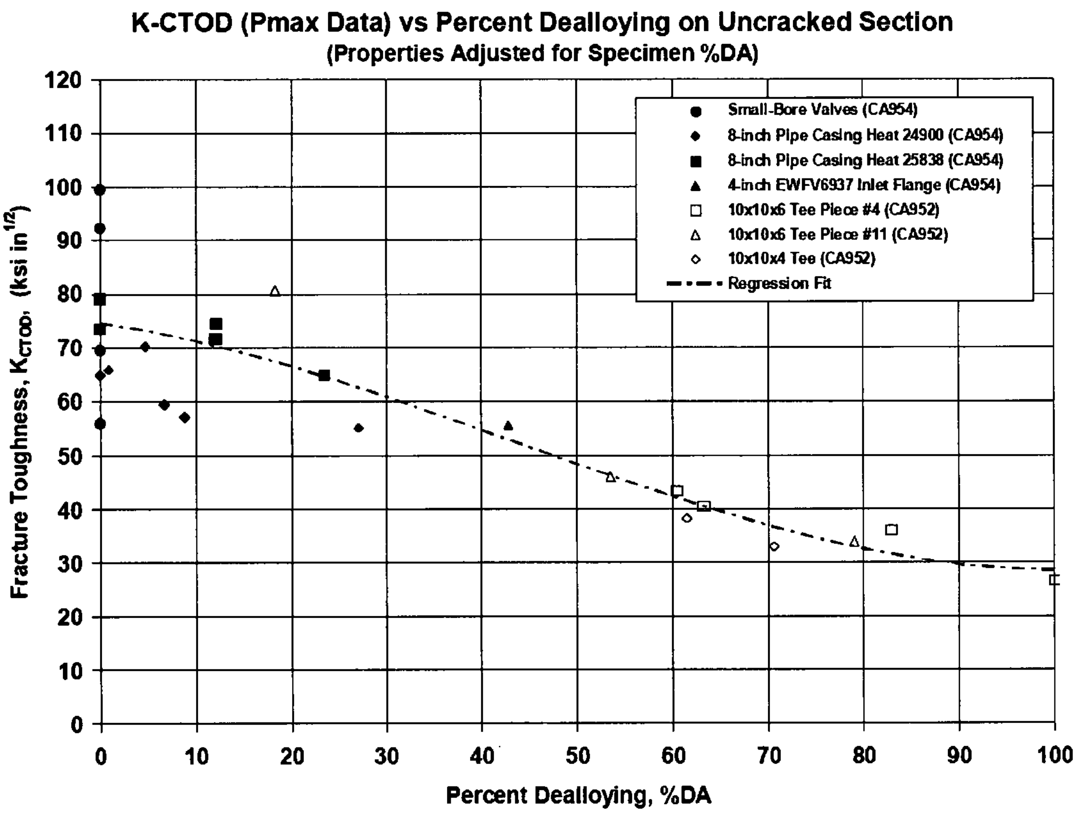
The reduction in material strength is consistent with the earlier work and shows an asymptotic limit of 30 ksi, based on the regression analysis of the test data. This is the same limit value assumed in the 1994 integrity assessment for the fully-dealloyed condition.





STP Observation:

The trend in yield strength (approximately 28 Ksi) has been established, and has been determined to be consistent with that of the ultimate strength.



STP Observation:

Fracture toughness of 65 ksi $in^{1/2}$ for undealloyed material, as assumed in the original integrity assessment, remains valid.

For each of above material properties (ultimate, yield, and fracture toughness), a regression analysis was performed that determined the empirical correlation between the property and dimensional degree of dealloying in the test specimen. The resulting correlations provide the following information:

1) Trending the mechanical properties for use in structural integrity calculations, and

2) The evaluation of the CTOD test data for establishing the trend in fracture toughness. The tested material properties can then be used to support operability evaluations based on average degree of dimensional dealloying.

Where the degree of dealloying is indeterminate, STP will use material properties equivalent to those that would be found if the component was, on average, 60% dealloyed. STP will continue adding test data, as it becomes available through destructive examinations, to update the material property charts and reassess the material properties against measured average degrees of dealloying.

Volumetric examinations and radiography of STP's leaking components has not identified a quantifiable boundary between dealloyed and undealloyed areas. This information is necessary to determine internal flaw sizes and characterize the dealloying flaws; therefore, determining the size (length) of a potential internal flaw requires a correlation between OD crack angle and

internal degradation. The determined internal flaw length is used to confirm structural integrity to reasonably ensure that the ECW system remains Operable. Note that the internal dealloying flaw lengths can only be verified by conducting destructive examinations of the components.

STP has proactively removed additional components using various risk ranking parameters and did not identify any dealloyed components suitable for ACTs and PEs. Based on experience, it is unlikely STP will find the number of susceptible components desired by the NRC until through-wall leakage is observed in the future. STP instead proposes an alternate that will establish a reasonable basis upon which there can be confidence in the ability of susceptible components to perform their intended functions throughout the period of extended operation (PEO):

- STP will continue to perform ACTs and PEs on all identified leaking components until the NRC recommended additional 8 ACTs and 14 PEs are completed.
- If no leaking components are identified, STP will remove two cast components of different sizes per unit during scheduled outages lasting more than 30 days. The component removal strategy will be to remove a minimum of 3 component sizes with 3 tests in each component size plus one randomly selected component throughout the testing phase of this process. This will continue until the NRC recommended additional 8 ACTs and 14 PEs are completed or total of 20 additional components are removed from service for additional testing.
- STP will perform PEs on all leaking components until the end of PEO.
- In regard to ACTs, following completion of the above mentioned 9 ACTs and 21 PEs, 20% of future leaking components will be tested until the end of PEO, unless results indicate a larger testing regiment is warranted.
- STP will continue updating material property regression graphs following the completion of the component PE where sufficient material was available to perform material properties testing.

The current collection of ACTs and PEs represents reasonable assurance that a susceptible component will perform its intended functions through the current license. This is based on:

1) Correlations used to determine internal crack sizes have remained valid for the recently removed components for which additional ACTs were performed.
2) Review of the recent ACTs, PEs, and additional material property evaluations support the original (1994) analysis and subsequent aging of the in-service material through 2013. The results of the ACTs (pressure and bending moment), to date, support the analytical methodology that determines components load carrying capacity is conservative and that the components have maintained their ASME code safety factors.
3) The analysis methodology conservatively treats through wall dealloyed flaws as potential cracks, even though not all dealloyed locations are cracked i.e. no surface separation has occurred.

The proposed duration of ACTs and PEs, from the end of the current license through the end of PEO, also represents a reasonable approach to manage the future aging effects. This is because testing provides for timely identification and a continuous evaluation of any emergent leaking components, thereby providing the means to ensure that any ongoing aging effects related to dealloying do not adversely affect metallurgical properties or challenge the validity of the associated correlations.

LRA Appendices A1.37 and B2.1.37; Commitments 39 and 44 in Table A4.1 and LRA Basis Document PSALBZ (B2.1.37) are revised to reflect:

- 100% of leaking components shall have PEs performed until the end of PEO.
- For ACTs, following completion of the above-mentioned 9 ACTs, 20% of all future leaking components shall be tested until the end of PEO.

Enclosure 2 provides the line-in/line-out revision to LRA Appendices A1.37 and B2.1.37.

Enclosure 3 provides the line-in/line-out revision to LRA Table A4-1 for LRA Commitments 39 and 44 and completed LRA Commitment 46.

Issue:

c) The RAI response did not address the minimum level of degradation (e.g., degree of dealloying) that a component must exhibit in order to be used as an ACT specimen. The degree of dealloying in a tested component must be sufficient so that its material properties (e.g., fracture toughness, yield strength) are representative of an advanced degree of dealloying. Therefore, some removed leaking components may not be acceptable specimens for validating the analytical methodology. An example would be a specimen that has a very narrow angle of through-wall dealloying and minimal layer-type dealloying around the circumference.

Request:

c) State and justify the minimum level of degradation that a component must exhibit in order to be used as an appropriate test specimen for ACTs.

STP Response:

The purpose of the ACT is to confirm that the analytical methodology conservatively predicts the load carrying capacity of leaking components removed from service. Any component that experiences leakage is an appropriate test specimen for the ACT. STP is not excluding any conditions from consideration, thus ensuring test results are relevant to all conditions.

Issue:

d) The response to RAI B2.1.37-4, Issue 3, "describe how the percentage of dealloying is identified when testing specimens," does not account for areas where dealloying has penetrated through-wall, but not progressed to completion (i.e., significant depletion of aluminum). While the AMP, UFSAR Supplement, and Commitments state that samples will be tested for chemical composition including aluminum, it is not clear how this data will be used in conjunction with determining the degree of dealloying.

There are many references to 100-percent dealloyed tensile properties throughout the analyses credited by the program. It is not clear to the staff that the tensile properties were obtained from specimens that were 100-percent dealloyed from both a dimensional (i.e., percent through-wall) and chemical composition basis (i.e., aluminum depletion).

Table 2.5, "Tensile Test results on Dealloyed Samples of CA-954 Material from Fittings," of ST-HL-AE-2748, "Failure Analysis and Structural Integrity of Leaking Small Bore Aluminum Bronze Cast Valve Bodies and Fittings in the ECW System," provides a compilation of test sample tensile values and the percent dealloyed. A footnote to the percent dealloyed column of this chart states, "based on SCM of tensile fracture surface." The staff does not know what "SCM" stands for, and no other criterion for the percent dealloyed values is stated in the document.

The staff believes that if the degraded components that are tested are not 100-percent dealloyed from both a dimensional and chemical composition basis, the material properties obtained from those tests may not represent the lowest possible values.

Therefore, the program needs to state how partially dealloyed material property results will be integrated into trending data.

Request:

d) State or provide the following:

- **a description of "SCM testing," as referenced in Table 2.5 of ST-HL-AE-2748, and what criteria were used to establish the percent dealloyed from this testing .**
- **a copy of any other testing results that correlate tensile properties to percent dealloying based on both a dimensional (i.e., percent through-wall) and chemical composition (i.e., aluminum depletion) basis, if available**
- **how the percentage of dealloying will be determined, from a dimensional and chemical composition basis, for testing that will be conducted in the future**
- **how partially dealloyed material properties will be integrated into trending data**

STP Response:

The documentation of the material properties test reports is available for NRC review. The summary of the test results and responses to specific requests are provided in the bulleted responses below.

Request:

- **a description of "SCM testing," as referenced in Table 2.5 of ST-HL-AE-2748, and what criteria were used to establish the percent dealloyed from this testing .**

STP Response:

The description of "SCM testing" is provided in a footnote to the percent dealloyed column (Table 2.5) of ST-HL-AE-2748. The footnote refers to 100 percent dealloyed tensile properties as being the tensile strength of a specimen for which sectional-area measurement (SCM) after break was observed to be 100 percent dealloyed from a dimensional aspect (i.e., percent through-wall). The description does not, in any manner, refer to chemical composition (i.e., aluminum depletion). The footnote implies, that out of all specimens tested, only two were found to have the entire cross sectional area dealloyed where the break occurred, while the other specimens had partial areas dealloyed. The percent dealloyed is the percentage of total area estimated as dealloyed area.

Request:

- **a copy of any other testing results that correlate tensile properties to percent dealloying based on both a dimensional (i.e., percent through-wall) and chemical composition (i.e., aluminum depletion) basis, if available**

STP Response:

STP is not aware of any documented tests that have correlated tensile strength to percent dealloying based on both a dimensional and chemical composition. Tensile tests are performed per ASTM E8-01, "Standard Test Methods for Tension Testing of Metallic Materials," American Society for Testing and Materials, Vol.3.01, (2001). The tensile strength is then correlated to dimensional degree of dealloying.

The Brookhaven National Laboratory has published a utility chemical analysis, documenting aluminum content in dealloyed materials. The chemical analysis was based on energy-dispersive spectroscopy (EDS), a semi-quantitative measurement that relied on spot sampling at the location of incident electron beam; therefore, the information was considered as qualitative, rather than quantitative. Due to spot sampling the depleted aluminum content may vary along the dealloying path because of potential variation of crystallization and corroding environment. For component integrity analysis it is more appropriate to use material strength properties of a composite section based on degree of dealloying across the cross section (dimensional dealloying) and not on chemical composition basis.

Request:

- **how the percentage of dealloying will be determined, from a dimensional and chemical composition basis, for testing that will be conducted in the future**

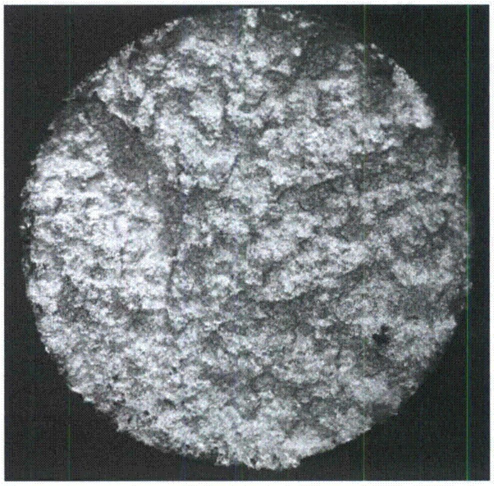
STP Response:

STP uses ASTM E1282-11 Standard Guide for Specifying the Chemical Compositions and Selecting Sampling Practices and Quantitative Analysis Methods for Metals, Ores, and Related Materials. STP records the following:

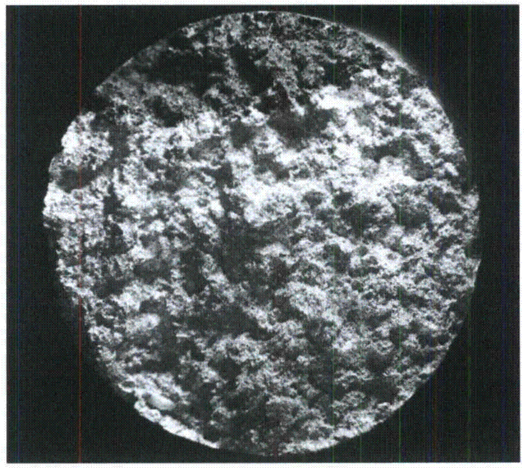
Dimensional Testing

1. The dimensional degree of dealloying is estimated as follows. The three different levels of dealloying associated with typical tensile fracture surfaces are visible by their reddish-brown color (shown below). The undealloyed area appears as the bright gold-tan region.
   The dealloying measurements were made by optical analysis of the fracture surfaces. The area of each region (dealloyed and undealloyed) was measured by digital analysis of the fracture surfaces (pixel counting). The percent dealloying (%DA) was calculated as the ratio of dealloyed area over the total area. These values are reported for each tensile specimen as percent dealloying (dimensional degree of dealloying). One hundred percent dealloying in the test specimen is when the full section at the fracture plane is dealloyed.

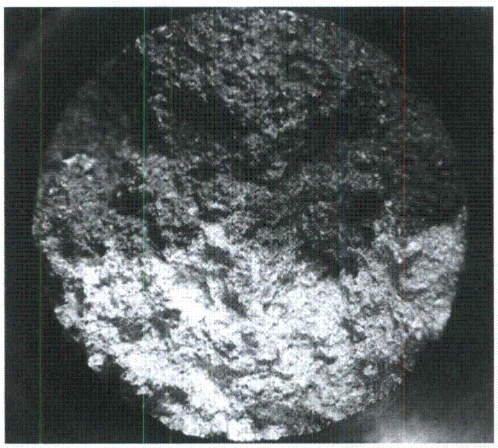
Fracture Surface Appearance for Various Amounts of Dealloying in 0.35-inch Diameter Tensile Bars



a) Negligible Dealloying



b) 15.9% Dealloying



c) 53% Dealloying

2. After completing the pixel counting activity, material strength properties (ksi) will be recorded and plotted on the y-axis; % dealloying (dimensional degree of dealloying) through component cross section will be plotted on the x-axis. Typical plots are shown in STP response ‘b’ above.

Chemical Testing

STP has tested some selected samples of fractured surfaces for aluminum content by percent (%) weight. These measurements are obtained by taking detailed surface area scans of 1 mm^2 in size along the linear traverses across the fracture surfaces using the Scanning Electron Microscope (SEM) and EDS. These scans included both dealloyed and undealloyed regions to obtain the distribution of Al, Fe, and Cu content within these regions.

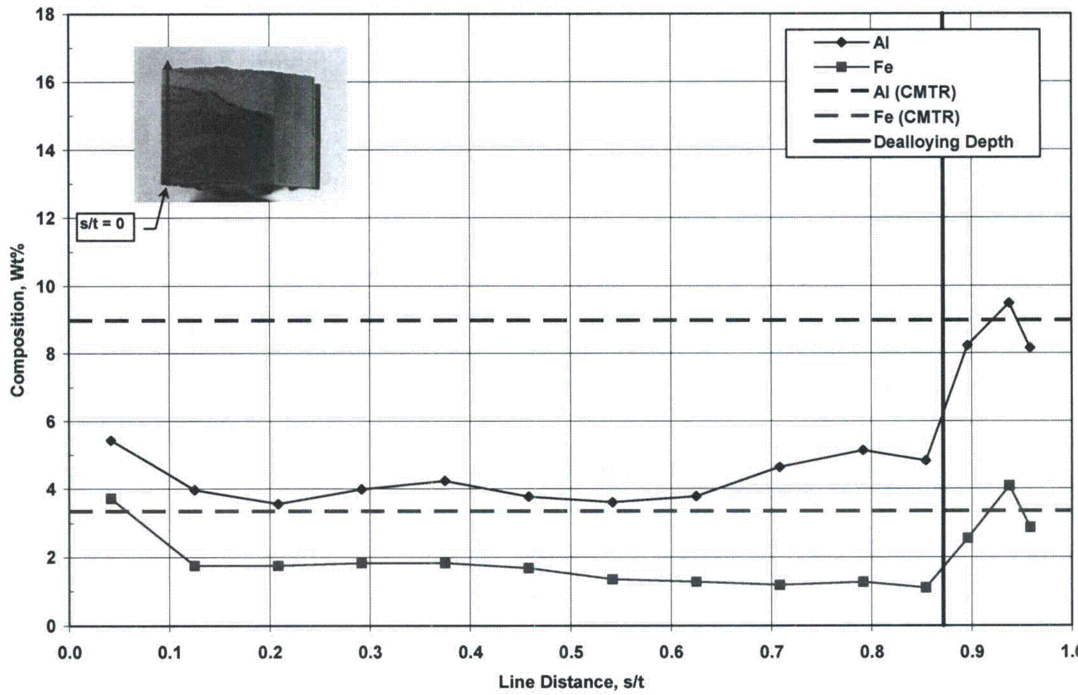
STP observed that the transition from dealloyed to undealloyed Al-Brz is sharp and distinct, and visible to the eye. It is evident from the figure below that the Al and Fe compositions along the fracture surface (Traverse 1) indicate a relatively uniform but reduced amount of both Al and Fe within the dealloyed region from the ID surface to the maximum depth of dealloying. Beyond that point, the compositions of Al and Fe exhibit a step increase in magnitude within the undealloyed Al-Brz material.

Similar surface scans on other samples have shown the same trend. Within the dealloyed region, the distribution of depleted AL and Fe content is relatively uniform across the dealloyed region returning to the bulk chemistry level a very short distance into the undealloyed region.

The uniform distribution behavior is observed through the thickness as well as cross-width of the samples. This indicates the fracture path is essentially fully dealloyed with respect to the loss in aluminum and iron of the transformed phases within the eutectoid. This supports STP's simple dimensional definition for the amount of dealloying for a given test specimen fracture section based on an area ratio bases.

STP observations indicate that not all aluminum will deplete as components age.

Surface Area Scan - Traverse 1
10x10x6-inch Tee CTOD Sample #11 Specimen SENB-2



Request:

- **how partially dealloyed material properties will be integrated into trending data**

STP Response:

STP is trending two yield strengths (0.2% Offset and 0.5% Elongation Under Load), ultimate strength, and fracture toughness for various degrees of dealloying.

A regression analysis has been performed to determine an empirical correlation between tensile properties and the fracture toughness with the amount of dealloying. The regression analyses also smoothed out scattered data to a trending curve (correlation). The extended trending curve is used to characterize the mechanical property in those instances where results from a physical test are not available.

Issue:

e) **While the revised AMP, Enhancements, UFSAR Supplement, and Commitments describe acceptance criteria for tensile, yield and fracture toughness properties, the RAI response does not describe specific follow-on actions that would be taken when abnormal test or inspection results are obtained, beyond stating that results would be trended, an engineering evaluation would be performed, or that the condition will be documented in the corrective action program. The acceptability of the Selective Leaching of Aluminum Bronze plant-specific AMP will be based upon (a) either empirical testing results or attainment of dealloyed material properties to be used in revised structural integrity analyses, and (b) the continuing demonstration of the ability to detect aging using external visual inspections prior to the degradation adversely impacting the ability of a susceptible component to perform its intended function. The staff notes the possibility that results of the tests and inspections could invalidate the analytical assumptions to such an extent that structural integrity could not be reasonably expected to be demonstrated for leaking components, or that an in-situ leaking fitting could be found that cannot be shown to meet structural integrity requirements. In the latter case, given that there are approximately 300 other susceptible components, it would be unreasonable to assume that only this component was not capable of meeting its intended function, and therefore the basis of the program (i.e., using external visual inspections to detect degradation prior to adversely impacting the ability of a susceptible component to perform its intended function) would be invalidated. The staff requires further details to understand what specific actions will be taken for the following outcomes:**

   - **During a PE or ACT, a crack or degree of dealloying is discovered outside of the current correlation as shown on page 12 of AES-C-1964-5. It is unclear to the staff whether a new correlation curve will be developed and whether existing leaking components will be reanalyzed with the new correlation. It is the staff's position that, given that the correlation of OD crack angle to projected internal degradation will have been demonstrated to be nonconservative, some additional fittings will need to be immediately examined, even though not leaking, to determine whether this was a one-off data point or whether there are many more susceptible fittings which have larger internal cracking or dealloying than would be projected from observing the through-wall indications on the OD.**

- **An ACT test result yields a data point below the size-appropriate acceptance curve (e.g., Figure 4-2, "Evaluation of Flange Bend Test Results," in AES-C-1964-5). It is unclear to the staff whether the analytical methodology will be revised to reflect the lower data point. For example, if it is suspected that the lower data point occurred because an appropriately low fracture toughness value was not used, it is unclear whether the fracture toughness value in the calculation would be decreased until the curve is sufficiently shifted. Also, it is unclear whether existing leaking components will be reanalyzed with the revised methodology. It is the staff's position that any existing leaking component should be considered not capable of performing its intended function until the cause of the discrepancy is understood, a new analysis curve is developed, and any existing degraded components are evaluated against the new analysis curve.**

- **The in-situ evaluation of a newly-discovered leaking fitting (i.e., the fitting has not yet been removed from service) results in a determination that the degraded component is not operable. It is the staff's position that such a result invalidates the effectiveness of the program, since the program is based on the capability of external visual examinations to manage aging prior to loss of intended function. Consequently, the staff believes that all susceptible fittings should be considered not capable of performing their intended functions until a revised technical basis is established or the components are repaired or replaced.**

- **PE or ACT results demonstrate a trend where, due to continuing dealloying, tensile strength, yield strength, or fracture toughness properties are projected to be below the acceptance criteria prior to the end of the PEO. It is the staff's position that the initial testing used to establish reasonable assurance and the continuing confirmatory testing can provide a timely projection of degraded mechanical properties, and all susceptible components should be repaired or replaced prior to the as-found properties or the as-trended properties fall below the acceptance criteria.**

- **PE or ACT results demonstrate that layer-type dealloying is becoming predominant over plug-type, such that it is no longer possible to project internal degradation based on external observations. The staff recognizes that there is some level of layer dealloying occurring in most fittings, as illustrated in Figure 3-1, "Typical Dealloying/Cracking Cross Sections," of AES-C-1964-5. However, the through-wall dealloying of the samples inspected in 1994 demonstrated a plug-like nature and a correlation of OD crack angle to internal degradation was able to be reasonably established. It is the staff's position that continued use of the correlation requires that a maximum percent of cross-sectional layer-type dealloying be established and justified as an acceptance criterion.**

- **PE or ACT results demonstrate that cracking has extended into the un-dealloyed region. AES-C-1964-5 sections 3.0, "Method of Approach," and 5.0, "Significance of Part-Through Cracks," assume that cracking does not extend into the un-dealloyed portion of a component.**

Although under this scenario the specific component that had cracking extending into the un-dealloyed portion would have already been replaced, anyone or more of the hundreds of susceptible fittings could potentially have cracking of this nature. It is the staff's position that all susceptible components should be considered not capable of performing their intended functions until the cause of the extended cracking is understood, a new analysis curve is developed, and the existing degraded components are evaluated against the new analysis curve.

Request:

e) For the following test or inspection result outcome examples, state what specific actions would be taken and the basis for those actions. Amend the AMP, UFSAR Supplement, and Commitments to state the specific actions for these examples:

- **During a PE or ACT, a crack or degree of dealloying is discovered outside of the current correlation as shown on page 12 of AES-C-1964-5, "Evaluation of the Significance of Dealloying and Subsurface Cracks on Flaw Evaluation Method," In responding to this scenario, include a statement of how many additional fittings will be immediately examined, even though not leaking, to determine whether this is a one-off data point or whether there are many more susceptible fittings which have larger internal cracking or dealloying than would be projected from observing the through-wall indications on the OD. If no additional fittings will be immediately examined, state the basis for not conducting this expansion of inspection scope.**

- **An ACT test result yields a data point below the size-appropriate acceptance curve (e.g., Figure 4-2, "Evaluation of Flange Bend Test Results," in AES-C-1964-5)**

- **The evaluation of a newly-discovered leaking fitting results in a determination that the degraded component would not have been operable (i.e., the local critical bending stress is too high as compared to the observed external crack or dealloying angle).**

- **PE or ACT results demonstrate a trend where, due to continuing dealloying, tensile strength, yield strength, or fracture toughness properties are projected to be below the acceptance criteria prior to the end of the PEO.**

- **PE or ACT results demonstrate that layer-type dealloying predominates over plug-type, such that it is no longer possible to project internal degradation based on external observations. In addition:**

i. State the step-by-step process an examiner will use, when conducting profile exams to determine the transition point between layer-type and plug-type dealloying and thereby derives the internal dealloying angle.

ii. State the acceptance criterion for the maximum percent of cross-sectional layer-type dealloying that will be allowed to occur within the use of the current methodology for determining the acceptability of a degraded component.

- **PE or ACT results demonstrate that cracking has extended into the un-dealloyed region.**

STP Response:

The following actions outline the proposed approach for the overall strategic actions for test or inspection results:

STP will reevaluate operability determinations of all leaking components left in service, thereby assuring their structural integrity. These determinations will use the established material strengths limits.

STP will assess extent of condition for each case by:

1) immediate walkdown of all ECW systems in both units for identifying leaking components;
2) increased frequency of monitoring based on severity of condition;
3) implement periodic walkdowns;
4) expanded scope of ACT and PE, and
5) schedule repair and replacement activities, based upon the risk significance of the component (but will not defer action beyond the next refueling outage into which it may be scheduled). The expanded scope for each case is further described under specific actions considering severity of conditions identified.

The NRC staff is concerned that previous RAI responses did not adequately describe specific follow-on actions that would be taken when test or inspection results outside of the acceptance criteria are obtained. Due to the uncertainties associated with such hypothetical cases, STP provided limited responses describing the process that would be followed (i.e., results trended; an engineering evaluation performed; the condition documented in the corrective action program; and perform a deficiency-specific "Operational Decision-Making Issue" (ODMI)). An ODMI provides a method to document decisions considered in the disposition and handling of conditions identified by the station. Subsequently, the staff has requested that STP not only describe process steps that would be taken, but also to describe the specific actions that STP anticipates implementing. The process that is common to all actions is described below and is followed by potential deficiency-specific actions that pertain to the staff-described scenarios.

Process for Results Outside of Acceptance Criteria

For all scenarios, STP will use its corrective action program. Every deficiency will require an immediate determination of operability, an assessment of the extent of condition, and the performance of an appropriate cause evaluation. Each activity will be conducted to assure that there is reasonable assurance that the station can continue to operate safety.

For all non-conforming ACTs and PEs conditions, STP will reevaluate the operability of all leaking components remaining in service; these re-evaluations will consider any new technical implications that are identified by the non-conforming test result. The overall structural integrity of ECW system and its ability to meet its intended design basis functions will be the primary criteria in these re-evaluations.

If structural integrity cannot be demonstrated, STP will either repair or replace affected components; in all instances, compliance with the STP Technical Specifications will be maintained.

Following are some of the typical steps that STP may implement as part of the ODMI.

- Document condition in Corrective Action Program. Where possible, include acceptance criteria and severity of condition (see specific details below for Staff described scenarios)
- Notify Control Room of identified condition(s)
- Perform an Immediate Operability Determination
- Enter Technical Specification, as required, if the ECW trains are determined to be inoperable
- Perform a Prompt Operability Determination, using assistance from the Engineering organization
- Implement immediate compensatory measures during any period of extended evaluation. Such measures could include:
  - o Operations would observe identified locations during each shift for potential leakages.
  - o System Engineers will immediately walk down all trains of the ECW system, in both units.
- Conduct an extent of condition evaluation and provide interim compensatory measures beyond those noted above, based upon the specific technical implications of the deficiency
- Develop a plan for long-term corrective actions that include changes to long-term ECW program and replacement of affected components.

STP would develop a deficiency-specific ODMI for these conditions, detailing specific steps, based on the severity and risk-significance of the conditions identified. Depending upon the severity (material conditions/ASME Safety Factors, potential impacts on plant safety, and risk significance), STP would remove additional components for further testing.

Request:

- **During a PE or ACT, a crack or degree of dealloying is discovered outside of the current correlation as shown on page 12 of AES-C-1964-5, "Evaluation of the Significance of Dealloying and Subsurface Cracks on Flaw Evaluation Method," In responding to this scenario, include a statement of how many additional fittings will be immediately examined, even though not leaking, to determine whether this is a one-off data point or whether there are many more susceptible fittings which have larger internal cracking or dealloying than would be projected from observing the through-wall indications on the (OD). If no additional fittings will be immediately examined, state the basis for not conducting this expansion of inspection scope.**

STP Response:

STP uses a correlation to size internal flaws/cracks that are not able to be measured using volumetric examinations. STP measures the internal flaw length following removal of the component during PEs and compares it to the estimated ID crack length as originally estimated using the correlation. The average crack length is determined by averaging the measured outside and inside diameter lengths.

Acceptance Criteria:

1. Load Carrying Capacity: ACT results results show a higher load capacity than the predicted load carrying capacity.
2. Determination of ID Crack Length: The measured ID crack length is less than 110% of correlation estimated ID crack length.

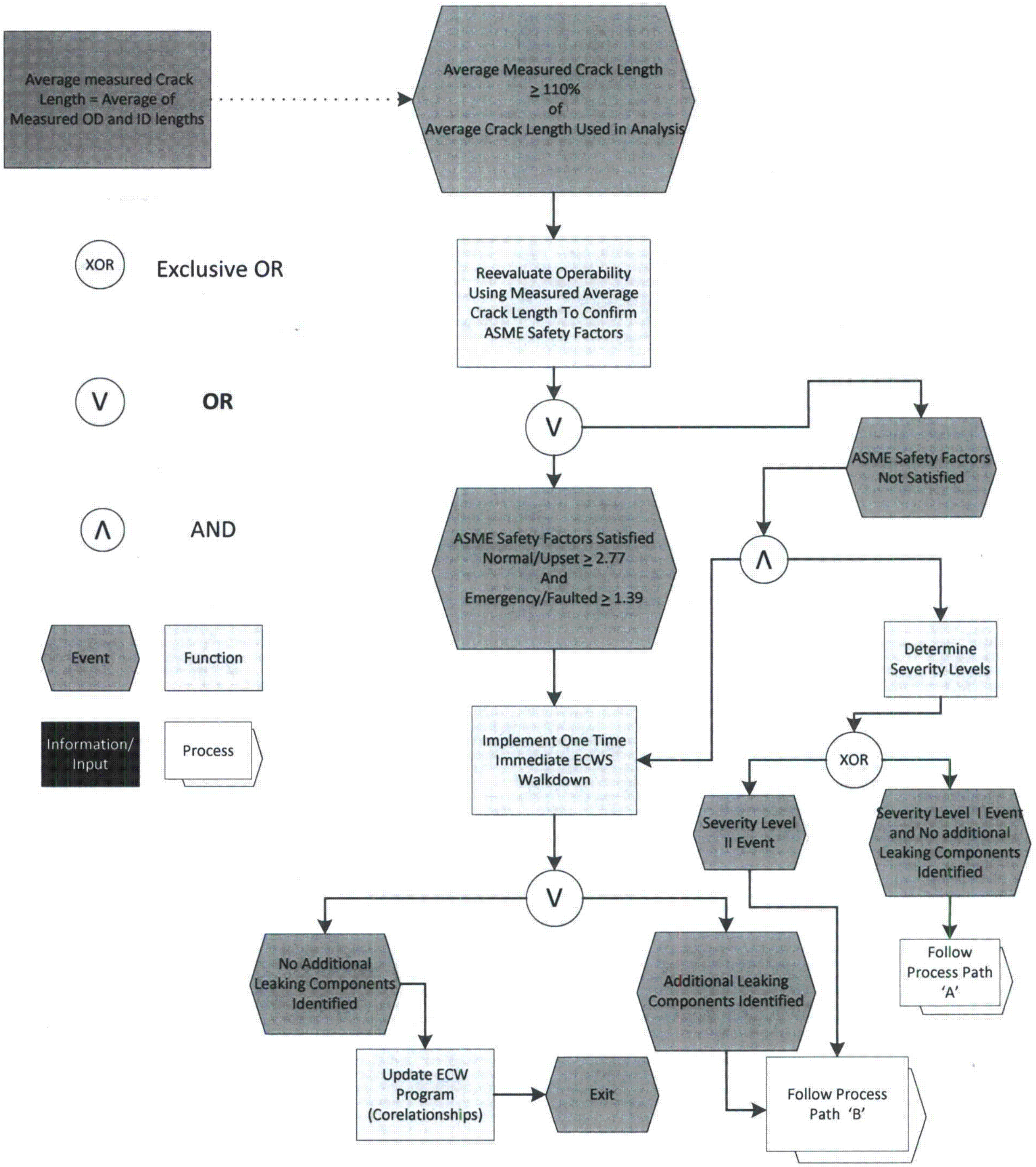
If acceptance criterion are not met, the severity of the condition will be determined.

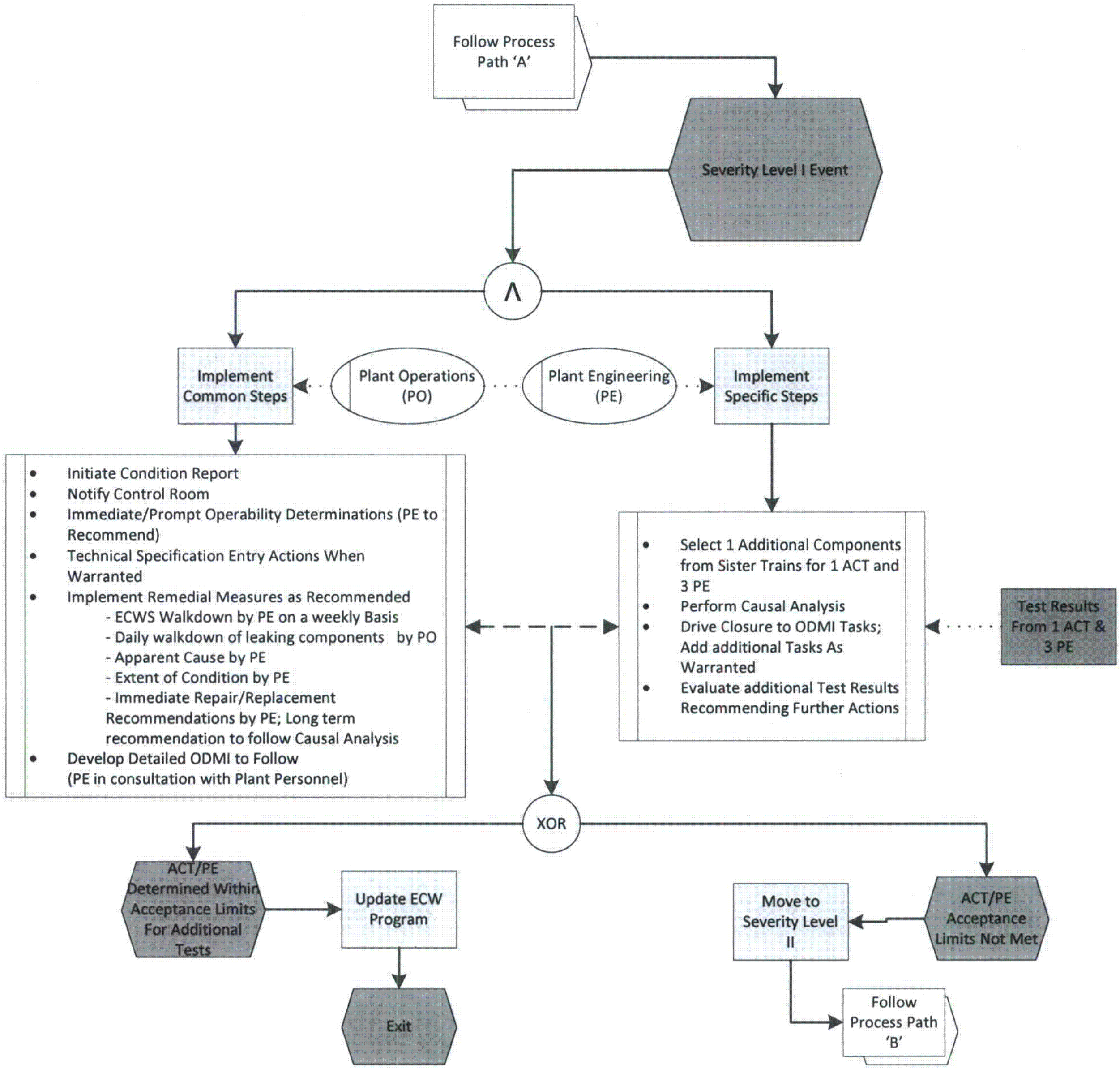
Severity of Condition:

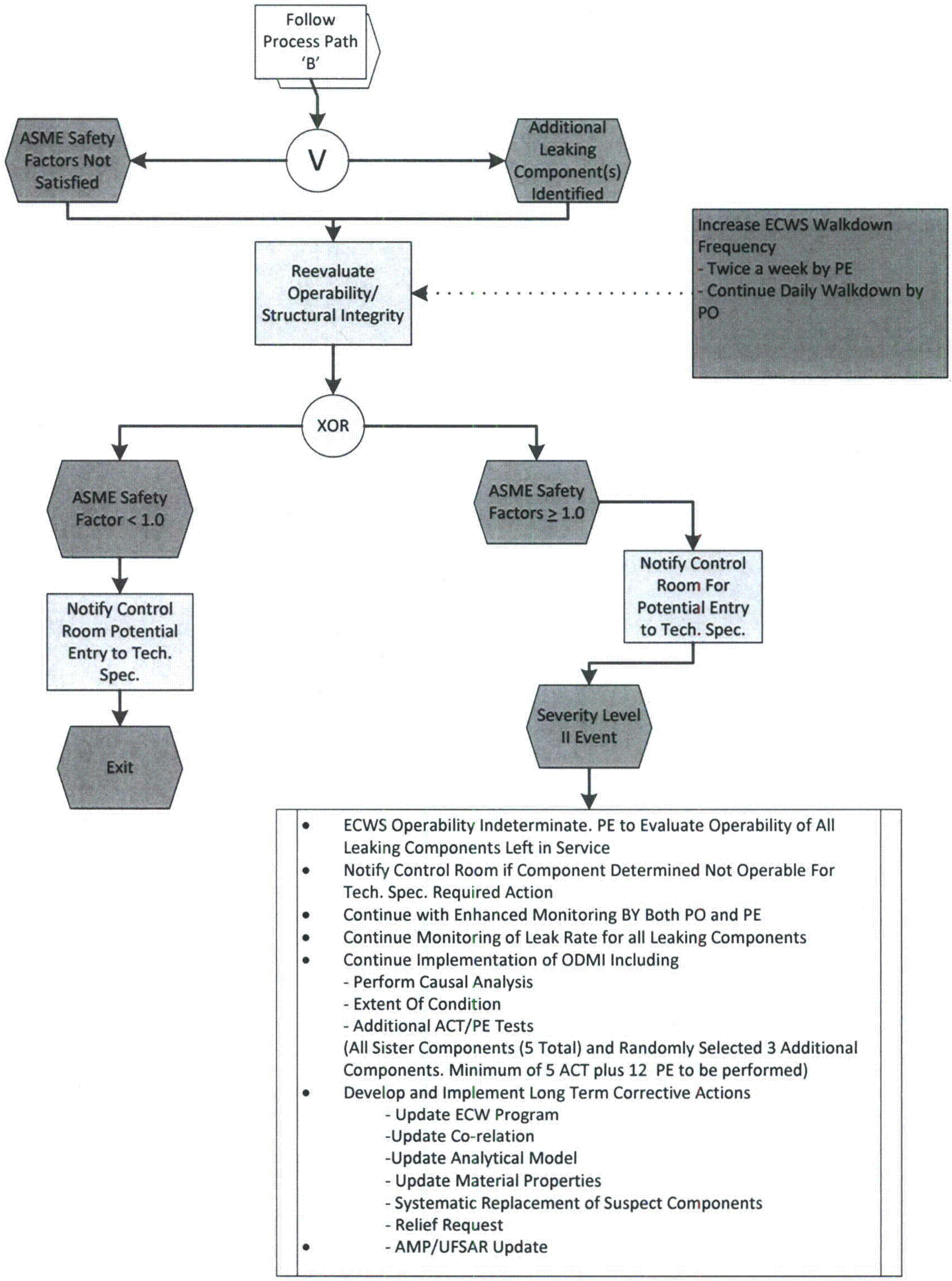
The following ASME Section XI Appendix H or C safety factors determine severity levels. The safety factors are recalculated using the average crack length to determine severity.

Severity Level	**Normal/Upset Condition**	**Emergency /Faulted Condition**	**Number of Additional Tests**
II	SF ≤ 1.5	SF ≤ 1.2	2 ACTs on sister component from remaining trains 5 PEs
I	SF > 1.5 and SF < 2.77	SF > 1.2 and SF < 1.39	1 ACTs 3 PEs

If the recalculated safety factors are within the ASME Code allowed limits, no additional actions are required other than precautionary actions intended to address the extent of condition as shown in the following Decision Flowcharts.


Average measured Crack Length = Average of Measured OD and ID lengths
Average Measured Crack Length ≥ 110% of Average Crack Length Used in Analysis
XOR
Exclusive OR
Reevaluate Operability Using Measured Average Crack Length To Confirm ASME Safety Factors
V
OR
ASME Safety Factors Not Satisfied
Λ
AND
ASME Safety Factors Satisfied Normal/Upset ≥ 2.77 And Emergency/Faulted ≥ 1.39
Determine Severity Levels
Event
Function
Information/ Input
Process
Implement One Time Immediate ECWS Walkdown
XOR
Severity Level II Event
Severity Level I Event and No additional Leaking Components Identified
No Additional Leaking Components Identified
Additional Leaking Components Identified
Follow Process Path 'A'
Update ECW Program (Corelationships)
Exit
Follow Process Path 'B'


Follow Process Path 'A'
Severity Level I Event
Λ
Implement Common Steps
Plant Operations (PO)
Plant Engineering (PE)
Implement Specific Steps
• Initiate Condition Report
• Notify Control Room
• Immediate/Prompt Operability Determinations (PE to Recommend)
• Technical Specification Entry Actions When Warranted
• Implement Remedial Measures as Recommended
- ECWS Walkdown by PE on a weekly Basis
- Daily walkdown of leaking components by PO
- Apparent Cause by PE
- Extent of Condition by PE
- Immediate Repair/Replacement Recommendations by PE; Long term recommendation to follow Causal Analysis
• Develop Detailed ODMI to Follow (PE in consultation with Plant Personnel)
• Select 1 Additional Components from Sister Trains for 1 ACT and 3 PE
• Perform Causal Analysis
• Drive Closure to ODMI Tasks; Add additional Tasks As Warranted
• Evaluate additional Test Results Recommending Further Actions
Test Results From 1 ACT & 3 PE
XOR
ACT/PE Determined Within Acceptance Limits For Additional Tests
Update ECW Program
Exit
Move to Severity Level II
ACT/PE Acceptance Limits Not Met
Follow Process Path 'B'


Follow Process Path 'B'
V
ASME Safety Factors Not Satisfied
Additional Leaking Component(s) Identified
Reevaluate Operability/ Structural Integrity
Increase ECWS Walkdown Frequency
- Twice a week by PE
- Continue Daily Walkdown by PO
XOR
ASME Safety Factor < 1.0
ASME Safety Factors ≥ 1.0
Notify Control Room Potential Entry to Tech. Spec.
Notify Control Room For Potential Entry to Tech. Spec.
Exit
Severity Level II Event
• ECWS Operability Indeterminate. PE to Evaluate Operability of All Leaking Components Left in Service
• Notify Control Room if Component Determined Not Operable For Tech. Spec. Required Action
• Continue with Enhanced Monitoring BY Both PO and PE
• Continue Monitoring of Leak Rate for all Leaking Components
• Continue Implementation of ODMI Including
- Perform Causal Analysis
- Extent Of Condition
- Additional ACT/PE Tests
(All Sister Components (5 Total) and Randomly Selected 3 Additional Components. Minimum of 5 ACT plus 12 PE to be performed)
• Develop and Implement Long Term Corrective Actions
- Update ECW Program
-Update Co-relation
-Update Analytical Model
- Update Material Properties
- Systematic Replacement of Suspect Components
- Relief Request
• - AMP/UFSAR Update

Request:

- **An ACT test result yields a data point below the size-appropriate acceptance curve (e.g., Figure 4-2, "Evaluation of Flange Bend Test Results," in AES-C-1964-5)**

STP Response:

An ACT data point below the size-appropriate acceptance curve suggests either analytical methods over-predict the load carrying capacity or factors other than dealloying affect test results. STP will perform a causal analyses to determine why the ACT yielded a data point below the size-appropriate curve. STP will develop an ODMI with specific actions based on severity of identified conditions. Additional ACTs and PEs may be required to determine if reduced material strengths or the fracture toughness appear to be the cause. The sister components and one randomly selected component from the affected train (total of 6 additional components) will be tested. Additionally, STP will reevaluate operability determinations of all leaking components still in service.

Acceptance Criteria:

- The ACT pressure ≥ hydro test pressure (125% of Design Pressure ~ 150 psi)
- Bending load ≥ 125% of applied loads (unintensified Eq. 9D ASME code stresses)

Severity of Condition:

The below listed criteria determines the severity levels.

Severity Level	**Criteria**	**Number of Components to be Tested**
II	The ACT pressure ≤ hydro test pressure (125% of Design Pressure ~ 150 psi) **and** Bending load ≤ 125% of applied loads (unintensified Eq. 9D stresses	5 ACTs sister component from remaining trains 1 ACT randomly selected component from affected train 8 PEs
I	The ACT pressure ≤ hydro test pressure (125% of Design Pressure ~ 150 psi) **or** Bending load ≤ 125% of applied loads (unintensified Eq. 9D stresses	3 ACTs 5 PEs

Specific remedial measures are based on severity as recommended by the following Decision Flowcharts.

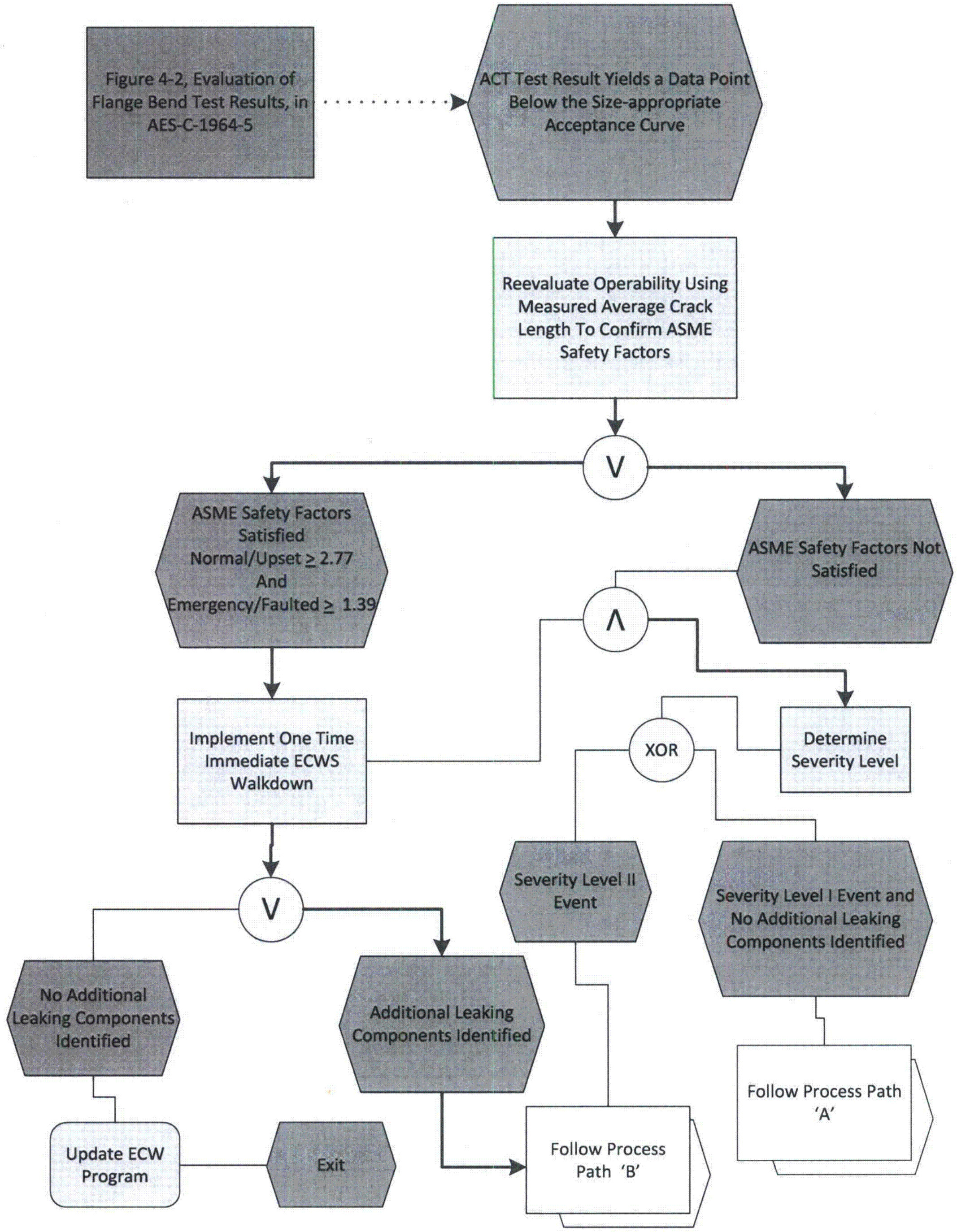
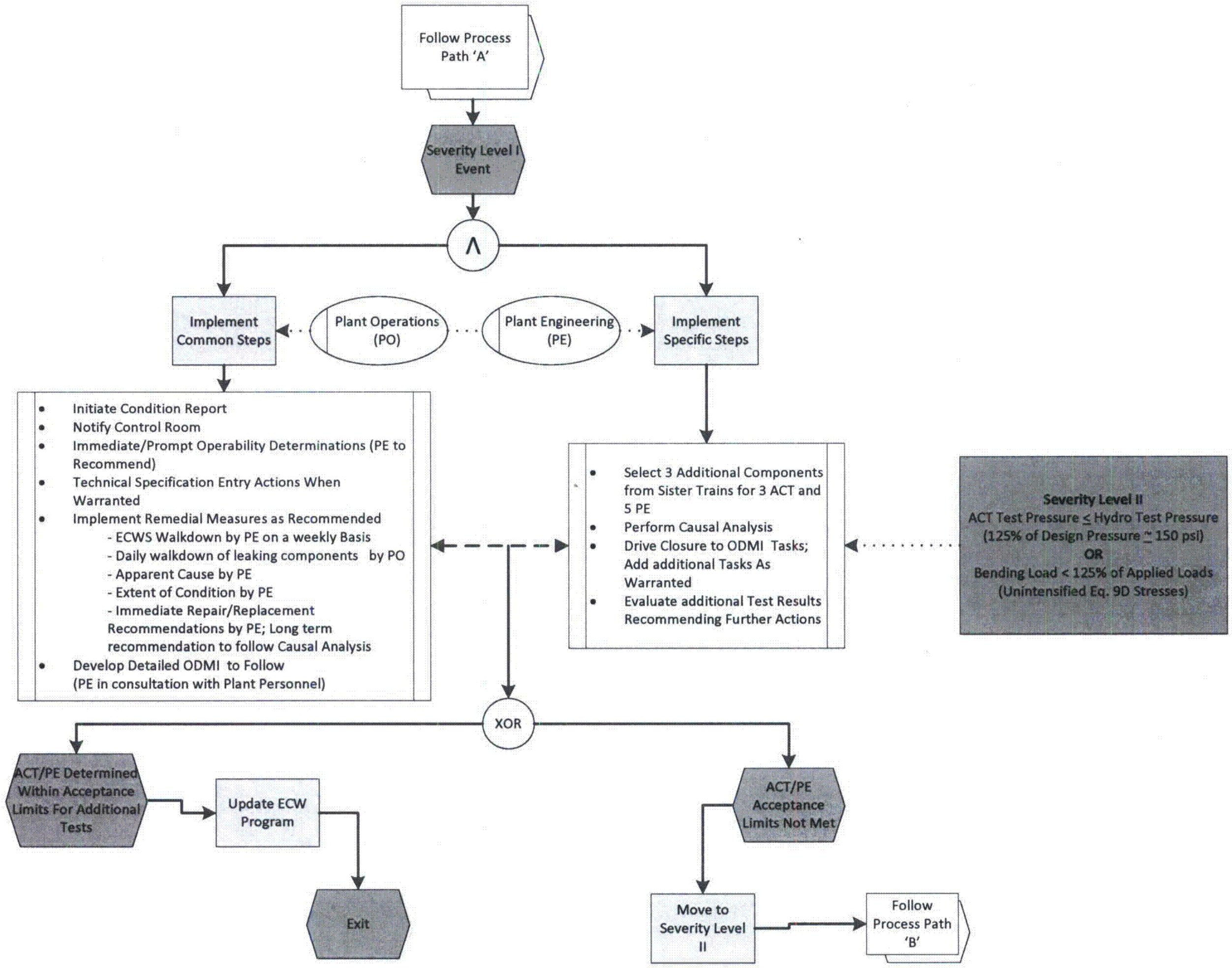
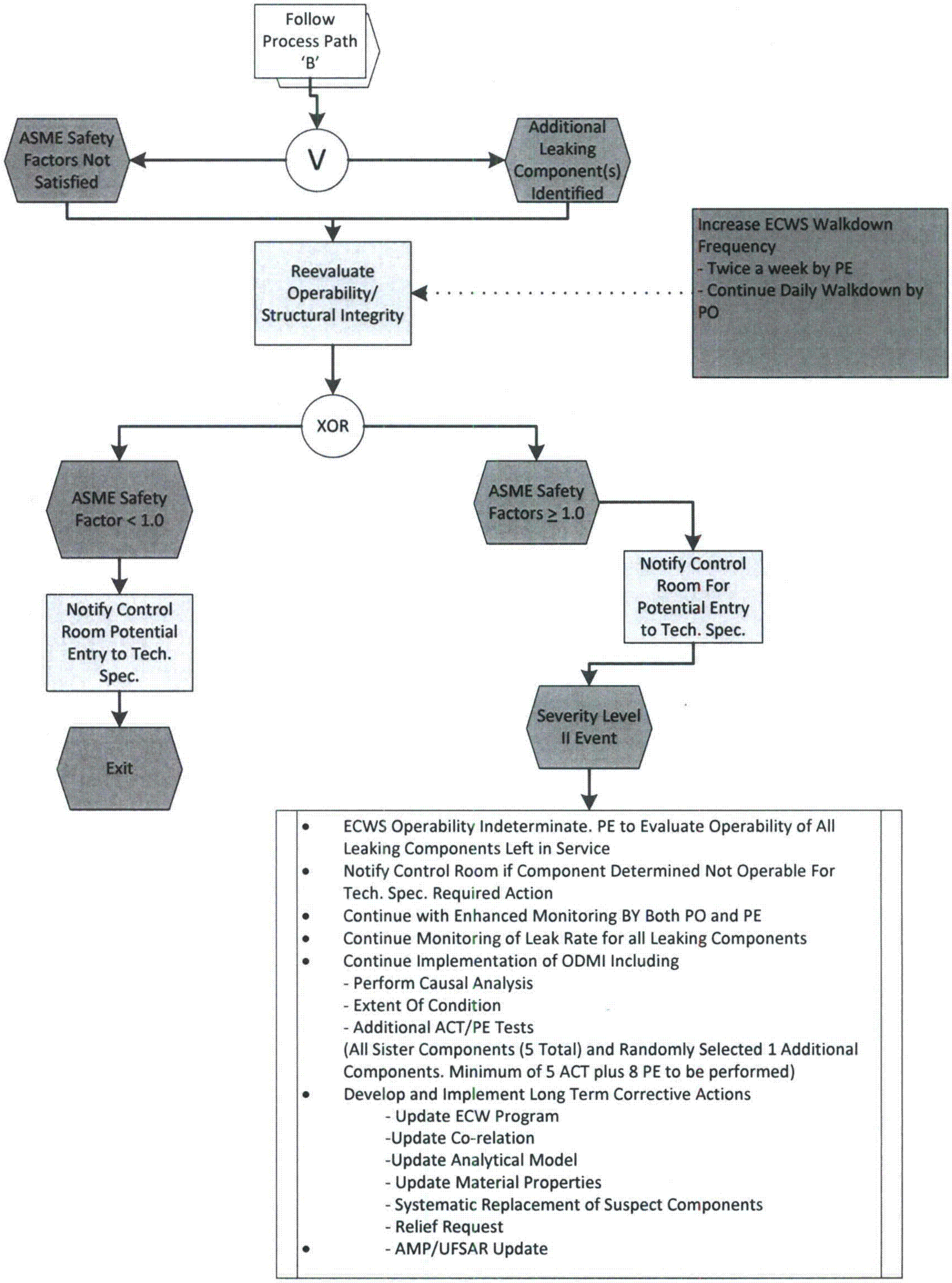


Figure 4-2, Evaluation of Flange Bend Test Results, in AES-C-1964-5
ACT Test Result Yields a Data Point Below the Size-appropriate Acceptance Curve
Reevaluate Operability Using Measured Average Crack Length To Confirm ASME Safety Factors
V
ASME Safety Factors Satisfied Normal/Upset ≥ 2.77 And Emergency/Faulted ≥ 1.39
ASME Safety Factors Not Satisfied
Λ
Implement One Time Immediate ECWS Walkdown
Determine Severity Level
XOR
Severity Level II Event
Severity Level I Event and No Additional Leaking Components Identified
V
No Additional Leaking Components Identified
Additional Leaking Components Identified
Follow Process Path 'A'
Update ECW Program
Exit
Follow Process Path 'B'


Follow Process Path 'A'
Severity Level I Event
Λ
Implement Common Steps
Plant Operations (PO)
Plant Engineering (PE)
Implement Specific Steps
• Initiate Condition Report
• Notify Control Room
• Immediate/Prompt Operability Determinations (PE to Recommend)
• Technical Specification Entry Actions When Warranted
• Implement Remedial Measures as Recommended
- ECWS Walkdown by PE on a weekly Basis
- Daily walkdown of leaking components by PO
- Apparent Cause by PE
- Extent of Condition by PE
- Immediate Repair/Replacement Recommendations by PE; Long term recommendation to follow Causal Analysis
• Develop Detailed ODMI to Follow (PE in consultation with Plant Personnel)
• Select 3 Additional Components from Sister Trains for 3 ACT and 5 PE
• Perform Causal Analysis
• Drive Closure to ODMI Tasks; Add additional Tasks As Warranted
• Evaluate additional Test Results Recommending Further Actions
Severity Level II
ACT Test Pressure ≤ Hydro Test Pressure
(125% of Design Pressure ~ 150 psi)
OR
Bending Load < 125% of Applied Loads
(Unintensified Eq. 9D Stresses)
XOR
ACT/PE Determined Within Acceptance Limits For Additional Tests
Update ECW Program
Exit
ACT/PE Acceptance Limits Not Met
Move to Severity Level II
Follow Process Path 'B'


Follow Process Path 'B'
V
ASME Safety Factors Not Satisfied
Additional Leaking Component(s) Identified
Reevaluate Operability/ Structural Integrity
Increase ECWS Walkdown Frequency
- Twice a week by PE
- Continue Daily Walkdown by PO
XOR
ASME Safety Factor < 1.0
Notify Control Room Potential Entry to Tech. Spec.
Exit
ASME Safety Factors ≥ 1.0
Notify Control Room For Potential Entry to Tech. Spec.
Severity Level II Event
• ECWS Operability Indeterminate. PE to Evaluate Operability of All Leaking Components Left in Service
• Notify Control Room if Component Determined Not Operable For Tech. Spec. Required Action
• Continue with Enhanced Monitoring BY Both PO and PE
• Continue Monitoring of Leak Rate for all Leaking Components
• Continue Implementation of ODMI Including
- Perform Causal Analysis
- Extent Of Condition
- Additional ACT/PE Tests
(All Sister Components (5 Total) and Randomly Selected 1 Additional Components. Minimum of 5 ACT plus 8 PE to be performed)
• Develop and Implement Long Term Corrective Actions
- Update ECW Program
-Update Co-relation
-Update Analytical Model
- Update Material Properties
- Systematic Replacement of Suspect Components
- Relief Request
• - AMP/UFSAR Update

Request:

- **The evaluation of a newly-discovered leaking fitting results in a determination that the degraded component would not have been operable (i.e., the local critical bending stress is too high as compared to the observed external crack or dealloying angle).**

STP Response:

The structural integrity of the ECW system provides a safety-related design basis functions that is paramount for the safe continued operation of both STP units. If structural integrity cannot be demonstrated, STP will either repair or replace affected components.

Request:

- **PE or ACT results demonstrate a trend where, due to continuing dealloying, tensile strength, yield strength, or fracture toughness properties are projected to be below the acceptance criteria prior to the end of the PEO.**

STP Response:

STP will monitor material properties of Aluminum Bronze coponents to ensure that they do not fall below the acceptance criteria prior to the end of the PEO, and will be trending these properties through the use of PEs. The PE data from all leaking dealloyed components will be added to the trend projection curves using a regression methodology. The magnitude of adverse trend is measurable and the updated properties will be used to estimate structural integrity of those affected components.

STP will monitor adverse trends and implement corrective measures (including replacement of affected components) before structural integrity of the ECW system is challenged. These measures include the following:

- Engineering evaluation of the remaining components determined to be at risk,
- Enhanced monitoring and non-destructive /or destructive examinations program,
- Perform additional ACTs and PEs performed (approximately 5 ACTs and 18 PEs),
- Updated critical bending stress curves found in AES-C-1964-1,
- Systematic replacement of components determined to be at risk,
- PSALBZ "ECW Aging Management Program" reviewed and updated to incorporate resulting information, and
- Notification to the NRC of pertinent changes to ECW program.

Criteria Defining Adverse Trend:

A decrease of 100% dealloyed material strengths and fracture toughness by 15% will be considered an adverse trend. The 15% is selected because the estimated variation of yield strength from mean (based on 0.2% yield strength test data) is approximately 4.1 ksi. which is equivalent to 15% of the lowest measured material strength.

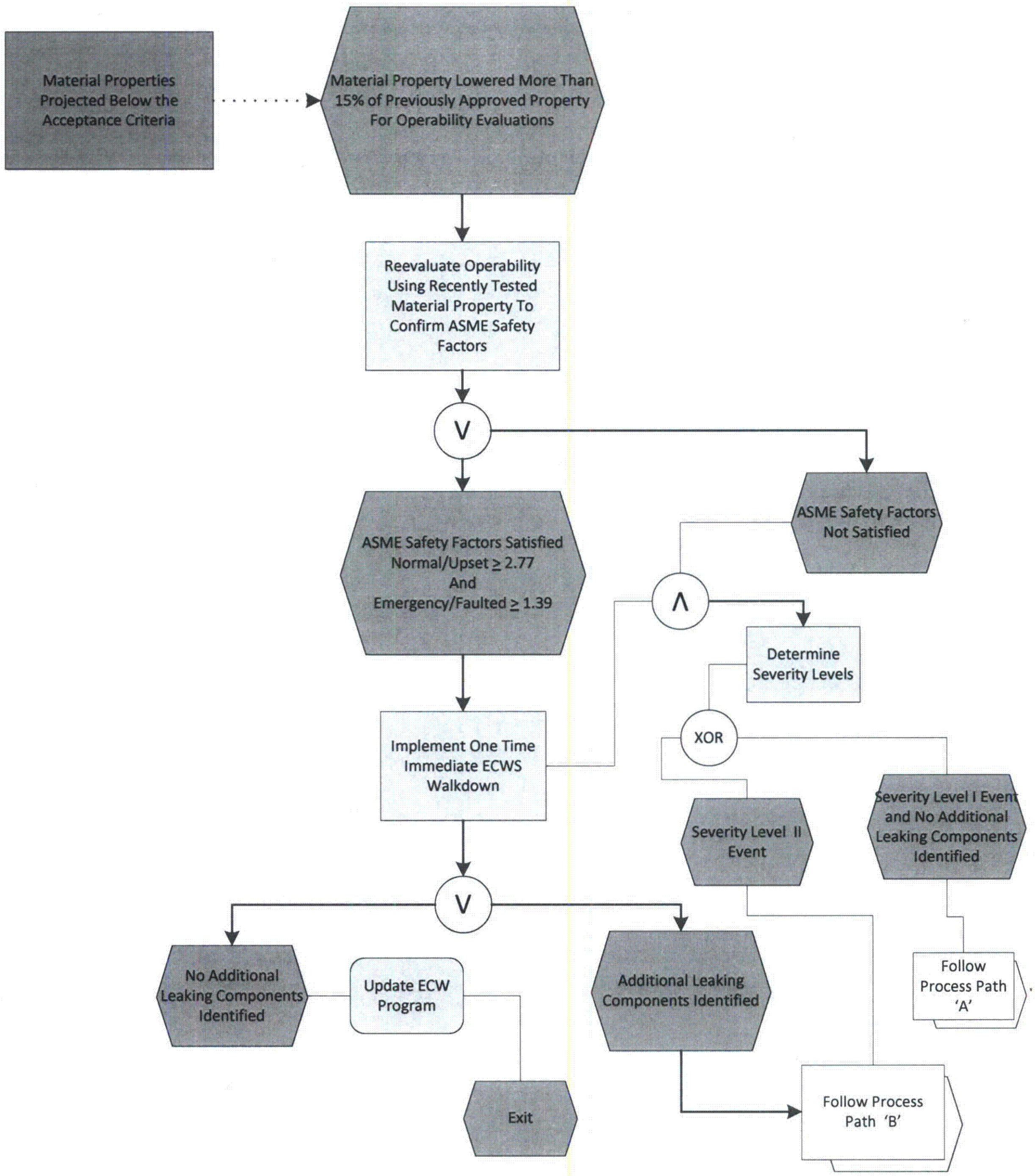
Number of components to be tested:

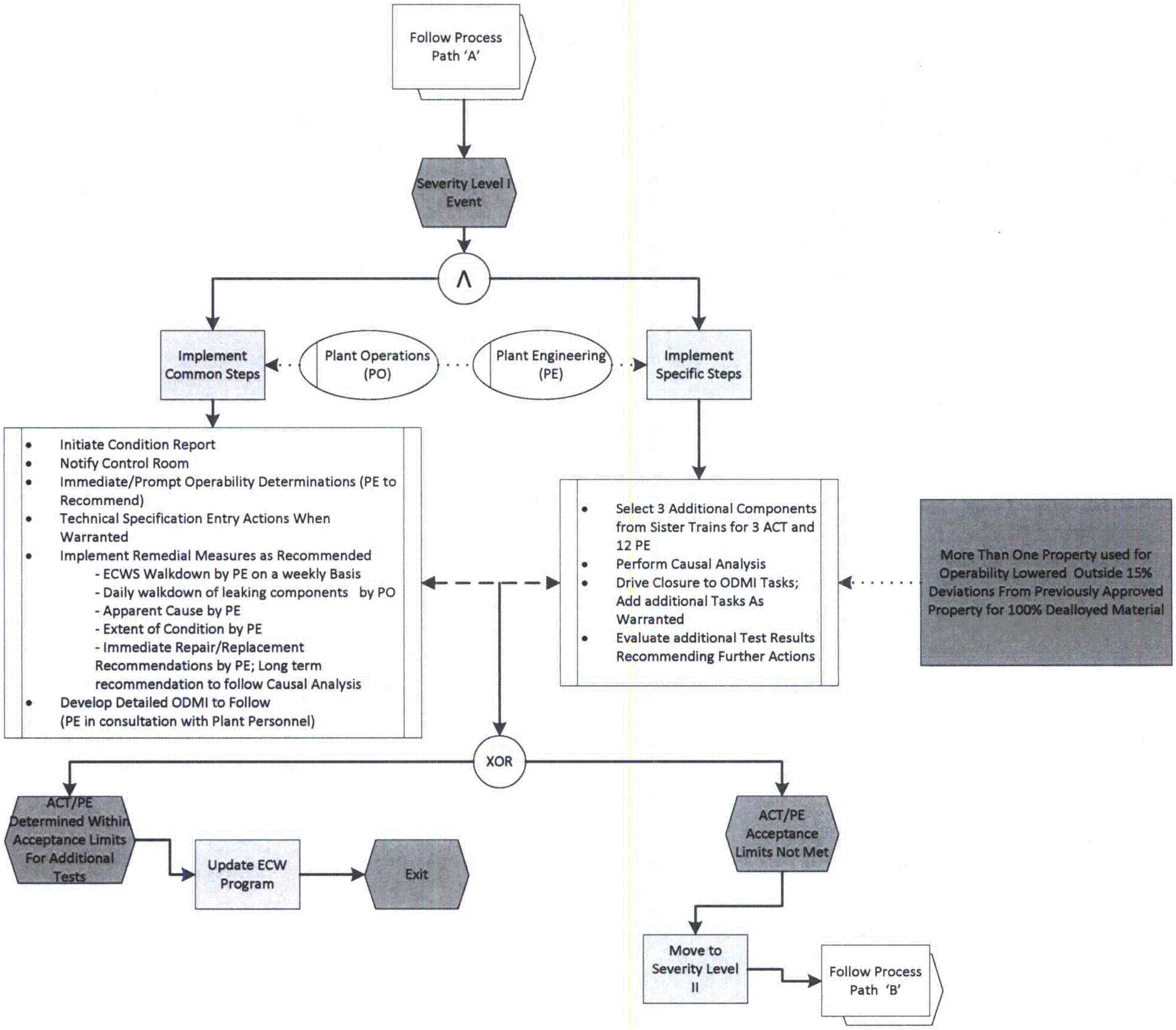
3 ACTs and 12 PEs from randomly selected components will be performed. If these tests demonstrate an adverse trend, an additional 5 ACTs and 18 PEs will be performed.

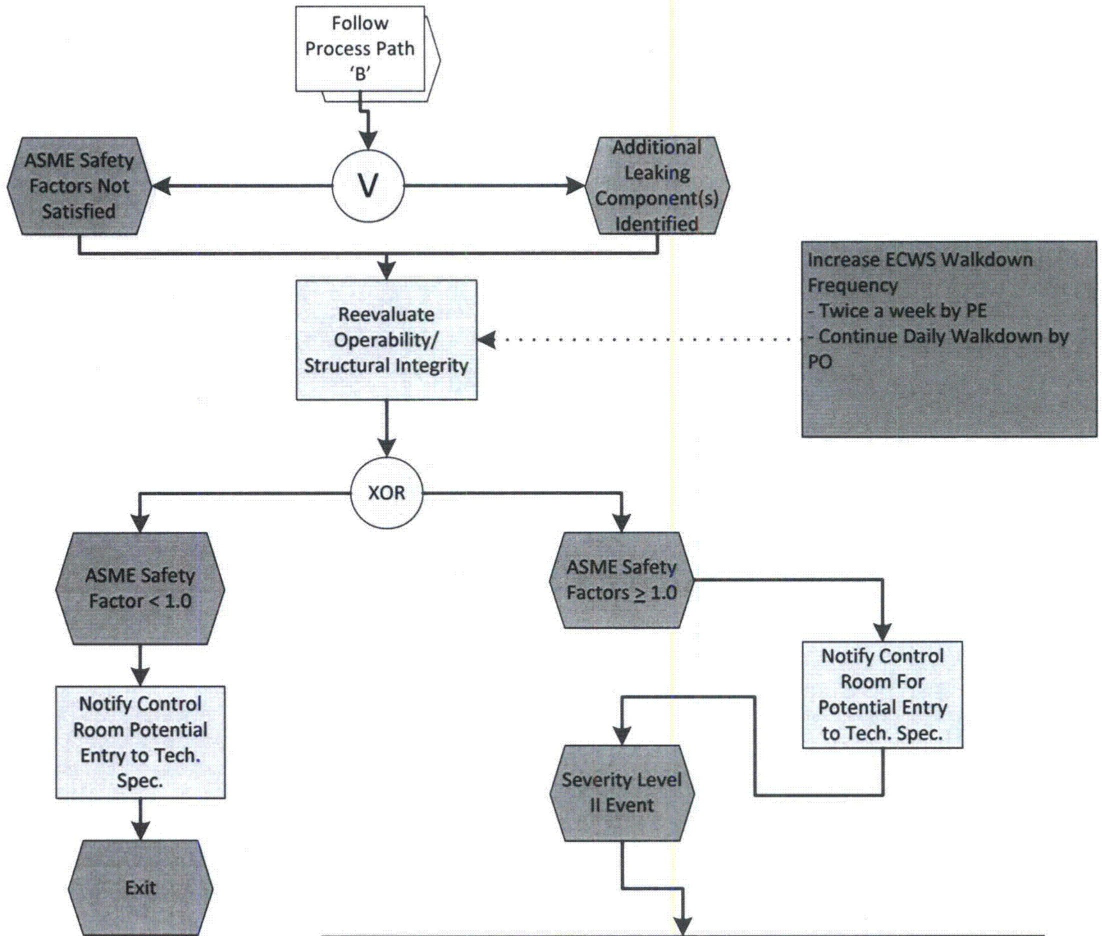
Severity of Condition:
The deviation in the post-test material properties will determine severity levels.

Severity Level	Acceptance Criteria	Number of Components to be Tested	Probable Actions
II	Continued deviation more than 15% from previously measured properties (from severity I tests) for 100% dealloyed material	5 ACTs and 18 PEs randomly selected component from affected train	- Enter Technical Specification. - Notify Control Room. - Seek temporary relief from the NRC for continued operation until root cause can be determined
I	More than 15% deviation from previously measured properties for 100% dealloyed material	3 ACTs 12 PEs	- Enter Technical Specification. - Notify Control Room. - Seek temporary relief from the NRC for continued operation until root cause can be determined. - Additionally tests are required to confirm potential entry to Severity Level II

Specific remedial measures are based on severity as recommended by the following Decision Flowchart.


Material Properties Projected Below the Acceptance Criteria
Material Property Lowered More Than 15% of Previously Approved Property For Operability Evaluations
Reevaluate Operability Using Recently Tested Material Property To Confirm ASME Safety Factors
V
ASME Safety Factors Not Satisfied
ASME Safety Factors Satisfied Normal/Upset ≥ 2.77 And Emergency/Faulted ≥ 1.39
Λ
Determine Severity Levels
XOR
Implement One Time Immediate ECWS Walkdown
Severity Level II Event
Severity Level I Event and No Additional Leaking Components Identified
V
No Additional Leaking Components Identified
Update ECW Program
Additional Leaking Components Identified
Follow Process Path 'A'
Exit
Follow Process Path 'B'


Follow Process Path 'A'
Severity Level I Event
Λ
Implement Common Steps
Plant Operations (PO)
Plant Engineering (PE)
Implement Specific Steps
• Initiate Condition Report
• Notify Control Room
• Immediate/Prompt Operability Determinations (PE to Recommend)
• Technical Specification Entry Actions When Warranted
• Implement Remedial Measures as Recommended
- ECWS Walkdown by PE on a weekly Basis
- Daily walkdown of leaking components by PO
- Apparent Cause by PE
- Extent of Condition by PE
- Immediate Repair/Replacement Recommendations by PE; Long term recommendation to follow Causal Analysis
• Develop Detailed ODMI to Follow (PE in consultation with Plant Personnel)
• Select 3 Additional Components from Sister Trains for 3 ACT and 12 PE
• Perform Causal Analysis
• Drive Closure to ODMI Tasks; Add additional Tasks As Warranted
• Evaluate additional Test Results Recommending Further Actions
More Than One Property used for Operability Lowered Outside 15% Deviations From Previously Approved Property for 100% Dealloyed Material
XOR
ACT/PE Determined Within Acceptance Limits For Additional Tests
Update ECW Program
Exit
ACT/PE Acceptance Limits Not Met
Move to Severity Level II
Follow Process Path 'B'



- ECWS Operability Indeterminate. PE to Evaluate Operability of All Leaking Components Left in Service
- Notify Control Room if Component Determined Not Operable For Tech. Spec. Required Action
- Continue with Enhanced Monitoring BY Both PO and PE
- Continue Monitoring of Leak Rate for all Leaking Components
- Continue Implementation of ODMI Including
  - Perform Causal Analysis
  - Extent Of Condition
  - Additional ACT/PE Tests
  (All Sister Components (5 Total) and Randomly Selected 3 Additional Components. Minimum of 5 ACTs plus 18 PE to be performed)
  - Develop and Implement Long Term Corrective Actions
    - Update ECW Program
    -Update Co-relation
    -Update Analytical Model
    - Update Material Properties
    - Systematic Replacement of Suspect Components
    - Relief Request
- - AMP/UFSAR Update

Request:

- **PE or ACT results demonstrate that layer-type dealloying predominates over plug-type, such that it is no longer possible to project internal degradation based on external observations. In addition:**

  i. **State the step-by-step process an examiner will use, when conducting profile exams to determine the transition point between layer-type and plug-type dealloying and thereby derives the internal dealloying angle.**

  ii. **State the acceptance criterion for the maximum percent of cross-sectional layer-type dealloying that will be allowed to occur within the use of the current methodology for determining the acceptability of a degraded component.**

Request:

- **PE or ACT results demonstrate that layer-type dealloying predominates over plug-type, such that it is no longer possible to project internal degradation based on external observations.**

STP Response:

The predominant type of dealloying observed is a combination of plug and layer dealloying occurring simultaneously. Exclusive layer type dealloying has not been observed because when a component casting cools, the casting does not cool at a uniform rate. Therefore, the phase structure throughout the component body is not identical.

An "Operational Decision-Making Issue" will be developed to further investigate and implement corrective measures for any component that demonstrates predominate layer-type dealloying. The investigation may require additional destructive examinations. Remedial measures may include increased monitoring, or more frequent examinations to replacement effected components. The analytical methodology may also have to be reevaluated and updated as necessary.

Request:

i. **State the step-by-step process an examiner will use, when conducting profile exams to determine the transition point between layer-type and plug-type dealloying and thereby derives the internal dealloying angle.**

STP Response:

The following provides the step-by-step process used to conduct a profile exam:

- The component is sectioned at the plane of externally observed dealloying.
- The sectioned surface is etched with Silver Nitrate solution, which distinguishes the dealloyed areas.
- The section is photographed for measuring subareas (manual or digital) of the dealloyed sectional surfaces.

- The angle of the outside flaw along the OD is constructed from the measured length of the through-wall flaw.
- The angle for the extent of the internal flaw is determined where non de-alloyed metal begins.
- For situations where some amount of layer dealloying exists at the through wall penetration, then a transitional measurement for the internal flaw angle is determined at the point where the layer is approximately 50% of the wall thickness.
- The average flaw length is then determined by averaging the OD and internal flaw angles.

Request:

ii. State the acceptance criterion for the maximum percent of cross-sectional layer-type dealloying that will be allowed to occur within the use of the current methodology for determining the acceptability of a degraded component.

STP Response:

The acceptance criterion for a dealloyed component is a component that does not leak. Non-leaking components average 60% through-wall thickness dealloying before leaking occurs. The distribution of sampled aluminum bronze fittings for STP Unit 1 is plotted in figure 2.5 (Ref. STP Letter to the NRC ST-HL-AE-2748 dated November 1, 1988, Attachment 2, Page 38 of 58). All components that were dealloyed more than 60% through their cross sections developed leaks. When the PE determines that average dealloyed wall thickness exceeds 60% and sufficient material is available for preparation of a test coupon, mechanical properties will be obtained. The resulting test data will then determine impact on previously performed operability and potential impact on the ECW program.

Request:

- **PE or ACT results demonstrate that cracking has extended into the un-dealloyed region.**

STP Response:

The scenario assumes part of a circumferential crack is extending into undealloyed base material. The likely conditions that could cause crack tip to extend into undealloyed base material are as follows:

- Physical crack existed through dealloyed material,
- The crack growth occurred through dealloyed material because of conducive environment and/or applied loads, or
- The crack now extends through undealloyed material mainly because of applied loading. The crack may have penetrated through minimum required wall thickness resulting in excessive primary membrane stresses and a potential to tear through the wall thickness.

The layered geometry of dealloying is not uniform through the component cross section. Dealloying without cracks has sufficient material strength to sustain applied loads.
It is reasonable to conclude that the crack pre-existed in the component.

It is also reasonable to assume that a crack extending through base material will be limited to a deeply penetrated segment of dealloyed area and not through entire dealloyed cross section of component. The local leakage resulting from such crack will be identified through the monitoring program.

STP performs ACTs and PEs through the PEO allowing timely identifications and implementations of corrective measures as follows:

- Engineering evaluation of the remaining components determined to be at risk,
- Enhanced monitoring, and destructive examination program,
- Perform additional ACTs and PEs performed (Approximately 5 ACTs and 18 PEs),
- Updated critical bending stress curves found in AES-C-1964-1,
- Systematic replacement of components determined to be at risk.
- PSALBZ "ECW Aging Management Program" reviewed and updated to incorporate resulting information, and
- Notification to the NRC of pertinent changes to ECW program.

Criteria Defining Adverse Trend:

One non-leaking component PE exhibiting all below listed characteristics:

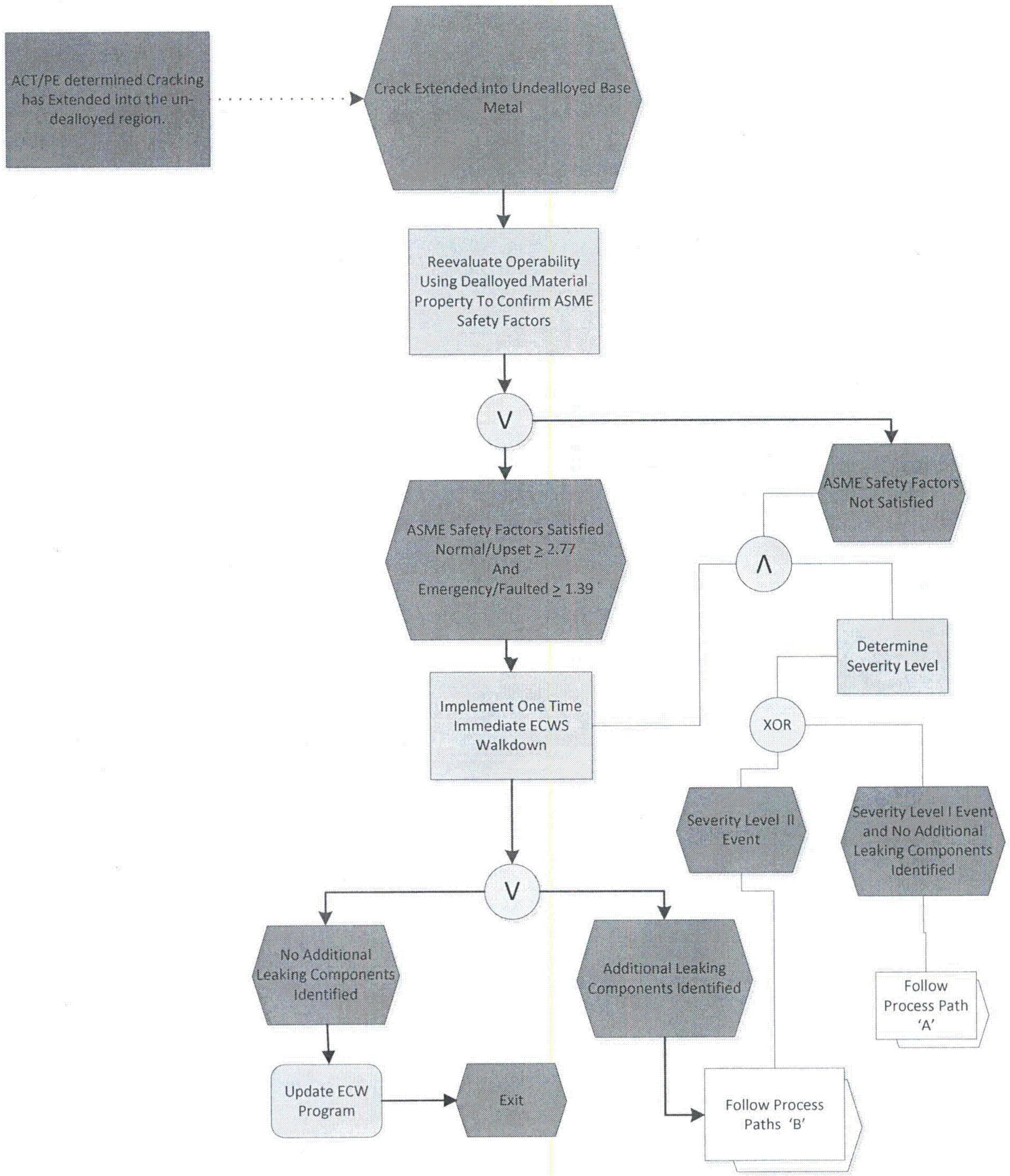
- Presence of layered dealloying throughout the circumference of component section.
- Average thickness of layered dealloying exceeds 60% through wall thickness
- Presence of circumferential crack in the dealloyed layer. Average crack angle (2Θ) to be less than 70 degrees
- Crack Depth penetrates undealloyed base material at least 20% of remainder undealloyed thickness at crack tip location

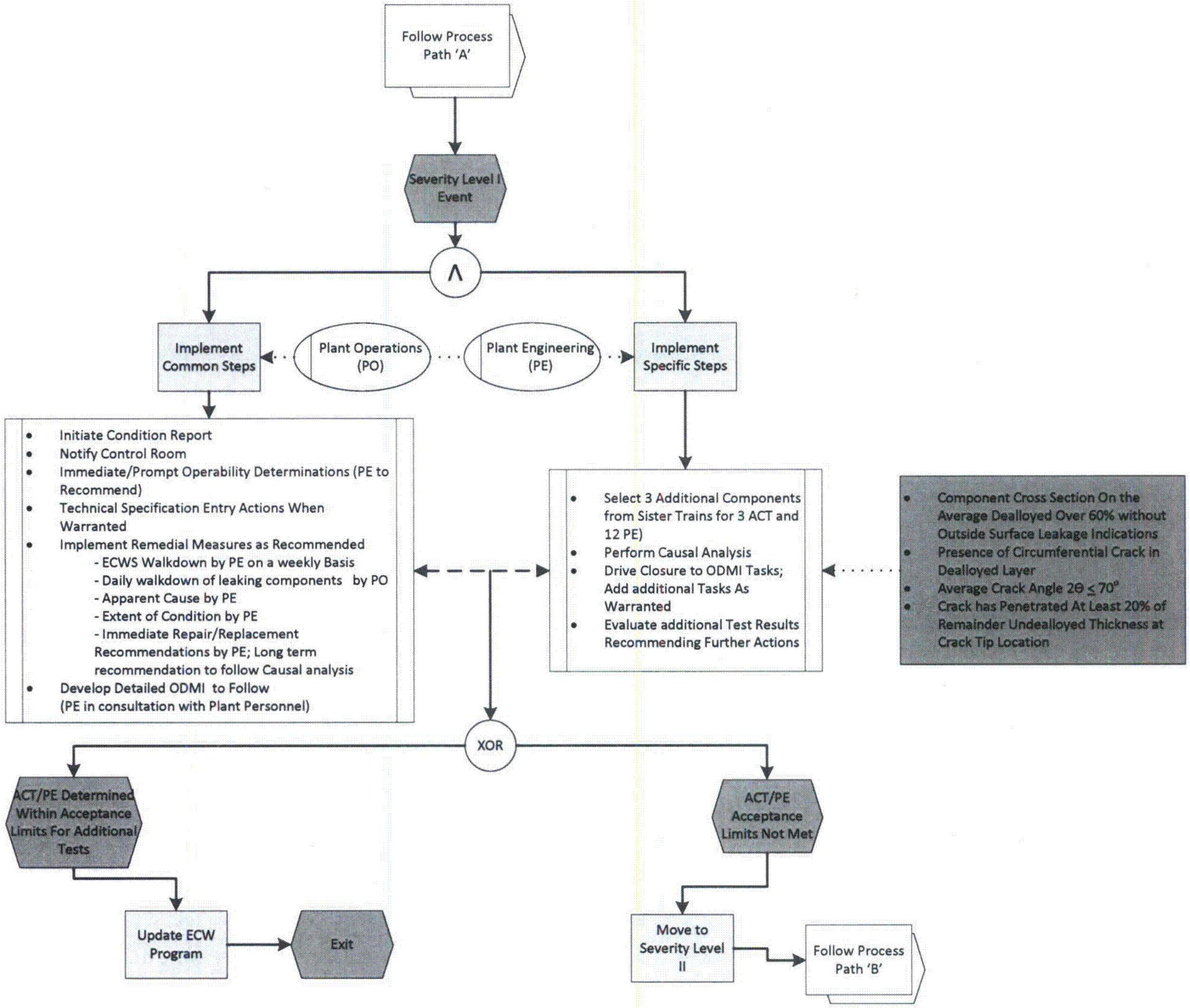
Severity of Condition:

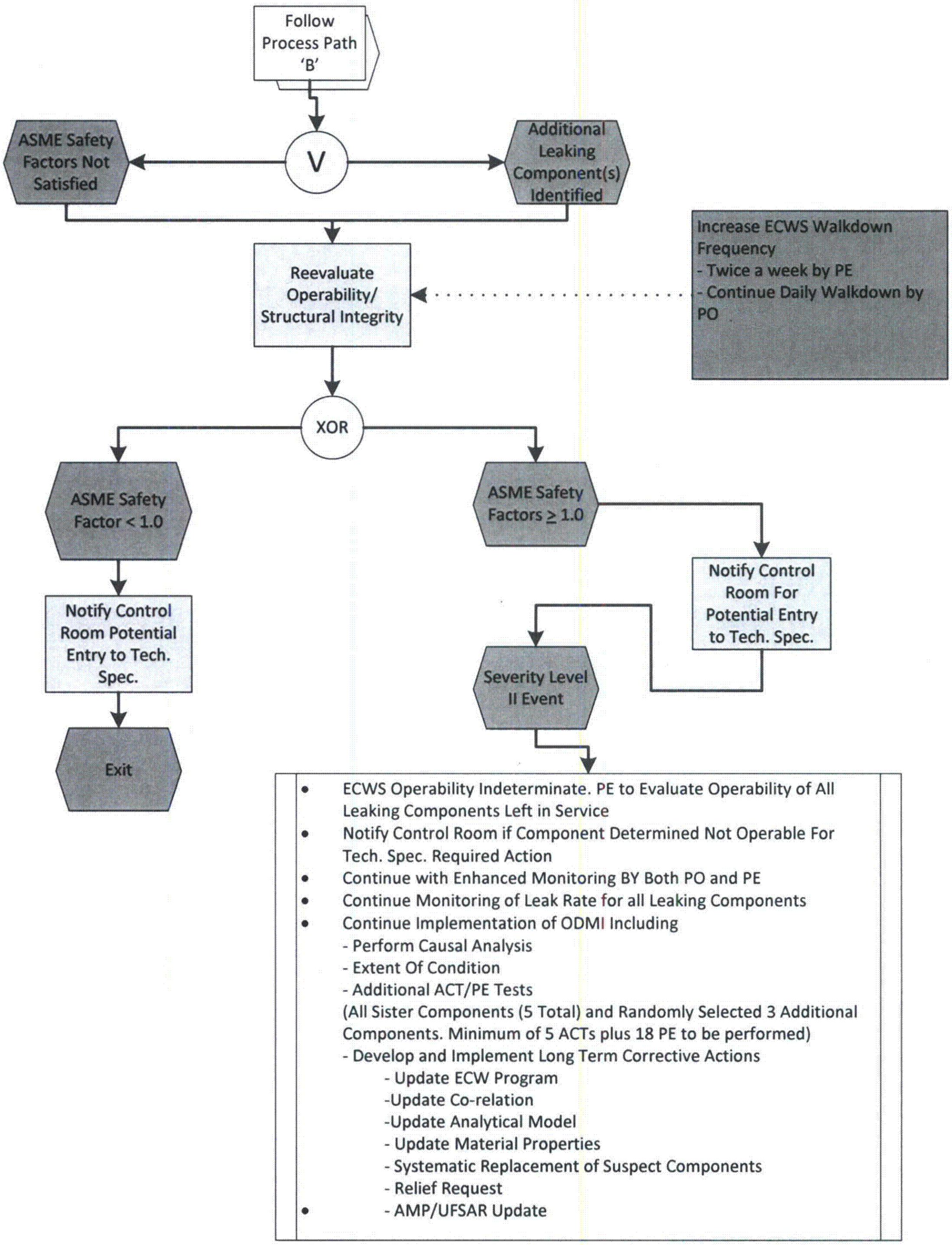
Crack penetration length will determine severity levels.

Severity Level	Acceptance Criteria	Number of Components to be Tested	Probable Action
II	Length of ID crack exceeds 70 degrees (2Θ) and has penetrated at least 20% of base material	5 ACTs and 18 PEs randomly selected component from affected train	- Enter Technical Specification - STP may seek temporary relief from the NRC for continued operation until root cause can be determined
I	Length of ID crack is NOT exceeding 70 degrees (2Θ) and penetration in base material is less than 20% of base material	3 ACTs 12 PEs	- Enter Technical Specification - Notify Control Room - Seek temporary relief from the NRC for continued operation until root cause can be determined - Additionally tests are required to confirm potential entry to Severity Level II

Specific remedial measures are based on severity as recommended by the following Decision Flowcharts.


ACT/PE determined Cracking has Extended into the un-dealloyed region.
Crack Extended into Undealloyed Base Metal
Reevaluate Operability Using Dealloyed Material Property To Confirm ASME Safety Factors
V
ASME Safety Factors Not Satisfied
ASME Safety Factors Satisfied Normal/Upset ≥ 2.77 And Emergency/Faulted ≥ 1.39
Λ
Determine Severity Level
Implement One Time Immediate ECWS Walkdown
XOR
Severity Level II Event
Severity Level I Event and No Additional Leaking Components Identified
V
No Additional Leaking Components Identified
Additional Leaking Components Identified
Follow Process Path 'A'
Update ECW Program
Exit
Follow Process Paths 'B'


Follow Process Path 'A'
Severity Level I Event
Λ
Implement Common Steps
Plant Operations (PO)
Plant Engineering (PE)
Implement Specific Steps
• Initiate Condition Report
• Notify Control Room
• Immediate/Prompt Operability Determinations (PE to Recommend)
• Technical Specification Entry Actions When Warranted
• Implement Remedial Measures as Recommended
- ECWS Walkdown by PE on a weekly Basis
- Daily walkdown of leaking components by PO
- Apparent Cause by PE
- Extent of Condition by PE
- Immediate Repair/Replacement Recommendations by PE; Long term recommendation to follow Causal analysis
• Develop Detailed ODMI to Follow (PE in consultation with Plant Personnel)
• Select 3 Additional Components from Sister Trains for 3 ACT and 12 PE)
• Perform Causal Analysis
• Drive Closure to ODMI Tasks; Add additional Tasks As Warranted
• Evaluate additional Test Results Recommending Further Actions
• Component Cross Section On the Average Dealloyed Over 60% without Outside Surface Leakage Indications
• Presence of Circumferential Crack in Dealloyed Layer
• Average Crack Angle 2Θ ≤ 70°
• Crack has Penetrated At Least 20% of Remainder Undealloyed Thickness at Crack Tip Location
XOR
ACT/PE Determined Within Acceptance Limits For Additional Tests
Update ECW Program
Exit
ACT/PE Acceptance Limits Not Met
Move to Severity Level II
Follow Process Path 'B'


Follow Process Path 'B'
V
ASME Safety Factors Not Satisfied
Additional Leaking Component(s) Identified
Reevaluate Operability/ Structural Integrity
Increase ECWS Walkdown Frequency
- Twice a week by PE
- Continue Daily Walkdown by PO
XOR
ASME Safety Factor < 1.0
ASME Safety Factors ≥ 1.0
Notify Control Room Potential Entry to Tech. Spec.
Notify Control Room For Potential Entry to Tech. Spec.
Severity Level II Event
Exit
ECWS Operability Indeterminate. PE to Evaluate Operability of All Leaking Components Left in Service
Notify Control Room if Component Determined Not Operable For Tech. Spec. Required Action
Continue with Enhanced Monitoring BY Both PO and PE
Continue Monitoring of Leak Rate for all Leaking Components
Continue Implementation of ODMI Including
- Perform Causal Analysis
- Extent Of Condition
- Additional ACT/PE Tests
(All Sister Components (5 Total) and Randomly Selected 3 Additional Components. Minimum of 5 ACTs plus 18 PE to be performed)
- Develop and Implement Long Term Corrective Actions
- Update ECW Program
-Update Co-relation
-Update Analytical Model
- Update Material Properties
- Systematic Replacement of Suspect Components
- Relief Request
- AMP/UFSAR Update

Issue:

f) The staff has questions regarding how field observations of leaking degraded components are used in conjunction with the analytical output of AES-C-1964-1, "Calculation of Critical Bending Stress for Dealloyed Aluminum-Bronze Castings in the ECW System," and the existing pipe stress analyses in order to analyze for structural integrity as it relates to the component performing its intended function. In particular, the staff has concerns related to:

- **In the correlation in AES-C-1964-5, the observed OD crack angle is used to derive an average through-wall dealloying angle. However, the critical bending stress curves in AES-C-1964-1 use a crack angle, not an average through-wall dealloying angle. The staff lacks sufficient information to be able to understand the link between the correlation and its use in the critical bending stress curves. Note that the response to RAI B2.1.37-4, Enclosure 1, page 3 of 9, incorrectly characterizes the correlation, "[t]he examination results were used to establish a correlation between length of a flaw on the outer diameter and the size of any internal crack and the extent of the dealloyed region of the component."**

Also, it is not clear to the staff why an average angle would be used when Figures C-2200-1, "Flaw Characterization-Circumferential Flaws," and C-4310-1, "Circumferential Flaw Geometry," of ASME Code Section XI, and Figure 5-1, "Circumferential Flaw Geometry -Net Section Collapse Model," of AES-C-1964-1 use the inside dimensions of the flaw.

The staff plotted the OD and inside diameter (ID) crack and dealloying angle data from Section 4.1, "Metallurgical Data," of AES-C-1964-5 (i.e., dealloyed OD vs. dealloyed ID and crack OD vs. crack ID). Two crack data points and three dealloying data points fell outside (nonconservative) of the correlation. If it is not appropriate to use an average through-wall dealloying angle, a new correlation using inside dimensions will need to be developed. The staff lacks sufficient information to understand whether such a new correlation could affect the structural integrity determination of recently degraded components, and by extension, degraded components discovered during the PEO.

- **The wording of the response to part (e) of RAI B2.1.37-3 is not clear on what minimum structural factor will be used for the normal/upset conditions and emergency and faulted conditions.**

- **It is not clear to the staff how external dimensions of the indication are sized. For example, when an indication consists of a crack within a larger dealloyed region, it is not clear which feature is measured. Also, it is not clear how a singular rounded (surface) indication, or multiple in-line rounded (surface) indications, are characterized.**

- **It would appear that, based on the external dimensions of the flaw, an average flaw angle is developed based on the AES-C-1964-5 correlation and used as input into the critical bending stress analyses in AES-C-1964-1, regardless of whether the through-wall degradation is dealloying with no crack, a part-through crack with dealloying, or through-wall crack with dealloying. However, the staff seeks confirmation that this is correct. The responses to the scenario-based questions in the request should resolve this issue**

- **Given the ambiguities between the calculations, it is not clear to the staff that the steps in a structural integrity determination of a degraded susceptible aluminum bronze component in the essential service water system can be consistently performed without a procedure. In addition to the ambiguities, based on plant-specific OE, consistent performance is also challenged since these evaluations are conducted infrequently.**

Request:

- **State:**

  - **Why an average through-wall dealloying angle is the output of the correlation in AES-C1964-5 rather than the inside wall dimension.**

  - **How the correlation from AES-C-1964-5 will be modified if use of the average dealloying angle is not appropriate. Additionally, reconsider the structural integrity evaluation for any degraded components discovered since 2011 and state whether the components would still be considered to meet structural integrity criteria (using this modified correlation) and therefore would still be capable of performing their intended function with the new correlation.**

  - **Whether the structural factor for the normal/upset conditions will always be at least 2.77, and for emergency and faulted conditions at least 1.39. If not, state what the minimum structural factors would be and the basis for the values being less than those stated in ASME Code Section XI.**

  - **For the four scenarios of OD observed degradation below:**

    i. **Four small rounded indications of through-wall dealloying located in a circumferential axis at 10:00, 11:00, 1:00, and 2:00 on a 10-inch flange.**

    ii. **One indication at 10:00, one-half inch long, with what appears to be rounded ends and no measurable width on a 4-inch flange.**

    iii. **One "greenish" stain approximately 1/8 inch diameter at the 10:00 position on a 6-inch flange.**

    iv. **One crack-like indication, one-half inch long, within a larger greenish stain with a circumferential length of one inch.**

State:

- **the size of the OD flaw**
- **the corresponding size of the internal flaw that would be used in the structural integrity determination**
- **which figure would be used from AES-C-1964-1**
- **the stress component input values that would be utilized from the highest stress location in the essential service water system with susceptible components for that size as obtained by the stress analyses on record and how they would be combined in the structural integrity determination**
- **what structural factor will be used**
- **the critical bending stress as derived from the figures in AES-C-1964-1 whether the component would be considered to be capable of meeting its intended function**

- **What site procedure provides step-by-step instructions for determining the structural integrity of a degraded susceptible aluminum bronze component in the essential service water system? If no such procedure is currently used, state the basis for why it is acceptable to have the staff completing the evaluation steps in the absence of written instructions.**

Request:

- **Why an average through-wall dealloying angle is the output of the correlation in AES-C-1964-5 rather than the inside wall dimension.**

STP Response:

The average through-wall dealloying angle is used to estimate flaw length. This approach is comparable to one described in NRC GL 90-05 where flaw length is estimated at the required minimum thickness (t_{min}).

ASME Section XI Appendix H, Figure H-2200-1 'Flaw Characterization – Circumferential Flaws' depicts flaw length 'l' at front tip of the crack 'a' through thickness 't'. Note staff reference ASME Section XI, Appendix C figure C-2200-1, 'Flaw Characterization-Circumferential Flaw' is identical to Appendix H figure H-2200-1. ASME Section XI, Appendix C, Figure C-4300-1, 'Circumferential Flaw Geometry' has no specific length shown. The length 'l' is defined as general flaw length dimension in a nomenclature of Appendix C.

Using the average through-wall angle provides an estimate of the through-wall flaw length used in the analysis described in AES-C-1964-5. The critical bending stress curves developed in the APTECH calculation AES-C-1964-1 provide a tabulated solution to limit load; additionally, fracture analysis equations are included for quick reference. The evaluating engineer is still responsible for determining appropriate crack angle (Θ/π), based on conditions observed in the field.

Request:

- **How the correlation from AES-C-1964-5 will be modified if use of the average dealloying angle is not appropriate. Additionally, reconsider the structural integrity evaluation for any degraded components discovered since 2011 and state whether the components would still be considered to meet structural integrity criteria (using this modified correlation) and therefore would still be capable of performing their intended function with the new correlation.**

STP Response:

Use of average through-wall angle is appropriate because it has provided adequate estimates of flaw lengths to date. The correlation was based on test data gathered from previously sectioned components, and is representative of the average through-wall angle described previously.

STP identified OD and ID measured crack lengths from five additional components (1-24" and 4-30" Diameter Pipe size). The existing correlations shown in Figure 4.1 in APTECH calculation AES-C-1964-5 bound these five components. Additional information obtained from future PEs will be compared to Figure 4.1 "Correlation between through wall cracks and through wall dealloying", found in AES-C-1964-5. When warranted, the correlation that bounds the PE data will be updated.

Request:

- **Whether the structural factor for the normal/upset conditions will always be at least 2.77, and for emergency and faulted conditions at least 1.39. If not, state what the minimum structural factors would be and the basis for the values being less than those stated in ASME Code Section XI.**

STP Response:

The ASME Code Section XI structural factors for the normal/upset conditions (2.77) as well as the emergency and faulted conditions (1.39) will be applied when determining operability for components with dealloyed conditions. Whenever ASME Section XI structural factors can not be met, a ODMI will be developed to address non-conforming condition using process similar to one described under issue 'e' above. ASME Section XI structural factors below 1.0 will require immediate repair or replacement of leaking component.

Request:

- **For the four scenarios of OD observed degradation below:**

  i. **Four small rounded indications of through-wall dealloying located in a circumferential axis at 10:00, 11:00, 1:00, and 2:00 on a 10-inch flange.**

  ii. **One indication at 10:00, one-half inch long, with what appears to be rounded ends and no measurable width on a 4-inch flange.**

iii. **One "greenish" stain approximately 1/8 inch diameter at the 10:00 position on a 6-inch flange.**

iv. **One crack-like indication, one-half inch long, within a larger greenish stain with a circumferential length of one inch.**

STP Response:

Attachment D presents the methodology and a sample calculation that demonstrates how APTECH calculation AES-C-1964-1 estimates critical bending stresses. The sample calculation is provided for Case i and includes all equations used. Following the same methodology, the results of all four cases requested above are summarized in APTECH calculation AES-C-1964-1 Table 1, "Evaluation Summary". The information requested is organized by columns for each case.

(Note: The scope of the current version of the APTECH calculation is limited to commonly observed dealloying cases and pipe sizes 3 inches and larger.)

STP uses the ASME Code recommended methodology that include different acceptable variations such as: when considering Case i, the four flaws could be analyzed in two different ways. First, the evaluation could treat them as four independent flaws; alternatively, they could be combined into two flaws by combining the data at positions 10 and 11, and 1 and 2. The station then calculates the neutral axis and critical bending stresses using equations published in the following references.

References:

1. Failure Bending Moment for Pipe With an Arbitrary-Shaped Circumferential Flaw, authored by Yinsheng Li, Kunio Hasegawa, Akira Shibuya, and Nathaniel Cofie. Published in a Journal of Pressure Vessel Technology dated August 2011, Volume 133.
2. Prediction of Collapse Stress for Pipes With Arbitrary Multiple Circumferential Surface Flaws, authored by Yinsheng Li, Kunio Hasegawa, Akira Shibuya, and Nathaniel Cofie. Published in a Journal of Pressure Vessel Technology dated December 2010, Volume 132.
3. Net Section Plastic Collapse Analysis of Two-Layered Materials and Applications to Weld Overlay Design, authored by Arthur F. Deardorff, Nathaniel Cofie, David G. Dijamco, and Aparna Chintapali. Published ASME PVP 2006 Pressure Vessel and Piping Conference July 2006.

Issue:

g) The staff also seeks the following information to complete its evaluation of the proposed AMP:

- **A list of the number of remaining susceptible components, broken down by size.**
- **A copy of AES-C-1964-4, "Evaluation of 6-Inch Flange Test," submitted on the docket.**
- **An update on leaking components that have occurred since July 28, 2011, the last entry in Table 1, "ECW De-Alloying Data," of the response to RAI B2.1.37-1.**

- **The results of the leak rate analysis stated in Commitment No. 46, in response to RAI B2.1.37-4 Issue 5.**

- **The "scope of program" and "parameters monitored or inspected" program elements of the Selective Leaching of Aluminum Bronze program state, "components greater than one inch will be replaced by the end of the subsequent refueling outage." The staff noted that UFSAR Section 9A, "Assessment of the Potential Effects of Through-Wall Cracks in ECWS Piping," states, in part, that relief requests are submitted when leaks are identified except for, "leaks in lines 1 inch or under which are exempt from ASME Code Section XI replacement rules." The staff cannot find a basis for allowing one inch and under lines to have repair or replacement times extend beyond the subsequent refueling outage.**

- **Request:**

g) Provide the following:

- **A list of the number of remaining susceptible components broken down by size. This list is required for the staff to conduct an independent review of the analytical output information in relation to flaw size tolerance.**

- **A copy of AES-C-1964-4, "Evaluation of 6-Inch Flange Test." This calculation will be used by the staff as input to determine the acceptability of the proposed aging management program and, therefore, should be on the docket.**

- **An update to Table 1 of the response to RAI B2.1.37-1 to reflect leaking components that have occurred since July 28, 2011.**

- **The basis for why 1-inch and under lines are not replaced by the end of the subsequent outage. Also, state the basis for why 1-inch and under lines can be demonstrated to meet their intended function prior to replacement**

STP Response:

- A listing of the number of susceptible components, collated by size, is provided as Attachment A.

- A copy of AES-C-1964-4, "Evaluation of 6-Inch Flange Test," Is provided as Attachment B.

- An update to Table 1 of the response to RAI B2.1.37-1, reflecting leaking components that have occurred from July 28, 2011, through the end of 2013, is provided as Attachment C.

- The results of the leak rate analyses referenced in Commitment No. 46, in response to RAI B2.1.37-4 Issue 5, are provided as Attachment E.

- UFSAR Section 9A, "Assessment of the Potential Effects of Through-Wall Cracks in ECWS Piping," states, in part, that relief requests are submitted when leaks are identified except for, "leaks in lines 1 inch or under which are exempt from ASME Code Section XI replacement rules." Change Notice CN-3073 revised the UFSAR, removing the relief request exemption for leaks in lines, 1" and below.

  LRA Appendices A1.37 and B2.1.37, and LRA Basis Document PSALBZ (B2.1.37), are revised to document that STP will replace leaking components by the next refueling outage.

Attachment A

List of the susceptible components, broken down by size.

List of the susceptible components, broken down by size

Nominal Size	Unit 1 Cast Flange	Unit 2 Cast Flange	Unit 1 Cast Tee	Unit 2 Cast Tee	Unit 2 Cast reducer	Unit 1 Cast Pump Casing	Unit 2 Cast Pump Casing	Unit 2 Cast Elbow	Unit 2 Cast Cap	Unit 1 Cast Valve	Unit 2 Cast Valve	Total Casts	Unit 1 Root Valve Socket Adapter	Unit 2 Root Valve Socket Adapter	Unit 1 Above Grd Butt Welds W/BR	Unit 2 Above Grd Butt Welds W/BR	Unit 1 Below Grd Butt Welds W/BR	Unit 2 Below Grd Butt Welds W/BR	Total Welds
½													17[1]	29[1]					
1																			
3	25	38						1		18	18	100			74	87			161
4	15	34								12	10	71			69	47			116
6	32	31	2	1						12	13	91			134	107			241
8	33	24								10	10	77			25	31			56
10	11	6							1	6	6	30			45	48	64	12	169
14										3	3	6			2	13			15
24										3	3	6			3	6			9
30						3	3			12	12	30			37	38	135	140	350
10X4			3	3	1							7							
10X6			6	4								10							
10X4			3	2								5							
Total	116	133	14	10						76	75	424	17	29	389	377	199	152	1163

[1] One inch manual valves with susceptible 1" to ½" socket adaptor welds not included in total weld number

Attachment B

Calculation AES-C-1964-4, "Evaluation of 6-Inch Flange Test," APTECH Project AES 93061964-1Q (June 3, 1994).

CALCULATION COVER SHEET

ST-7R-HS-090008
PEN: M05.02.02

Document No.: AES-C-1964-4

Title: Evaluation of 6-Inch Flange Test

Client: Houston Lighting and Power Company

Project No.: AES 93061964-1Q

APTECH Office: Sunnyvale

Sheet No. 1 of 31

Purpose: The purpose of this calculation is to evaluate the pressure test and bend test data for a 6-inch aluminum-bronze cast flange.

Assumptions: See Section 2.0 for major assumptions.

Results: The pressure test results indicate the flange was able to carry at least 4.4 times the design pressure in its degraded condition without failure. The bend test results indicate the bending stress to fail the flange was 23.3 ksi. This stress value exceeded the predicted critical bending stress calculated for the flange geometry. Therefore, the flaw evaluation method for calculated critical bending stress is conservative.

Revision No.:	Prepared By: / Date:	Checked By: / Date:	Verified By: / Date:	Approved By: / Date:	Revision Description
0	RCC 12/31/93	YG 18MAY94	MHC 23MAY94	RCC 6/3/94	Initial Issue

APTECH ENGINEERING SERVICES, INC.

QAE17
REV. 9/88

APTECH ENGINEERING SERVICES, INC.

Document No.: AES-C-1964-4	Made by: [signature]	Date: 12/2/93	Client: HL&P
Title: Evaluation of 6-Inch Flange Test	Checked by: [signature]	Date: 18 MAY 94	Project No.: AES 93061964-1Q
	Revision No.: 0		Sheet No.: 2 of 31

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APTECH ENGINEERING SERVICES, INC.

Document No.: AES-C-1964-4	Made by: *[signature]*	Date: 12/14/93	Client: HL&P
Title: Evaluation of 6-Inch Flange Test	Checked by: *[signature]*	Date: 18 MAY 94	Project No.: AES 93061964-1Q
	Revision No.: 0		Sheet No.: 3 of 31

1.0 INTRODUCTION

A 6-inch flange was pressure tested (hydrotest) and tested in three-point bending by HL&P to establish the structural capacity of cast aluminum bronze (Al-Bronze) castings in a service-degraded condition. The flange was previously removed from service due to dealloying and leakage from a through-wall crack. The dealloying/cracking was located at the weld region of the flange and ran circumferentially around the casting.

The pressure test was performed on a flange/pipe assembly. The flange/pipe assembly was comprised of two flanges bolted together with two short pipe segments that were capped at each end. The internal surface was coated with a thin layer of Belzona to prevent the crack from leaking at low pressures. The flange/pipe assembly was internally pressurized (hydrotested) until the flange leaked. The flange/pipe assembly was then depressurized and loaded in three-point bending until failure. The purpose of this calculation is to evaluate the test results and to compare the final failure bending load to the predicted failure load from the fracture mechanics model developed for circumferentially flawed Al-Bronze castings (1).

The principal results of the test were recorded manually (2). Strain gage and pressure transducer data were recorded electronically and stored on disk (3). Fabrication of the test assembly, installation of strain gages and pressure sensors, recording of signals, and testing were all performed by HL&P contract personnel.

2.0 ASSUMPTIONS

The following assumptions are used in the evaluation of test results:

1. Beam theory was used to determine the bending moment and stress in the flange-pipe test assembly.

2. The different material properties between the steel and Al-Bronze segments of the flange-pipe assembly were ignored. These differences will have little or no effect on the stress determination at the plane of interest.

3. In the evaluation of the bend test results, the effect of the part-through crack was conservatively ignored.

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Document No.: AES-C-1964-4	Made by: LCC	Date: 12/4/93	Client: HL&P
Title: Evaluation of 6-Inch Flange Test	Checked by: JLG	Date: 18 MAY 94	Project No.: AES 93061964-1Q
	Revision No.: 0		Sheet No.: 5 of 31

3.0 SUMMARY OF TEST PROCEDURE

3.1 Test Geometry

The flange/pipe test specimen is schematically shown in Figure 3-1. The test flange was welded to an Al-Bronze pipe segment. A mating flange/pipe assembly was fabricated from an Al-Bronze flange and steel pipe and bolted to the Al-Bronze flange-pipe assembly. Both pipe ends were capped to create a sealed assembly for pressure testing. The overall length of the test assembly was approximately 55 inches. Fabrication of flange-pipe assembly and test fixture hardware was performed by HL&P.

As a backup to the load measuring devices, strain gages were applied to the test pipe. All instrumentation was installed and monitored by on-site personnel. Four axial gages (two at 0° and two at 180°) were applied approximately 2 inches axially from the outboard weld edge. These four gages were wired in the bridge to measure bending strain. The 180° gage was at a circumferential location of approximately the center of the circumferential crack. Later measurements on the failed flange (4) indicated the axial position of the bending gages to be 3.45 inches from the crack plane cross section. A three element (axial, 45°, hoop) rosette gage was also applied approximately 4 inches from weld edge at 180° position. Later measurements on the failed flange indicated the rosette to be 5.25 inches from the fracture plane.

The nominal dimensions for 6-inch NPS Schedule 40 pipe are given below:

D = 6.625 inches
t = 0.280 inch
R_o = 6.625/2 = 3.3125 inches
R_i = $R_o - t$ = 3.3125 - 0.280 = 3.0325 inches
R = $(R_o + R_i)/2$ = 3.1725 inches
R/t = 3.1725/0.28 = 11.33

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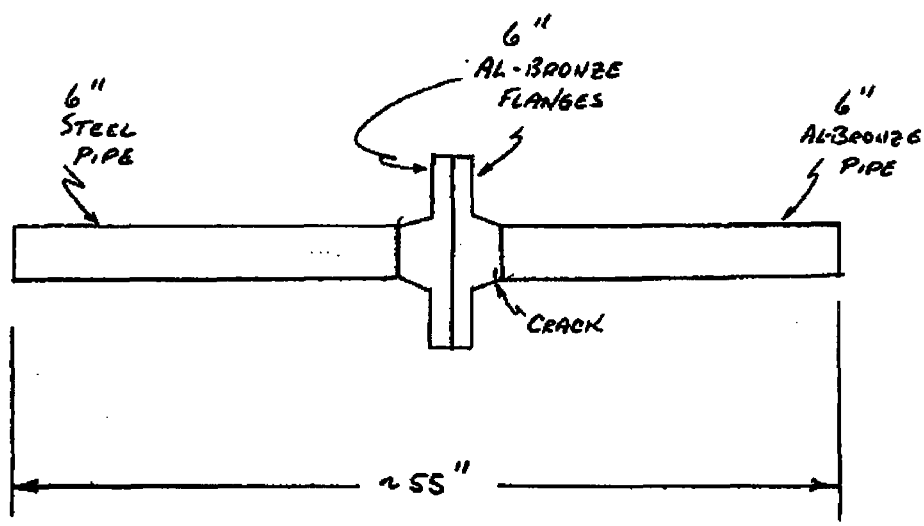

Figure 3-1 — Flange/Pipe Assembly.

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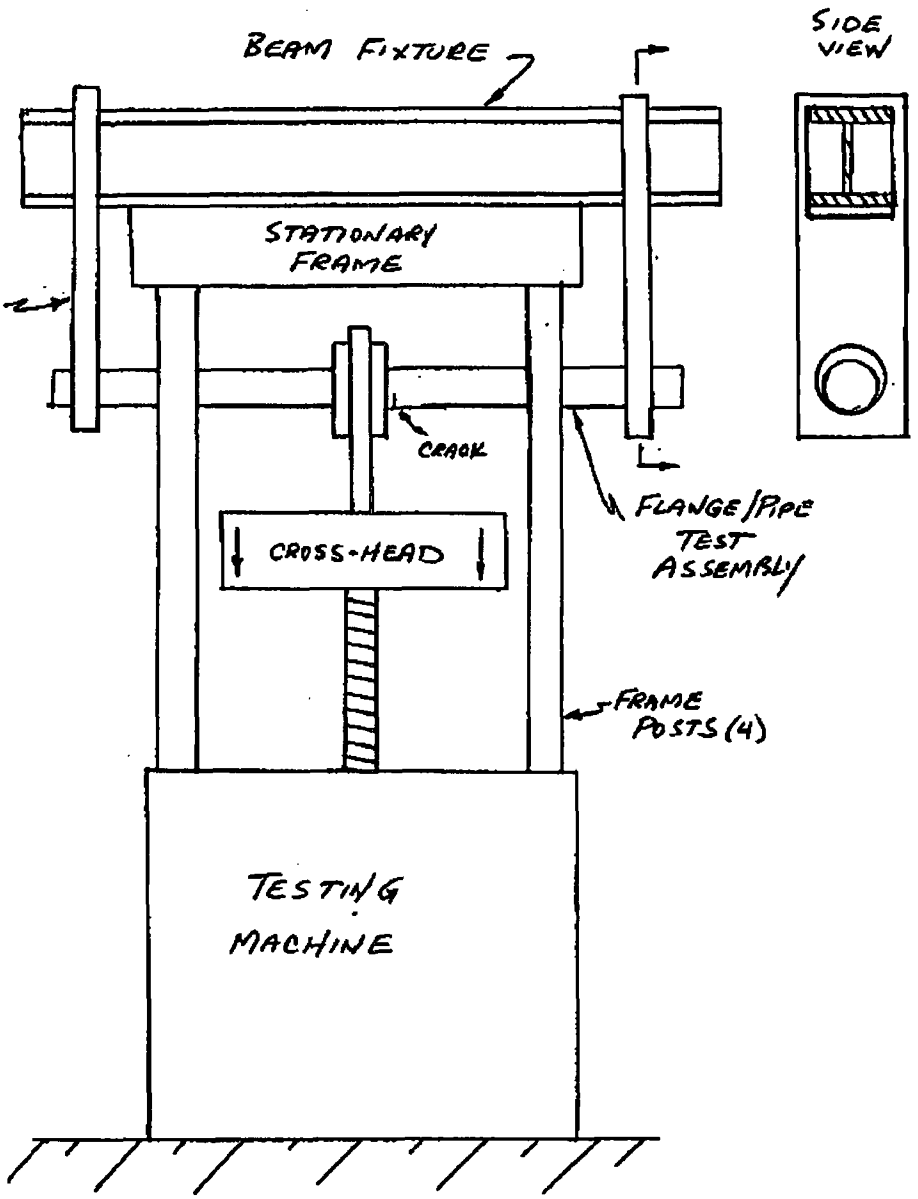

Figure 3-2 — Schematic Illustration of Bend Test Fixture.

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The pipe perimeters along the OD and ID surfaces are:

$$P_{OD} = \pi D = \pi(6.625) = 20.813 \text{ inches}$$

$$P_{ID} = 2\pi R_i = 2\pi(3.0325) = 19.054 \text{ inches}$$

3.2 Pressure Test Procedure

The pipe assembly was filled with water and then pressurized manually by a hand pump. The pump was an AMETEK twin seal pressure pump Model T-1, Serial No. 92541 with a maximum pressure capacity of 15,000 psi (2). In addition to the pressure transducer, pressure was measured by a dial pressure gage which was monitored by the pump operator. The pressure transducer output was recorded. The pressure was increased in approximately 50 psig increments and held for approximately 15 seconds at each pressure plateau. The test was terminated at 530 psig internal pressure when leakage occurred due to failure of the coating seal and pressure could not be maintained by the pump. Strain and pressure gage values were recorded during the test with a sample rate of five readings per second.

3.3 Bend Test Procedure

After the pressure test was completed, the pipe assembly was drained of water and placed in a three-point bend fixture attached to a mechanical tension testing machine. A schematic of the test fixture is shown in Figure 3-2. The fixture was constructed from wide flange steel beam and A516 Grade 70 steel plate. The end brackets and center clevis were designed to allow free rotation of pipe ends. The maximum load capacity of the machine is 120,000 lbs. The pipe assembly was mounted in the machine with the crack located on the bottom side (maximum tension side). Measurements were made from the central load point to each end of the pipe where the end plates make contact with the pipe (pinned-ends). After positioning the end plates, C-clamps were fixed to the beam to prevent sliding. The beam was also clamped to the machine cross-head to prevent slippage during the test. The load was controlled hydraulically by monitoring the dial gage. The load was increased in approximately 5000 lb load increments until failure of the flange. The load on the dial

gage was recorded manually at various times during the test. The maximum load was indicated by the follower indicator on the dial. Strain gage values were recorded during the test with a sample rate of five readings per second.

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4.0 PRESSURE TEST RESULTS

The pressure test assembly and instrumentation are shown in Figure 4-1. The pressure test data as recorded by the pressure transducer are plotted in Figure 4-2 (3). The recorded data covers a period of time of approximately eight minutes. Also shown in Figure 4-2 is the recorded hoop strain. In general, very good agreement in the trend between hoop strain and internal pressure is observed. At approximately 390 psi, small leakage was observed emanating from the crack (2) indicating rupture of the internal coating. Pressure was then increased until a maximum pressure of 530 psig was reached. Pressures higher than 530 psig could not be maintained because pressure loss due to leakage exceeded manual pump pressure rate. Therefore, the pressure integrity of the degraded flange is ≥530 psig. For a system design pressure of 120 psig and a maximum operating pressure of 80 psig (5), the following margins on pressure are calculated:

$$\text{Margin on design} \geq 530/120 = 4.4 \text{ times}$$

$$\text{Margin on operation} \geq 530/80 = 6.6 \text{ times}$$

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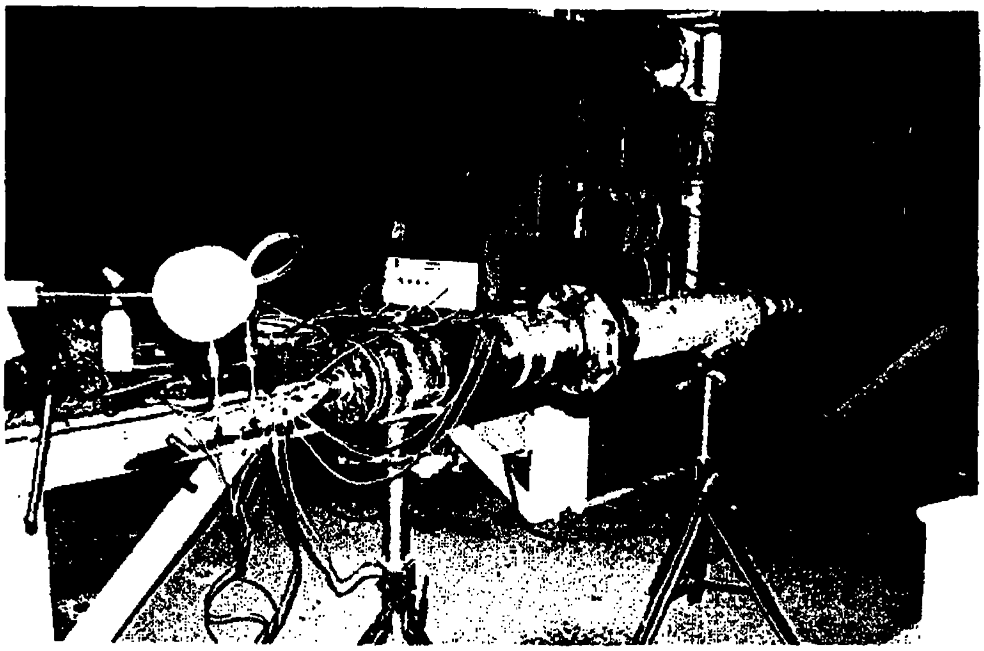

Figure 4-1 — Pressure Test Setup.

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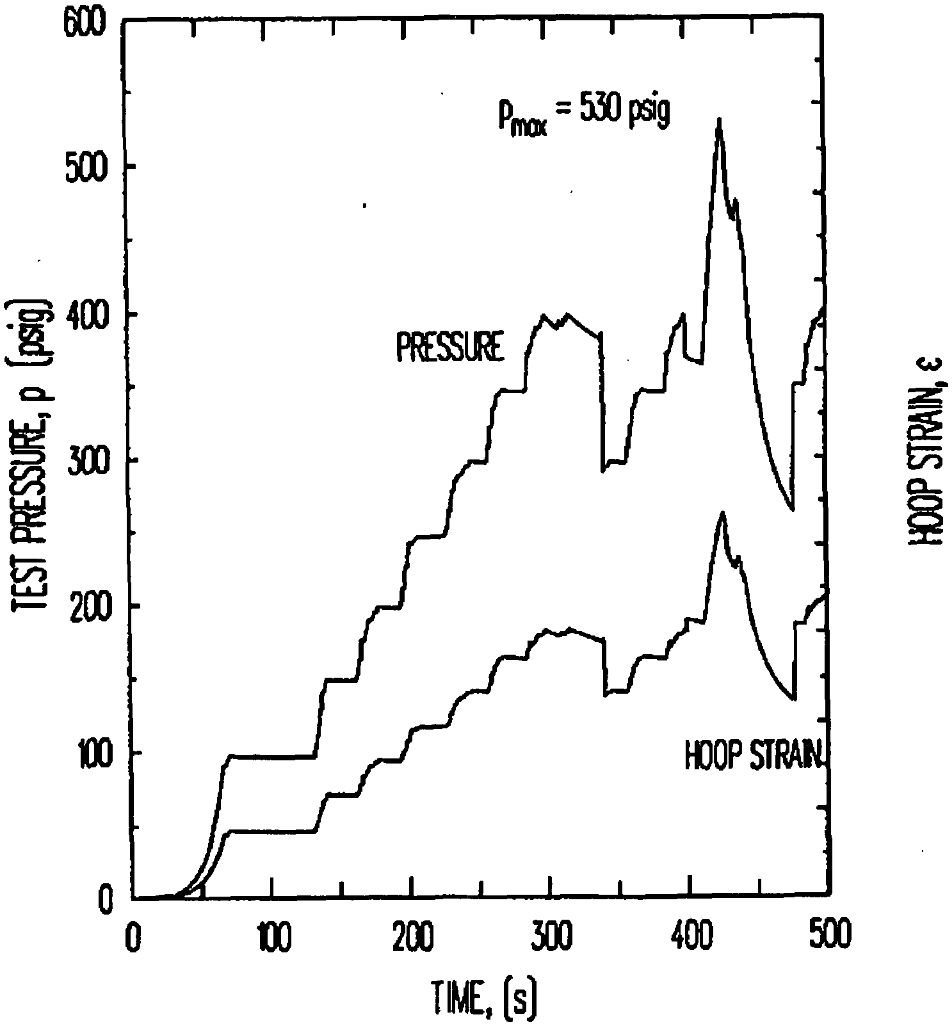

Figure 4-2 — Flange Pressure Test Data.

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5.0 BEND TEST RESULTS

The flange-pipe assembly was loaded in three-point bending as shown in Figure 5-1. The crack was placed on the tensile side of the assembly. The following critical lengths were measured prior to loading (2):

L_1 = Distance from center load point to left pin support = 25½ inches

L_2 = Distance from center load point to right pin support = 24½ inches

L_C = Distance from right pin support to cracked plane = 21⅝ inches

The total length between pin supports (L) is $L_1 + L_2$ = 25½ + 24½ = 50 inches.

The test was photographed and video recorded by HL&P. The bend test assembly and loading frame are shown in Figure 5-2. This photograph shows the flange/pipe under load during the performance of the test.

The bend test load versus time is shown in Figure 5-3. The loading rate was approximately 1000 lbs/min. Also shown in Figure 5-3 is the bending strain recorded by the gages. In general, the trend of bending strain is in agreement with the indicated load. It is apparent that permanent plastic straining had occurred during the test by the observation of negative strain near zero test load.

Several audible "pops" were heard during the loading. The "pops" that were noted during the test are shown in Figure 5-3. The maximum load achieved during the test was 18,200 lbs. The load dropped off in a stable manner after maximum load was reached. At a load of 2000 lbs, the crack had extended to about 3/4 of circumference. Final flange separation did not occur until after the test was stopped and the pipe assembly was being removed from the fixture.

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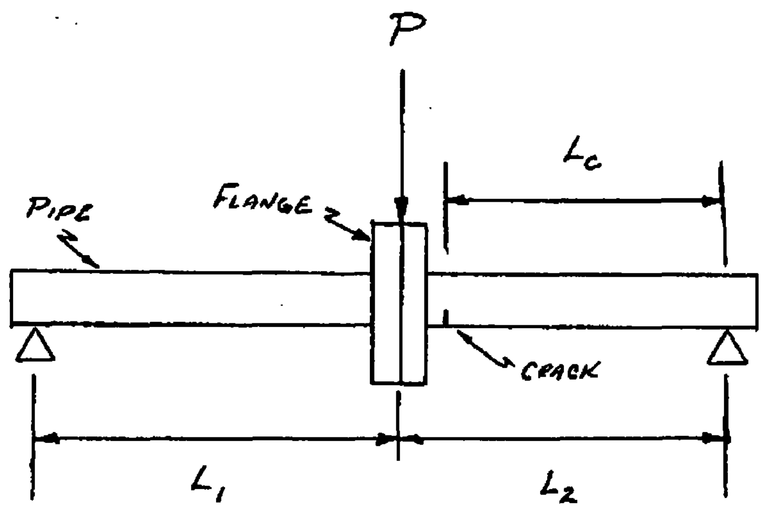

L_1	=	25½ inches
L_2	=	24½ inches
L_c	=	21⅝ inches
L	=	$L_1 + L_2$ = 50 inches

Figure 5-1 — Pipe Assembly Loading.

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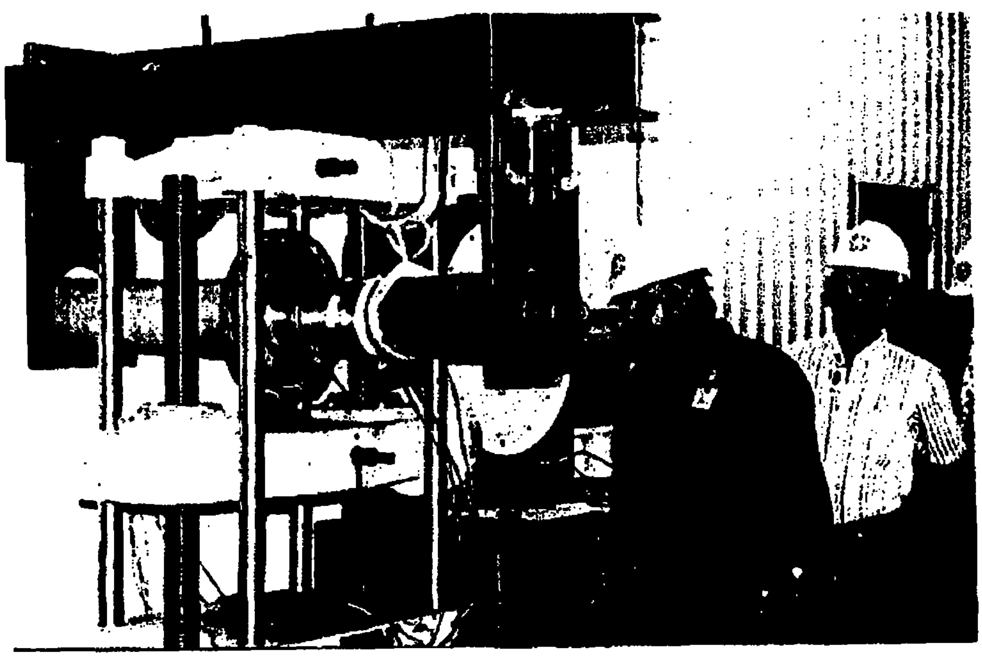

Figure 5-2 — Flange/Pipe Assembly During Testing.

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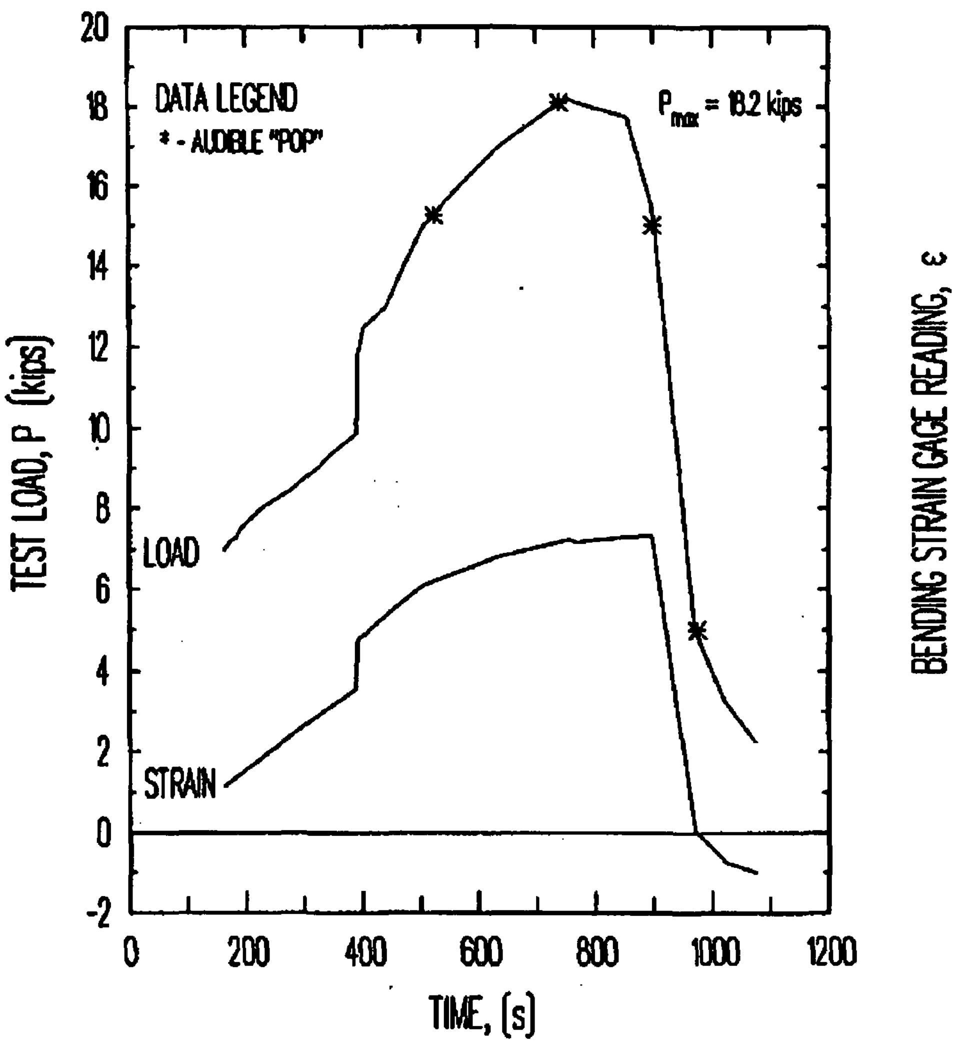

Figure 5-3 — Flange Bend Test Data.

The maximum applied stress at the crack plane was calculated from the assembly geometry and maximum load employing beam theory (6). The moment at the location of the crack is:

$$M = P(L_1 L_c / L)$$

$$M = 18{,}200(25.50)(21.625) / 50 = 200{,}720 \text{ in-lbs}$$

The maximum moment in the assembly acting directly under the load point is:

$$M = P L_1 L_2 / L$$

$$M = 18{,}200(25.50)(24.50) / 50 = 227{,}410 \text{ in-lbs}$$

The nominal moment at the crack plane location is 201/227 or approximately 89% of the maximum moment in the assembly during testing.

6.0 COMPARISON OF CALCULATED AND MEASURED CRITICAL BENDING STRESS

6.1 Summary of Post Test Measurements

The fracture surface of the failed flange section was examined by HL&P (4). The examination identified the extent of dealloying as well as the location and size of cracks. The results of this examination are illustrated in Figure 6-1. The section was dealloyed circumferentially to a depth from approximately 35% to 90% of the wall thickness. Two existing cracks were observed: a through-wall crack at 180° position and a part-through crack at approximately 330°. With regard to the bend test, the part-through crack did not significantly affect the structural bending capacity of the flange since it was located in the compressive region of the section.

From the angular position of the through-wall crack (2θ where θ is defined as the half crack angle), the following ID and OD surface lengths are computed:

$$\ell_{OD} = (2\theta_{OD} / 360°)\ P_{OD} = [(210 - 155) / 360]\ 20.813$$

$$\ell_{OD} = 3.18 \text{ inches}$$

$$2\theta_{OD} = 55°$$

$$\ell_{ID} = (2\theta_{ID} / 360°)\ P_{ID} = [(225 - 145) / 360]\ 19.054$$

$$\ell_{ID} = 4.23 \text{ inches}$$

$$2\theta_{ID} = 80°$$

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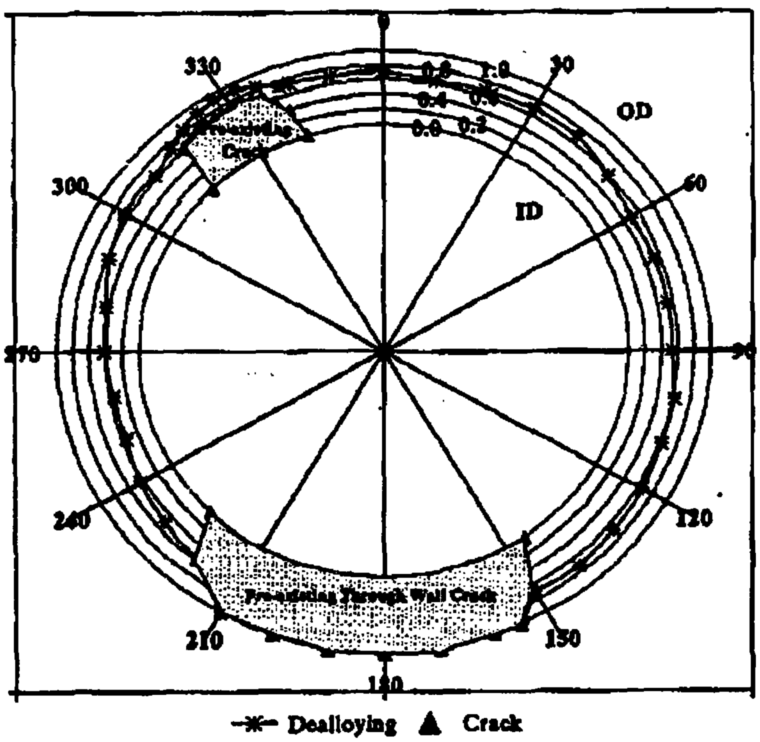

Figure 6-1 — Cross Sectional View of Fracture Surface Showing Dealloyed Regions and Cracking.

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The average crack length is:

$$\ell_{ave} = (3.18 + 4.23) / 2 = 3.71 \text{ inches}$$

$$2\theta_{ave} = (55 + 80) / 2 = 67.5°$$

6.2 Calculated Critical Bending Stress

The critical bending stress for Al-Bronze castings in the ECW system was previously determined for the purpose of evaluating the safety margins of degraded castings (1). The calculated critical stress is compared to the stress achieved in the flange bend test in order to verify the theoretical failure models. Since the bend test was performed with no internal pressure, the calculations contained in Ref. 1 were revised to redefine the axial pressure stress to zero. This revised calculation is given in Appendix A of this calculation.

The calculated critical bending stress for failure of the flange under pure bending is shown in Figure 6-2. The critical bending stress for both limit load and fracture models are illustrated. This critical bending stress is the elastically calculated stress based on the "uncracked" section properties of the flange-pipe that would fail the casting with a given through-wall crack length, ℓ. In order to compare these model results with the results of the bend test, the maximum moment from the test must be converted to an elastically equivalent bending stress for the uncracked section.

The elastic stress computed at the crack plane (assuming crack is not present) is calculated from:

$$\sigma_b = M / Z$$

$$Z = \text{Section modulus} = \frac{\pi}{4} (R_o^4 - R_i^4) / R_o$$

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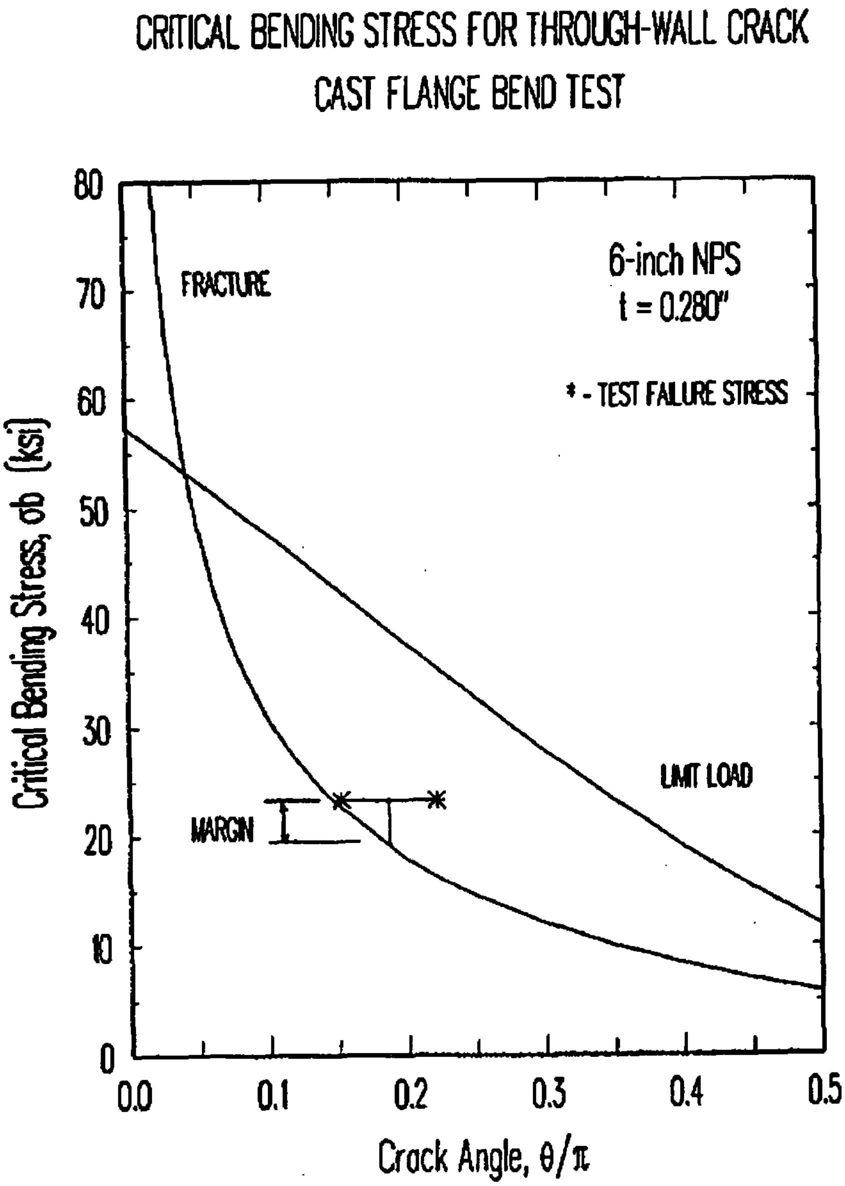

Figure 6-2 — Calculated Versus Measured Bend Test Results.

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$$= \frac{\pi}{4}(3.3125^4 - 3.0325^4) \;/\; 3.3125 = 8.496 \text{ in}^3$$

Using the previously calculated moment at the plane of failure:

$$\sigma_b = 200{,}720 \;/\; 8.496 = 23{,}630 \text{ psi}$$

Therefore, the maximum "elastic" bending stress acting at the crack location is 23,630 psi.

This stress value is plotted in Figure 6-2 for the ID and OD surface flaw lengths (i.e., $2\theta = 80°$ and $55°$, respectively). The test failure point fell within the range of the model predictions. It would be expected that the actual behavior of the flange lay somewhere between the limit load and fracture model results given the large amount of dealloying present (Figure 6-1). From the failure cross-section shown in Figure 6-1, the average dealloying depth away from the cracks is between 50 to 70%. Even with this amount of dealloying, the fracture stress was calculated to be (16.4 + 22.6)/2 = 19.5 ksi from Page 30 for an average crack angle of 68°. Therefore, the fracture model margin in predicting this test is 23.63/19.5 or 1.21. The fracture model is conservative even with 50 to 70% part-through dealloying. This result is possible because the fracture conditions of the section will be controlled by the tougher (undealloyed) material.

Despite the excessive dealloying and somewhat irregular crack shape, the fracture model gave a conservative estimate of the flange failure stress even when the OD surface length of the through-wall crack was used. For this calculation, the test prediction is 23.63/22.6 = 1.05. Therefore, the model is conservative even with subsurface cracks and dealloying to the extent shown in Figure 6-1.

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7.0 SUMMARY AND CONCLUSIONS

The following summary and conclusions are drawn from the flange test results and analysis:

1. The pressure integrity of the dealloyed/cracked flange exceeded 6.6 times maximum operating pressure and 4.4 times design pressure of the ECW system.
2. The maximum load resisted by the flange-pipe assembly was 18,200 lbs. This load was equivalent to a nominal bending stress of 23,630 psi in the pipe.
3. The calculated critical bending stress based on the fracture model was 16.4 to 22.6 ksi depending on whether ID or OD surface flaw length is used to define through-wall crack angle.
4. Based on the above findings, the dealloyed/cracked flange exhibited significant structural integrity. The flaw evaluation method for computing critical bending stress is conservative.

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8.0 REFERENCES

1. Document No. AES-C-1964-1, "Calculation of Critical Bending Stress for Dealloyed Castings in the ECW System," APTECH Project AES 93061964-1Q (November 1993) (ICD I-2).

2. Document No. AES-S-1964-1, "Flange Test Notes and Summary," APTECH Project AES 93061964-1Q (November 18, 1993)(ICD I-4).

3. "Flange Test Raw Data and Summary Information," HL&P (November 18, 1993) (ECD E-26).

4. Houston Lighting and Power Company Lab Report MT-4907 by W.F.J. Deeg, "Mapping of Dealloying in Aluminum Bronze Pipe to Flange Weld Bend Test" (December 10, 1993) (ECD E-25).

5. Bechtel Calculation RC5401, "DGB ECW Return Lines, Trains A, B & C" (July 20, 1992) (ECD-5).

6. Roark, R.J., Formulas for Stress and Strain, 4th Edition, McGraw Hill (1965), Prob. 12 Pg. 106.

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Appendix A

CALCULATION OF CRITICAL BENDING STRESS FOR 6-INCH NPS CASTING UNDER PURE BENDING

A1 INTRODUCTION

The critical bending stress for combined pressure and bending loadings was previously determined for all casting sizes in the ECW system (1). This appendix calculates the critical bending stress for zero pressure (pure bending) for the 6-inch NPS case. The results of this calculation are used for comparison with experimentally measured bending loads from the 6-inch flange test conducted by HL&P.

A2 LIMIT LOAD ANALYSIS

The limit load model and evaluation are discussed in Ref. 1. The flaw model geometry is shown in Figure A-1. The governing equations for critical bending stress P_b for pure bending case is given by:

$$P_b' = \frac{2\sigma_f}{\pi} [2 \sin \beta - \sin \theta] \qquad \text{(A-1a)}$$

$$\beta = \frac{\pi}{2} [1 - (\theta / \pi)] \qquad \text{(A-1b)}$$

where,

σ_f = Flow stress = 45 ksi (1)
θ = Half through-wall crack angle
β = Angular position to neutral axis

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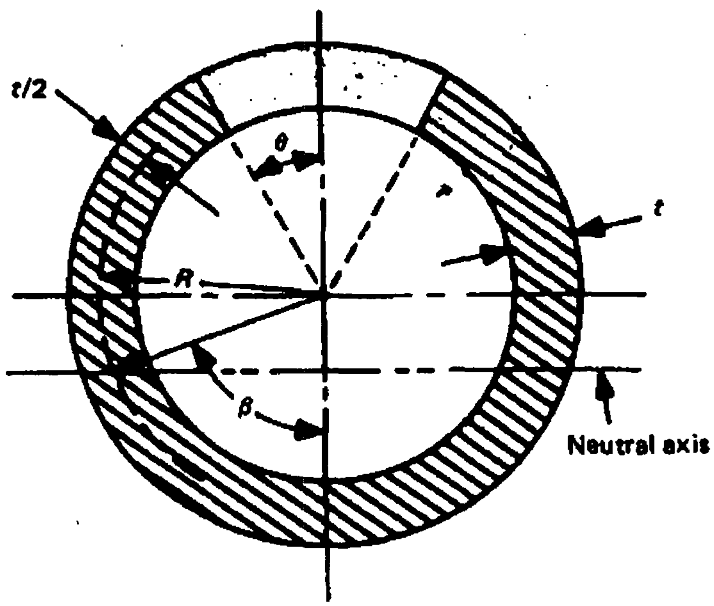

Figure A-1 — Circumferential Flaw Geometry.

Equation A-1 was solved for a range of crack angles. The results for the critical bending stress for limit load are shown in Table A-1. For the test flange, the OD crack angle is 55°:

$$\frac{\theta}{\pi} = \frac{55^\circ}{360^\circ} = 0.153$$

$$P_b' = 42.4 \text{ ksi}$$

For an ID crack angle of 80° as measure for the test flange:

$$\frac{\theta}{\pi} = \frac{80^\circ}{360^\circ} = 0.222$$

$$P_b' = 35.4 \text{ ksi}$$

Therefore, the limit load model predicts a failure stress of 35.4 to 42.4 ksi for the flange bend test. This stress represents a globally applied "elastic" stress based on gross section properties.

A3 FRACTURE ANALYSIS

The same basic flaw model shown in Figure 6-1 was used in the fracture assessment. The fracture condition is given by:

$$K_I = K_{Ia}$$

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Table A-1

SUMMARY OF LIMIT LOAD RESULTS FOR PURE BENDING
(6-INCH NOMINAL PIPE SIZE)

<u>Input Parameters:</u>

D_o = 6.625 in
R = Mean radius = 3.1725 in
P_R = Mean perimeter = $2\pi R$ = $2\pi(3.1725)$ = 19.933 in
t = 0.280 in
R/t = 11.33

Crack Angle (θ/π)	Crack Length (in) $\ell = (\theta/\pi)P_R$	θ	β	$\theta + \beta$	P_b' (ksi)
0.001	0.0199	0.0031	1.5692	1.5724	57.206
0.005	0.0997	0.0157	1.5629	1.5787	56.844
0.010	0.1993	0.0314	1.5551	1.5865	56.389
0.015	0.2990	0.0471	1.5472	1.5944	55.930
0.020	0.3987	0.0628	1.5394	1.6022	55.469
0.025	0.4983	0.0785	1.5315	1.6101	55.004
0.030	0.5980	0.0942	1.5237	1.6179	54.536
0.040	0.7973	0.1257	1.5080	1.6336	53.592
0.050	0.9967	0.1571	1.4923	1.6493	52.638
0.060	1.1960	0.1885	1.4765	1.6650	51.673
0.070	1.3953	0.2199	1.4608	1.6808	50.700
0.080	1.5947	0.2513	1.4451	1.6965	49.720
0.090	1.7940	0.2827	1.4294	1.7122	48.732
0.100	1.9933	0.3142	1.4137	1.7279	47.738
0.110	2.1927	0.3456	1.3980	1.7436	46.738
0.120	2.3920	0.3770	1.3823	1.7593	45.735
0.130	2.5913	0.4084	1.3666	1.7750	44.728
0.140	2.7907	0.4398	1.3509	1.7907	43.718
0.150	2.9900	0.4712	1.3352	1.8064	42.707
0.153	3.0454	0.4800	1.3308	1.8108	42.426
0.200	3.9867	0.6283	1.2566	1.8850	37.653
0.222	4.4296	0.6981	1.2217	1.9199	35.426
0.250	4.9834	0.7854	1.1781	1.9635	32.677
0.300	5.9800	0.9425	1.0996	2.0420	27.874
0.350	6.9767	1.0996	1.0210	2.1206	23.327
0.400	7.9734	1.2566	0.9425	2.1991	19.107
0.450	8.9700	1.4137	0.8639	2.2777	15.273
0.500	9.9667	1.5708	0.7854	2.3562	11.866
0.550	10.9634	1.7279	0.7069	2.4347	8.915
0.600	11.9600	1.8850	0.6283	2.5133	6.432
0.700	13.9534	2.1991	0.4712	2.6704	2.835
0.800	15.9467	2.5133	0.3142	2.8274	0.867

and from Ref. 1 for pure bending, the critical bending stress for fracture, σ_b^c, is:

$$\sigma_b^c = \frac{K_{Ic}}{F_b\ (\pi\ \ell\ /\ 2)^{1/2}} \qquad \text{(A-2)}$$

where,

K_{Ic} = Fracture toughness = 65 ksi $in^{1/2}$ (1)
ℓ = Crack length at mean radius position
F_b = Surface correction factor for global bending

The correction factor F_b is taken from Ref. 1:

$$F_b = 1 + A_b\ (\theta/\pi)^{1.5} + B_b\ (\theta/\pi)^{2.5} + C_b\ (\theta/\pi)^{3.5} \qquad \text{(A-3)}$$

where,

A_b = $-3.26543 + 1.52784\ (R/t) - 0.072698\ (R/t)^2 + 0.0016011\ (R/t)^3$
B_b = $11.36322 - 3.91412\ (R/t) + 0.18619\ (R/t)^2 - 0.004099\ (R/t)^3$
C_b = $-3.18609 + 3.84763\ (R/t) - 0.18304\ (R/t)^2 + 0.00403\ (R/t)^3$

Equation A-2 was solved for a range of crack angles. The results for the critical bending stress for fracture are shown in Table A-2. For the test flange, the OD crack angle is 55°:

$$\frac{\theta}{\pi} = \frac{55^\circ}{360^\circ} = 0.153$$

$$\sigma_b^c = 22.6\ \text{ksi}$$

For an ID crack angle of 80° as measured for the test flange:

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Title: Evaluation of 6-Inch Flange Test	Checked by: [illegible]	Date: 18 MAR 94	Project No.: AES 93061964-1Q
	Revision No.: 0		Sheet No.: 30 of 31

$$\frac{\theta}{\pi} = \frac{80^\circ}{360^\circ} = 0.222$$

$$\sigma_b^c = 16.4 \text{ ksi}$$

Therefore, the fracture model predicts a failure stress of 16.4 to 22.6 ksi for the flange bend test. This stress represents a globally applied "elastic" stress based on gross section properties.

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Document No.: AES-C-1964-4	Made by: RCC	Date: 12/31/93	Client: HL&P
Title: Evaluation of 6-Inch Flange Test	Checked by: [signature]	Date: 18 MAR 94	Project No.: AES 93061964-1Q
	Revision No.: 0		Sheet No.: 31 of 31

Table A-2
SUMMARY OF FRACTURE RESULTS FOR PURE BENDING
(6-INCH NOMINAL PIPE SIZE)

Input Parameters:

D_o = 6.625 in t = 0.280 in
R = 3.1725 in R/t = 11.33
P_R = 19.933 in

Calculated Parameters:

A_b = 7.0417
B_b = -15.0449
C_b = 22.7727

Crack Angle (θ/π)	Crack Length (in) $L = (\theta/\pi)P_R$	θ	F_b (Eq. A-3)	σ_b^* (ksi)
0.001	0.0199	0.0031	1.000	367.25
0.005	0.0997	0.0157	1.002	163.87
0.010	0.1993	0.0314	1.007	115.37
0.015	0.2990	0.0471	1.013	93.67
0.020	0.3987	0.0628	1.019	80.60
0.025	0.4983	0.0785	1.026	71.58
0.030	0.5980	0.0942	1.034	64.84
0.040	0.7973	0.1257	1.052	55.22
0.050	0.9967	0.1571	1.071	48.51
0.060	1.1960	0.1885	1.091	43.45
0.070	1.3953	0.2199	1.113	39.45
0.080	1.5947	0.2513	1.135	36.17
0.090	1.7940	0.2827	1.159	33.42
0.100	1.9933	0.3142	1.182	31.07
0.110	2.1927	0.3456	1.207	29.03
0.120	2.3920	0.3770	1.231	27.23
0.130	2.5913	0.4084	1.256	25.64
0.140	2.7907	0.4398	1.282	24.22
0.150	2.9900	0.4712	1.308	22.94
0.153	3.0454	0.4800	1.315	22.60
0.200	3.9867	0.6283	1.442	18.01
0.222	4.4296	0.6981	1.505	16.37
0.250	4.9834	0.7854	1.588	14.63
0.300	5.9800	0.9425	1.752	12.10
0.350	6.9767	1.0996	1.945	10.09
0.400	7.9734	1.2566	2.181	8.42
0.450	8.9700	1.4137	2.474	7.00
0.500	9.9667	1.5708	2.843	5.78
0.550	10.9634	1.7279	3.307	4.74
0.600	11.9600	1.8850	3.888	3.86
0.700	13.9534	2.1991	5.491	2.53
0.800	15.9467	2.5133	7.855	1.65

Attachment C

Table reflecting leaking components that have occurred since July 28, 2011

TABLE 1 – ECW DATA Updated from July 28, 2011 – 2013						
No	**Date**	**Component Type**	**Metallurgical Exam Information**	**Location**	**Information without Metallurgical Exam**	**References Comments**
55	7-28-11	U2 Cast Valve Body		1-EW-FV6936 ECW 2B Return Header Blowdown Valve	Residue buildup at several discrete spots on the valve body at the Return Header machined inlet portion near the flange.	CR 11-12309
56	1-9-12	U2 4" Cast valve body		C2EWFV6937 Return Header Blowdown Valve	Residue buildup indicative of through-wall dealloying at Valve Body	CR 12-1044
57	6-12-12	U2 10" Cast flange		3R282TEW0274 Chiller ECW Cross-Tie valve flange	Residue buildup indicative of through-wall dealloying on the cross-tie side flange	CR 12-22876
58	3-4-14	U1 1"-1/2" Root Valve Socket Adapter		3R281TEW0283 CCW Pump Supplemental Cooler 11A FI/FT high side root valve	Discoloration spots at 9 o'clock and 2 o'clock on shop weld	CR 14-4206

Attachment D

CREE 12-29261-95, "STP evaluation methodology and associated analyses calculating the critical bending stresses for the four flaw cases"

(FOR INFORMATION ONLY. THE CASES ANALYZED ARE HYPOTHETICAL IN NATURE AND DO NOT REPRESENT ACTUAL PLANT CONDITIONS.)

The attached CREE provides a typical analytical methodology used by STP to evaluate the four hypothethecal non-conforming conditions. It is not intended to be the bounding analytical methodology for evaluating all future potential non-conforming conditions.

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Form 1	Engineering Evaluation	

CR Action #: 12-29261-95 **CR Level:** CNAQ-E **DTL #1008468 except as noted below**

CREE Type: ☑ GENERAL Evaluation (See Addendum 2)

☐ MATERIAL DEFICIENCY - - - > (Classify) (See Addendum 1) ☐ DEGRADED [DTL #1008489] ☐ NONCONFORMING [DTL #1008488] ☐ NEITHER

☐ Aging ECO (See Addendum 7) ☐ RIS 2005-20 Issue (See Addendum 8) ☐ GL 86-10 Evaluation (See Addendum 9) ☐ FME (See Addendum 10)

Problem Statement :

STP Nuclear Operating Company (STPNOC) submitted a License Renewal Application (LRA) for the South Texas Project Units 1 and 2 via STPNOC letter dated October 25, 2010, from G.T. Powell to NRC Document Control Desk, "License Renewal Application" (NOC-AE-10002607). Within NRC Letter dated December 18, 2012, "Requests for Additional Information for the Review of the South Texas Project, Units 1 and 2, License Renewal Application – Set 26 (ST-AE-NOC-14002493) the NRC staff requested additional information for review of the STP LRA. Specifically, part "f" requests that STP identify how field observations of leaking degraded components are used in conjunction with the analytical output of AES-C-1964-1, "Calculation of Critical Bending Stress for Dealloyed Aluminum-Bronze Castings in the ECW System," and the existing pipe stress analyses in order to analyze for structural integrity as it relates to the component performing its intended function. The staff described four flaw cases in the ECW System requiring STP methodology and estimations of the critical bending stresses that STP will use in evaluating operability. The purpose of the CREE is to document the STPNOC evaluation methodology and associated analyses required to calculate the critical bending stresses used for the four flaw cases provided by the NRC.

Conclusion:

See Table 1: Evaluation Summary (Pages 6 and 7) for the analyses results and responses in relation to the NRC staff described four flaw cases in the ECW System.

Additional Actions Required? ☑ No ☐ Yes **If Yes, list CR Action #s** N/A

Todd Maxey / [signature]	03/11/2014	Technical Review Required if SCAQ/CAQ-S Wei Chang / [signature]	~~03/11/2014~~ 06/12/2014 WC
Preparer (Print/Sign)	**Date**	**Technical Reviewer (Print/Sign)**	**Date**
Swapan Saha / [signature]	3/12/14	Richard Kersey / [signature]	3/12/2014 RPKersey 6/12/2014
		Supervisor (Print/Sign)	**Date**
		Manager Approval Required if SCAQ/CAQ-S	
Other Reviewers (Print/Sign)	**Date**	**Manager (Print/Sign/Title)**	**Date**

This form when complete, SHALL be retained.

Background

STP Nuclear Operating Company (STPNOC) submitted a License Renewal Application (LRA) for the South Texas Project Units 1 and 2 via STPNOC letter dated October 25, 2010, from G.T. Powell to NRC Document Control Desk, "License Renewal Application" (NOC-AE-10002607). Within NRC Letter dated December 18, 2012, "Requests for Additional Information for the Review of the South Texas Project, Units 1 and 2, License Renewal Application – Set 26 (ST-AE-NOC-14002493) the NRC staff requested additional information for review of the STP LRA. Specifically, part "f" requests that STP identify how field observations of leaking degraded components are used in conjunction with the analytical output of AES-C-1964-1, " Calculation of Critical Bending Stress for Dealloyed Aluminum-Bronze Castings in the ECW System," and the existing pipe stress analyses in order to analyze for structural integrity as it relates to the component performing its intended function. The staff described four flaw cases in the ECW System requiring STP methodology and estimations of the critical bending stresses that STP will use in evaluating operability. The four flaw cases/scenarios are described as follows:

i. Four small rounded indications of through-wall dealloying located in a circumferential axis at 10:00, 11:00, 1:00, and 2:00 on a 10-inch flange.
ii. One indication at 10:00, one-half inch long, with what appears to be rounded ends and no measurable width on a 4-inch flange.
iii. One "greenish" stain approximately 1/8 inch diameter at the 10:00 position on a 6-inch flange.
iv. One crack-like indication, one-half inch long, within a larger greenish stain with a circumferential length of one inch.

The NRC staff requested that STP state the following for each of the aforementioned cases:

- The size of the OD (Outside Diameter) flaw.
- The corresponding size of the internal flaw that would be used in the structural integrity determination.
- Which figure would be used from AES-C-1964-1.
- The stress component input values that would be utilized from the highest stress location in the Essential Cooling Water System (ECWS) with susceptible components for that size as obtained by the stress analyses on record and how they would be combined in the structural integrity evaluation.
- What structural factor would be used
- The critical bending stress as derived from the figures in AES-C-1964-1 and whether the component would be considered to be capable of meeting its intended function.

Evaluation

The four cases described above are evaluated in the following section. A spreadsheet has been developed to calculate the critical bending stresses for both the limit load and fracture mechanisms (LEFM). Case i will be solved step by step to show the methodology within the spreadsheet. The remaining cases are solved using the spreadsheet and are contained within Attachment 1.

Case "i)" described above requires evaluation of four small rounded indications of through-wall dealloying located in a circumferential axis at 10:00, 11:00, 1:00, and 2:00 on a 10-inch flange. Assuming each of the indications is approximately 1/8" long, the angular distance between the 10:00 and 11:00 flaw would be less than 30 degrees; this would also be true for the indications at the 1:00 and 2:00 positions. For the indications between 11:00 and 1:00, the angular distance would be greater than 30 degrees. Given this, the flaw will be assumed as one large flaw with a length equivalent to the farthest extent of each flaw.

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The outside diameter length of the flaw is given by the following:

Outside Diameter Length (L_{OD}) = Outside Radius (R_O) x Angular Distance (2θ)

$L_{OD} = (R_O)(2\theta) = (10.75/2)(120°)(\pi/180°) = 11.257"$ — Outside Diameter Flaw Length

Therefore, L_{OD} is assumed to be approximately 11.75" to 12" for conservatism. The flange is modeled using piping properties.

Inputs:

NPS = 10"	Nominal Component Size
$t = 0.365"$	Piping Wall Thickness (Ref. 6)
$D_o = 10.75"$	Nominal Outside Piping Diameter (Ref. 6)
$S_y = 25$ ksi	Yield Stress (Ref. 3)
$S_u = 65$ ksi	Ultimate Stress (Ref. 3)
$K_{IC} = 65$ ksi$\sqrt{in.}$.	Fracture Toughness (Ref. 3)

Analysis:

$R_o = D_o/2 = 10.75/2 = 5.375$ in.	Outside Radius
$R_{Mean} = (D_o - t)/2 = (10.75-0.365)/2 = 5.1925$ in.	Mean Radius
$\sigma_f = (S_y + S_u)/2 = (25+65)/2 = 45$ ksi.	Flow Stress
$\theta_c = L_{OD}/D_o = 12"/10.75" = 1.1163$ radians	Outside Diameter Flaw Half-Angle
$2\theta_c = 2(\theta_c)(180°/\pi) = (2)(1.1163)(180°/\pi) = 127.9162°$	Outside Diameter Flaw Angle

Average and inside crack lengths are determined per Aptech provided relationships listed below (Ref. 4):

$2\theta_d = 5(2\theta_c)$	$0 \le 2\theta_c \le 8°$
$2\theta_d = 40°$	$8° \le 2\theta_c \le 28°$
$2\theta_d = 2\theta_c + 12°$	$2\theta_c > 28°$

$2\theta_d = 2\theta_c + 12° = 127.9162° + 12° = 139.9162°$	Flaw Angle at Mean Radius
$\theta_d = (2\theta_d)(\pi/180°)(1/2) = (139.9162°)(\pi/180°)(1/2) = 1.2210$ radians	Flaw Half-Angle at Mean Radius
$L = \theta_d(D_o - t) = (1.2210)(10.75-0.365) = 12.6801$ in.	Flaw Length at Mean Radius
$a = L/2 = (12.6801)/(2) = 6.3400$ in.	Flaw Half-Length at Mean Radius
$\theta_d/\pi = 1.2210/\pi = 0.3887$	Unitless Crack Angle

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Limit Load Analysis

P = 120 psig — Design Pressure for ECW System (Ref. 6)

$\sigma_m = (P*D_o)/(4*t) = (120*10.75)/(4*0.365) = 883.562$ psi = 0.8836 ksi — Axial Membrane Stress (Ref. 3)

$\beta = \frac{\pi}{2}\left(1-\left(\frac{\theta}{\pi}\right)-\frac{\sigma_m}{\sigma_f}\right) = (\pi/2)(1-0.3887-(0.8836/45)) = 0.9295$ radians — Angular Position of Neutral Axis[1]

$P'_b = (2\sigma_f/\pi)(2\sin(\beta)-\sin(\theta_D)) = ((2*45)/(\pi))*(2\sin(0.9295)-\sin(1.2210) = 18.9977$ ksi — Critical Bending Stress (LLPC)

Fracture Analysis

The linear elastic fracture mechanics analysis performed for a through wall circumferential crack where K_I applied stress intensity factor is maintained below K_{IC} (fracture toughness of the base material). The fracture toughness used within Aptech Calculation AES-C-1964-1 is 65 ksi$\sqrt{\text{in}}$. The fracture mechanics equations listed below are taken from APTECH calculation AES-C-1964-1 (Ref. 3).

The free surface correction factors are functions that depend on crack angle, θ_D/π, and casting geometry, R_{Mean}/t. For the range of R_{Mean}/t between 10 and 15, a simplified "curve fit" expression was developed from the work of Folias and Erdogan for short length cracks, and work from Sanders for long cracks is used.[2]

For uniaxial tension:

$R_{Mean}/t = (5.1925)/(0.365) = 14.22603$

$A_m = -2.02917+1.67763(R/t)-0.07987(R/t)^2+0.00176(R/t)^3$

$= -2.02917+1.67763(14.22603)-0.07987(14.22603)^2+0.00176(14.22603)^3 = 10.7399$

$B_m = 7.09987-4.42394(R/t)+0.21036(R/t)^2-0.00463(R/t)^3$

$= 7.09987-4.42394(14.22603)+0.21036(14.22603)^2-0.00463(14.22603)^3 = -26.5926$

$C_m = 7.79661+5.16676(R/t)-0.24577(R/t)^2+0.00541(R/t)^3$

$= 7.79661+5.16676(14.22603)-0.24577(14.22603)^2+0.00541(14.22603)^3 = 47.1359$

$F_m = 1+A_m(\theta/\pi)^{1.5}+B_m(\theta/\pi)^{2.5}+C_m(\theta/\pi)^{3.5}$

$= 1+10.7399\ (0.3887)^{1.5}+-26.5926\ (0.3887)^{2.5}+47.1359\ (0.3887)^{3.5} = 2.8232$

For Global Bending:

$A_b = -3.26543+1.52784(R/t)-0.072698(R/t)^2+0.0016011(R/t)^3$

$= -3.26543+1.52784(14.22603)-0.072698(14.22603)^2+0.0016011(14.22603)^3 = 8.3667$

Notes:

1. β is only valid for a/t = 1.0 (i.e. assumption is a through-wall crack) and $(\theta+\beta) \leq \pi$.
2. The free surface correction factors used in this analysis are consistent with those contained in Ref. 3 Table 6-5.

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$B_b = 11.36322 - 3.91412(R/t) + 0.18619(R/t)^2 - 0.004099(R/t)^3$

$= 11.36322 - 3.91412(14.22603) + 0.18619(14.22603)^2 - 0.004099(14.22603)^3 = -18.4393$

$C_b = -3.18609 + 3.84763(R/t) - 0.18304(R/t)^2 + 0.00403(R/t)^3$

$= -3.18609 + 3.84763(14.22603) - 0.18304(14.22603)^2 + 0.00403(14.22603)^3 = 26.1094$

$F_b = 1 + A_b(\theta/\pi)^{1.5} + B_b(\theta/\pi)^{2.5} + C_b(\theta/\pi)^{3.5}$

$= 1 + 8.3667\ (0.3887)^{1.5} + (-18.4393\ (0.3887)^{2.5}) + 26.1094\ (0.3887)^{3.5} = 2.2464$

$\sigma_b = (K_{IC})/(F_b(\pi a)^{1/2}) - \sigma_m(F_m/F_b)$

$= (65)/(2.2464(\pi * 6.34)^{1/2}) - (0.8836)(2.8232/2.2464) = 5.3730$ ksi

Therefore, Fracture controls and the critical bending stress is 5.3730 ksi.

Conclusion

A summary of the critical bending stress analysis results and responses for the NRC questions given is given in Table 1: Evaluation Summary on the following pages.

Additional Required Actions

None.

References

**These reference numbers provided only correlate with the body of this CREE and do not apply to Table 1: Evaluation Summary.

1. STPNOC letter dated October 25, 2010, from G. T. Powell to NRC Document Control Desk, "License Renewal Application" (NOC-AE-10002607) (ML103010257)
2. NRC letter dated December 18, 2012, "Requests for Additional Information for the Review of the South Texas Project, Units 1 and 2, License Renewal Application – Set 26 (TAC Nos. ME4936 and ME4937)" (ST-AE-NOC-14002493) (ML12333A227)
3. Document No. AES-C-1964-1, "Calculation of Critical Bending Stress for Dealloyed Aluminum Bronze Castings in the ECW System", APTECH Project AES 93061964-1Q, Revision 0, December 1993. STP STI: 1436366.
4. Document No. AES-C-1964-5, "Evaluation of the Significance of Dealloying and Subsurface Cracks on Flaw Evaluation Method", APTECH Project AES 93061964-1Q, Revision 0, December 1994. STP STI: 30040905.
5. Not used.
6. 5L019PS0004, Specification for Criteria for Piping Design and Installation, Revision 24.

Table 1: Evaluation Summary

Scenario Number	The size of the OD (Outside Diameter) flaw	The corresponding size of the internal flaw that would be used in the structural integrity evaluation	Which figure would be used from AES-C-1964-1	The stress component input values that would be utilized from the highest stress location in the Essential Cooling Water System with susceptible components for that size as obtained by the stress analyses on record and how they would be combined in the structural integrity evaluation.	What structural factor would be used	The critical bending stress as derived from the figures in AES-C-1964-1 and whether the component would be considered capable of meetings its intended function	Notes/Comments	References
i.	Option 1: One long flaw of 12"	Option 1: 12.68"	Option 1: Figure 7-6 from APTECH calculation AES-C-1964-1 may be used provided one large flaw from 10:00 to 2:00 is assumed	STP does not use the highest stress location in the ECW System unless the component specific stresses are not available. The component specific stresses are extracted from the applicable pipe stress calculation at the node point(s) corresponding to that section/element where load combinations are performed per the applicable ASME Section III requirements. For structural integrity analysis, primary membrane and bending stresses are separated and evaluated per the requirements of ASME Appendix H or C.	For Normal/Upset Service Conditions the structural factor that would be used is 2.77 and for Emergency/Faulted Service Conditions the structural factor that would be used is 1.39 per Appendix C or Appendix H.	Option 1: Critical bending stress assuming one large flaw from 10:00 to 2:00 positions will be approximately 5.3 ksi (calculated value is 5.37 ksi) (LEFM – Controls Bending Stress; critical bending stress for LLPC was calculated to be approximately 18.99 ksi) based on Figure 7-6 contained within Reference 1. STP assumes the component will be capable of meeting its intended design function due to the fact that no applied component stresses/loadings were provided.	1. The sizes of internal flaws are determined using the correlation equations provided in the APTECH Calculation AES-C-1964-5, Rev. 0, page 12 of 31. 2. The flaw length is rounded to the nearest decimal per IWA-3200(a).	1. Document No. AES-C-1964-1, "Calculation of Critical Bending Stress for Dealloyed Aluminum Bronze Castings in the ECW System." Rev. 0, December 1993. STP STI: 1436366. 2. Cofie, Nathaniel and others."Failure Bending for Pipes with an Arbitrary-Shaped Circumferential Flaw". 3. Cofie, Nathaniel and others. "Prodiction of Collapse Stress for Pipes with Arbitrary Multiple Circumferential Surface Flaws". 4. Not used. 5. Document No. AES-C-1964-5, "Evaluation of the Significance of Dealloying and Subsurface Cracks on Flaw Evaluation Method", APTECH Project AES 93061964-1Q, Revision 0, December 1994. STP STI: 30040905.
	Option 2: Four 1/8" to ¼" flaws per ASME Section XI, Paragraph IWA-3400 (b)	Option 2: Four flaws of approximately 1.25" long each	Option 2: Use evaluation techniques contained in References 2 and 3. The APTECH figures contained within Reference 1 apply only for single flaw evaluations and cannot be used for this option.			Option 2: Use techniques contained within References 2 and 3. APTECH figures apply only for single flaw evaluations and cannot be used for this option. STP did not calculate the critical bending stress for this option.	1. The angular position of the neutral axis (β) for bending about the net section is calculated by summing the individual impact (Σ(a/t)θ) of each flaw (LLPC only). 2. The sizes of internal flaws are determined using the correlation equations provided in the APTECH Calculation AES-C-1964-5, Rev. 0, page 12 of 31. 3. The flaw length is rounded to the nearest decimal per IWA-3200(a).	
	Option 3: Two flaws approximately 3.0" long each (Combine flaws at 10:00 and 11:00 position and also 1:00 and 2:00 position)	Option 3: Two large flaws approximately 4.1" long each	Option 3: Use evaluation techniques contained in References 2 and 3. The APTECH figures contained within Reference 1 apply only for single flaw evaluations and cannot be used for this option.			Option 3: Use techniques contained within References 2 and 3. APTECH figures apply only for single flaw evaluations and cannot be used for this option. STP did not calculate the critical bending stress for this option.	1. The angular position of the neutral axis (β) for bending about the net section is calculated by summing the individual impact (Σ(a/t)θ) of each flaw (LLPC only). 2. The sizes of internal flaws are determined using the correlation equations provided in the APTECH Calculation AES-C-1964-5, Rev. 0, page 12 of 31. 3. The flaw length is rounded to the nearest decimal per IWA-3200(a).	

Table 1: Evaluation Summary

Scenario Number	The size of the OD (Outside Diameter) flaw	The corresponding size of the internal flaw that would be used in the structural integrity evaluation	Which figure would be used from AES-C-1964-1	The stress component input values that would be utilized from the highest stress location in the Essential Cooling Water System with susceptible components for that size as obtained by the stress analyses on record and how they would be combined in the structural integrity evaluation.	What structural factor would be used	The critical bending stress as derived from the figures in AES-C-1964-1 and whether the component would be considered capable of meetings its intended function	Notes/Comments	References
ii.	0.5"	1.4881"	Figure 7-3 from APTECH calculation AES-C-1964-1	Component specific stress from the applicable pipe stress calculation at the node point(s) corresponding to that section/element.	For Normal/Upset Service Conditions the structural factor that would be used is 2.77 and for Emergency/Faulted Service Conditions the structural factor that would be used is 1.39 per Appendix C or Appendix H.	Critical bending stress will be approximately 35.6 ksi (calculated value is 35.62 ksi) (LEFM – Controls Bending Stress; critical bending stress for LLPC was calculated to be approximately 46.4 ksi) based on Figure 7-3 contained in Reference 1. STP assumes the component will be capable of meeting its intended design function due to the fact that no applied component stresses/loadings were provided.	1. The sizes of internal flaws are determined using the correlation equations provided in the APTECH Calculation AES-C-1964-5, Rev. 0, page 12 of 31. 2. The flaw length is rounded to the nearest decimal per IWA-3200(a).	1. Document No. AES-C-1964-1, "Calculation of Critical Bending Stress for Dealloyed Aluminum Bronze Castings in the BCW System." Draft Rev. 0, December 1993. 2. Not used. Document No. AES-C-1964-1, "Calculation of Critical Bending Stress for Dealloyed Aluminum Bronze Castings in the ECW System." Rev. 0, December 1993. STP STI: 1436366. 4. Document No. AES-C-1964-5, "Evaluation of the Significance of Dealloying and Subsurface Cracks on Flaw Evaluation Method", APTECH Project AES 93061964-1Q, Revision 0, December 1994. STP STI: 30040905.
iii.	0.25"	1.1972"	Figure 7-4 from APTECH calculation AES-C-1964-1	Component specific stress from the applicable pipe stress calculation at the node point(s) corresponding to that section/element.	For Normal/Upset Service Conditions the structural factor that would be used is 2.77 and for Emergency/Faulted Service Conditions the structural factor that would be used is 1.39 per Appendix C or Appendix H.	Critical bending stress will be approximately 42.6 ksi (calculate value is 42.69 ksi) (LEFM – Controls Bending Stress; critical bending stress for LLPC was calculated to be approximately 51.5 ksi) based on Figure 7-4 contained in Reference 1. STP assumes the component will be capable of meeting its intended design function due to the fact that no applied component stresses/loadings were provided.	1. The sizes of internal flaws are determined using the correlation equations provided in the APTECH Calculation AES-C-1964-5, Rev. 0, page 12 of 31. 2. The flaw length is rounded to the nearest decimal per IWA-3200(a).	
iv.	1"	2.2148"	Figure 7-4 from APTECH calculation AES-C-1964-1	Component specific stress from the applicable pipe stress calculation at the node point(s) corresponding to that section/element.	For Normal/Upset Service Conditions the structural factor that would be used is 2.77 and for Emergency/Faulted Service Conditions the structural factor that would be used is 1.39 per Appendix C or Appendix H.	Critical bending stress will be approximately 28.0 ksi (calculated value is 28.07 ksi) (LEFM – Controls Bending Stress; critical bending stress for LLPC was calculated to be approximately 46.4 ksi) based on Figure 7-4 contained in Reference 1. STP assumes the component will be capable of meeting its intended design function due to the fact that no applied component stresses/loadings were provided.	1. STP assumes flaw is on a 6" flange. 2. The sizes of internal flaws are determined using the correlation equations provided in the APTECH Calculation AES-C-1964-5, Rev. 0, page 12 of 31. 3. The flaw length is rounded to the nearest decimal per IWA-3200(a).	

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Form 3	**CREE Continuation Sheet**	

Attachment 1: Critical Bending Stress Analyses

CALCULATION OF CRITICAL BENDING STRESS FOR DEALLOYED ALUMINUM BRONZE CASTINGS

Flaw Location Information

Casting Number	N/A
Weld Number	N/A
Single/Multiple Flaws	Single
Crack Detected	N/A
Average Dealloying <60% or Indeterminate	N/A
Piping Stress Calculation	N/A
Pipe Stress Node	N/A

Component Geometry

Nominal Component Size	NPS =	10	in.
Wall Thickness	t =	0.365	in.
Nominal Outside Diameter	D_O =	10.75	in.
Outside Radius	R_O =	5.375	in.
Mean Radius	R_{Mean} =	5.1925	in.

Flaw Data

Outside Diameter Flaw Length	L_{OD} =	12	in.
Outside Diameter Flaw Half-Angle	θ_C =	1.1163	radians
Outside Diameter Flaw Angle	$2\theta_C$ =	127.9162	degrees
Flaw Angle at Mean Radius	$2\theta_D$ =	139.9162	degrees
Flaw Half-Angle at Mean Radius	θ_D =	1.2210	radians
Flaw Length at Mean Radius	L =	12.6801	in.
Flaw Half-Length at Mean Radius	a =	6.3400	in.
Unitless Flaw Angle at Mean Radius	θ_D/π =	0.3887	

Material Properties

Yield Stress	S_y =	25	ksi
Ultimate Stress	S_u =	65	ksi
Flow Stress	σ_f =	45	ksi
Fracture Toughness	K_{IC} =	65	ksi√in.

Pressure Stress

Membrane Stress	σ_m =	0.8836	ksi

Limit Load Analysis

Angular Position of the Neutral Axis	β =	0.9295	radians
Critical Bending Stress	σ_{bc} =	18.9977	ksi

Comments

Case i:
Four small rounded indications of through wall dealloying located in a circumferential axis at 10:00, 11:00, 1:00, and 2:00 on a 10-inch flange. This evaluation assumes one large flaw with a length equivalent to the farthest extent of each flaw.

Fracture Anaysis

	A_M =	10.7399	
	B_M =	-26.5926	
	C_M =	47.1359	
Free surface correction factor for uniform stress	F_M =	2.8232	
	A_B =	8.3667	
	B_B =	-18.4393	
	C_B =	26.1094	
Free surface correction factor for bending stress	F_B =	2.2464	
Critical Bending Stress	σ_{bc} =	5.3730	ksi

Summary

Limit Load Critical Bending Stress	σ_{bcLL} =	18.9977
Fracture Critical Bending Stress	σ_{bcF} =	5.3730
Dominant Failure Mode	LL/FR =	FR
Controlling Critical Bending Stress	σ_{bc} =	5.3730

CALCULATION OF CRITICAL BENDING STRESS FOR DEALLOYED ALUMINUM BRONZE CASTINGS

Flaw Location Information

Casting Number	N/A
Weld Number	N/A
Single/Multiple Flaws	Single
Crack Detected	N/A
Average Dealloying <60% or Indeterminate	N/A
Piping Stress Calculation	N/A
Pipe Stress Node	N/A

Component Geometry

Nominal Component Size	NPS =	4	in.
Wall Thickness	t =	0.237	in.
Nominal Outside Diameter	D_O =	4.5	in.
Outside Radius	R_O =	2.25	in.
Mean Radius	R_{Mean} =	2.1315	in.

Flaw Data

Outside Diameter Flaw Length	L_{OD} =	0.5	in.
Outside Diameter Flaw Half-Angle	θ_C =	0.1111	radians
Outside Diameter Flaw Angle	$2\theta_C$ =	12.7324	degrees
Flaw Angle at Mean Radius	$2\theta_D$ =	40.0000	degrees
Flaw Half-Angle at Mean Radius	θ_D =	0.3491	radians
Flaw Length at Mean Radius	L =	1.4881	in.
Flaw Half-Length at Mean Radius	a =	0.7440	in.
Unitless Flaw Angle at Mean Radius	θ_D/π =	0.1111	

Material Properties

Yield Stress	S_y =	25	ksi
Ultimate Stress	S_u =	65	ksi
Flow Stress	σ_f =	45	ksi
Fracture Toughness	K_{IC} =	65	ksi√in.

Pressure Stress

Membrane Stress	σ_m =	0.5696	ksi

Limit Load Analysis

Angular Position of the Neutral Axis	β =	1.3764	radians
Critical Bending Stress	σ_{bc} =	46.4182	ksi

Comments

Case ii:
One indication at 10:00, one-half inch long, with what appears to be rounded ends and no measurable width on a 4-inch flange.

Fracture Anaysis

	A_M =	7.8788	
	B_M =	-19.0405	
	C_M =	38.3209	
Free surface correction factor for uniform stress	F_M =	1.2310	
	A_B =	5.7599	
	B_B =	-11.7608	
	C_B =	19.5445	
Free surface correction factor for bending stress	F_B =	1.1739	
Critical Bending Stress	σ_{bc} =	35.6205	ksi

Summary

Limit Load Critical Bending Stress	σ_{bcLL} =	46.4182
Fracture Critical Bending Stress	σ_{bcF} =	35.6205
Dominant Failure Mode	LL/FR =	FR
Controlling Critical Bending Stress	σ_{bc} =	35.6205

CALCULATION OF CRITICAL BENDING STRESS FOR DEALLOYED ALUMINUM BRONZE CASTINGS

Flaw Location Information

Casting Number	N/A
Weld Number	N/A
Single/Multiple Flaws	Single
Crack Detected	N/A
Average Dealloying <60% or Indeterminate	N/A
Piping Stress Calculation	N/A
Pipe Stress Node	N/A

Component Geometry

Nominal Component Size	NPS =	6	in.
Wall Thickness	$t =$	0.28	in.
Nominal Outside Diameter	$D_O =$	6.625	in.
Outside Radius	$R_O =$	3.3125	in.
Mean Radius	$R_{Mean} =$	3.1725	in.

Flaw Data

Outside Diameter Flaw Length	$L_{OD} =$	0.25	in.
Outside Diameter Flaw Half-Angle	$\theta_C =$	0.0377	radians
Outside Diameter Flaw Angle	$2\theta_C =$	4.3242	degrees
Flaw Angle at Mean Radius	$2\theta_D =$	21.6210	degrees
Flaw Half-Angle at Mean Radius	$\theta_D =$	0.1887	radians
Flaw Length at Mean Radius	$L =$	1.1972	in.
Flaw Half-Length at Mean Radius	$a =$	0.5986	in.
Unitless Flaw Angle at Mean Radius	$\theta_D/\pi =$	0.0601	

Material Properties

Yield Stress	$S_y =$	25	ksi
Ultimate Stress	$S_u =$	65	ksi
Flow Stress	$\sigma_f =$	45	ksi
Fracture Toughness	$K_{IC} =$	65	ksi√in.

Pressure Stress

Membrane Stress	$\sigma_m =$	0.7098	ksi

Limit Load Analysis

Angular Position of the Neutral Axis	$\beta =$	1.4517	radians
Critical Bending Stress	$\sigma_{bc} =$	51.5165	ksi

Comments

Case iii:
One "greenish" stain approximately 1/8" diameter at 10:00 position on a 6-inch flange.

Fracture Anaysis

	$A_M =$	9.2855	
	$B_M =$	-22.7542	
	$C_M =$	42.6558	
Free surface correction factor for uniform stress	$F_M =$	1.1188	
	$A_B =$	7.0417	
	$B_B =$	-15.0449	
	$C_B =$	22.7727	
Free surface correction factor for bending stress	$F_B =$	1.0916	
Critical Bending Stress	$\sigma_{bc} =$	42.6966	ksi

Summary

Limit Load Critical Bending Stress	$\sigma_{bcLL} =$	51.5165
Fracture Critical Bending Stress	$\sigma_{bcF} =$	42.6966
Dominant Failure Mode	LL/FR =	FR
Controlling Critical Bending Stress	$\sigma_{bc} =$	42.6966

CALCULATION OF CRITICAL BENDING STRESS FOR DEALLOYED ALUMINUM BRONZE CASTINGS

Flaw Location Information

Casting Number	N/A
Weld Number	N/A
Single/Multiple Flaws	Single
Crack Detected	N/A
Average Dealloying <60% or Indeterminate	N/A
Piping Stress Calculation	N/A
Pipe Stress Node	N/A

Component Geometry

Nominal Component Size	NPS =	6	in.
Wall Thickness	t =	0.28	in.
Nominal Outside Diameter	D_o =	6.625	in.
Outside Radius	R_o =	3.3125	in.
Mean Radius	R_{Mean} =	3.1725	in.

Flaw Data

Outside Diameter Flaw Length	L_{OD} =	1	in.
Outside Diameter Flaw Half-Angle	θ_C =	0.1509	radians
Outside Diameter Flaw Angle	$2\theta_C$ =	17.2968	degrees
Flaw Angle at Mean Radius	$2\theta_D$ =	40.0000	degrees
Flaw Half-Angle at Mean Radius	θ_D =	0.3491	radians
Flaw Length at Mean Radius	L =	2.2148	in.
Flaw Half-Length at Mean Radius	a =	1.1074	in.
Unitless Flaw Angle at Mean Radius	θ_D/π =	0.1111	

Material Properties

Yield Stress	S_y =	25	ksi
Ultimate Stress	S_u =	65	ksi
Flow Stress	σ_f =	45	ksi
Fracture Toughness	K_{IC} =	65	ksi√in.

Pressure Stress

Membrane Stress	σ_m =	0.7098	ksi

Limit Load Analysis

Angular Position of the Neutral Axis	β =	1.3715	radians
Critical Bending Stress	σ_{bc} =	46.3634	ksi

Comments

Case iv:
One crack-like indication, one-half inch long, within a larger greenish stain with a circumferential length of one inch.

Fracture Anaysis

	A_M =	9.2855	
	B_M =	-22.7542	
	C_M =	42.6558	
Free surface correction factor for uniform stress	F_M =	1.2698	
	A_B =	7.0417	
	B_B =	-15.0449	
	C_B =	22.7727	
Free surface correction factor for bending stress	F_B =	1.2093	
Critical Bending Stress	σ_{bc} =	28.0717	ksi

Summary

Limit Load Critical Bending Stress	σ_{bcLL} =	46.3634
Fracture Critical Bending Stress	σ_{bcF} =	28.0717
Dominant Failure Mode	LL/FR =	FR
Controlling Critical Bending Stress	σ_{bc} =	28.0717

Attachment E

Commitment No. 46, in response to RAI B2.1.37-4 Issue 5

Summary of the results of the leak rate analysis

Excerpts taken from:
(STP Calculation 14-EW-003, "Flood and Leak Rate Analysis for a Circumferential Crack in Above Ground ECW Piping")

STP has administrative leakage limits of 8 GPM, 0.3375 GPM, and 2.3 GPM for the Mechnical Auxiliary Building (MAB), Standby Diesel Generator Buiding (SBDG), and the Essential Cooling Water Intake Structure (ECWIS) respectively. Therefore, the maximum total leakage at any time is controlled at approximately 10.5 GPM assuming each of the supplied buildings has at least one actively leaking component.

Flow requirements for the supplied safety related equipment. Unit 1 Train A (Typical)

Safety-Related Equipment	TAG/TPNS [1]	Design Specified Flow Requirement GPM (Ref. 4, 5, and 6)[3]	ECW piping Flow Capacity To Equipment Inlet GPM (Ref. 3)	Flow Safety factor (Flow Capacity – Flow Requirement)	Comments
Standby Diesel Generator Inter-coolers (Ref. 4)	3Q151MDG0134	560 GPM	572 GPM 6"EW1125WT3 @ 6.35 Ft per Second (FPS)	12GPM	Total ECW flow requirement 1350 GPM @ 70' TDH 10"EW1106WT 3 CAPABLE SUPPLYING 1498GPM
Standby Diesel Generator Auxiliary Equipment Skid Coolers (Ref. 4)	3Q151MSA0134	628 GPM for Jacket Water Cooler 298 GPM for Lube Oil Cooler	628 GPM 6"EW1127WT3 @6.97 FPS 298 GPM 4"EW1129WT3 @ 7.51 FPS	0 GPM[4] 0 GPM[4]	
Essential HVAC Chillers (300 Ton)	3V111VCH004	1100GPM	1100 GPM @ 7.05 FPS	0 GPM[4]	Tube Side HX
Component Cooling Water Heat Exchanger	3R201NHX101A	15000 GPM	15000 GPM 30"EW1102WT 3 @ 7.04 FPS	0 GPM[4]	Tube Side of HX
Component Cooling Water Pump Supplementary Coolers	3V101VAH001	36 GPM[2] 40 to 50 GPM per procedure 0POP02-EW-0001	75 GPM 3"EW1113WT3 @7.17 FPS	39 GPM per Design 25 GPM per procedure 0POP02-EW-0001	Tube Side HX

(1) All TAG TPNS numbers are referenced from Piping and Instrumentation Diagram (P&ID) Drawing 5R289F05038, Sht. 1, Rev. 15.

(2) Specification for Safety Class Air Handling Units 3V259VS0005 for the HL&P STPEGS, Page 19, Item C7 for CCW Pumps. Note that normal operating procedure (0POP02-EW-0001, Rev. 67, page 37 of 67), requires operation to set initial flow 40 to 50 GPM

(3) Design Flows are referenced from respective DBD and/or from respective equipment specification documents.

(4) The network flow analysis suggests potential leakages could impact Standby Diesel Generator Auxiliary equipment (Jacket water and lube oil cooler) in the SBDG building, and the Essential HVAC Chiller (300T) and CCWHX in the MAB because estimated flow requirements equals flow capacity (Flow Capacity – Flow requirement = 0 GPM).

The table above indicates that zero gallon flow safety margin exists for the Standby Diesel Generator Auxiliary equipment (Jacket water and lube oil cooler), Essential HVAC Chiller (300T) and CCWHX. Additional review of Hydraulic Network Analysis (Ref. MC-5812, Rev. 2) was performed to assure that safety-related equipment with zero margins will not be deprived of cooling flow when ECW leakage is allowed. The Hydraulic Network Analysis was performed for:

1. Normal (two train in operation)
2. Loss of Offsite Power (LOOP)
3. Safety Injection (all three trains in operation).

The mode of operation assuming a single failure in one of the trains during a LOOP was also analyzed. This case, however, assumed cross-tie operation during which 1330 GPM flow was supplied to the cross train. The cross-tie feeding lowered actual ECW flow from a normal design flow of 15,000 GPM to 14,285 GPM. The Log Mean Temperature Difference between the ECW (tube side of CCWHX) and CCW (shell side) using design temperature conditions will remain within design bound as long as the ECW inlet temperature remained less than 98°F. Thus, even at reduced ECW cooling flow, the design CCW heat load can be removed effectively. STP no longer uses cross tie operation; therefore, there is some additional flow capacity margin not credited in this analysis. The analysis review concludes there is flow margin to account for leakage in the ECW system.

The cooling water supply to safety-related equipment has adequate flow margins assuring their design bases functions with allowed loss of essential cooling water. For the remainder of the safety-related equipment, the flow capacity exceeds the design specified flow requirements by more than the 10.5 GPM maximum anticipated combined losses due to leakages.

STP has also estimated crack lengths that are likely to leak cooling water below the administrative limit. For selected upstream components, crack lengths are estimated to limit leakage rate below administrative leakage limits. In order to minimize impact on the downstream safety-related equipment, STP will be monitoring leakage rate as well as length of the crack allowed while a leaking component is in service. The table below summarizes analysis (PICEP) results.

Summary of Acceptable Leak Rates and Critical Crack Sizes[1]

Building ID	Administrative Limits[2]	Flooding Limits	Leak Rates through Crack GPM (Dealloyed Material)	Crack Size (inches) Limiting to Leakage Rate below Administrative Limit (Dealloyed material)	Pipe Size Evaluated Diameter in Inches
Mechanical Auxiliary Building	8 GPM over 7 days	8 GPM over 15 days	8 GPM over 7 days	7.9 Inch 6.4 Inch 7.24 inch 8.1 Inch 7.72 Inch 6.0 Inch	30 14 10 8 6 3
Stand-By-Diesel Generator Building	0.3375 GPM over 7 days	0.1575 GPM over 30 days	0.3375 GPM over 7 days	3.1239 Inch	8
ECW Intake Structure	2.3 GPM over 7 days	545 GPM over 1.44 hours	2.3 GPM over 7 days	3.018 Inch	24

1) These crack sizes are not intended to demonstrate structural integrity of the component and shall not be used for that purpose. It is to be used for estimating safety factor available for the observed leakage rate to potential leak rate through the crack size. (For example, 6" long crack is required to attain leak rate of 8 gpm for a 3 inch pipe. The critical crack size at which pipe may collapse is also approximately 6", therefore, to secure a safety factor of 2 one must not allow physical crack longer than 3 inches.)
2) Thirty days is assumed to restore make-up capability to the EC Pond after Design Basis Accident, while 7 days is assumed as sufficient time required establishing temporary pump facility to drain leakages out of MAB, ECWIS, and DGB buildings. Administrative limits are determined to maintain safety factors greater than 2 to flood limit.

Conclusion: The allowed loss of essential cooling water supply to the safety related equipment has adequate flow margins assuring the design bases functions are met. Also the leakage rate and crack lengths will be monitored further assuring structural integrity of the ECWS components.

Enclosure 2

STP LRA Changes with Line-in/Line-out Annotations

List of Revised LRA Sections

RAI	Affected LRA Section
B2.1.37-4	A1.37
B2.1.37-4	B2.1.37

A1.37 SELECTIVE LEACHING OF ALUMINUM BRONZE

The Selective Leaching of Aluminum Bronze program manages loss of material due to selective leaching of aluminum bronze (copper alloy with greater than eight percent aluminum) components exposed to raw water within the scope of license renewal.

The Selective Leaching of Aluminum Bronze program is an existing program that is implemented by STP procedure. The procedure directs that every six months (not to exceed nine months), an inspection of all aluminum bronze components be completed.

STP has buried piping with less than eight percent aluminum content, and that is not susceptible to dealloying. However, there are welds in which the filler metal is a copper alloy with greater than eight percent aluminum material. Therefore, the procedure directs that a yard walkdown be performed above the buried piping with aluminum bronze welds, from the intake structure to the unit and from the unit to the discharge structure to look for changes in ground conditions that would indicate leakage. If a leak from below-grade weld is discovered by surface water monitoring or during a buried ECW piping inspection, a section of each leaking weld will be removed for destructive examination.

Aluminum bronze (copper alloy with greater than 8 percent aluminum) components which are found to have indications of through-wall dealloying are evaluated, and scheduled for replacement by the corrective action program. Components with indications of through-wall dealloying~~, associated with piping greater than one inch in diameter,~~ will be replaced by the end of the ~~next refueling~~ outage.

Volumetric examinations of aluminum bronze material components that demonstrate external leakage will be performed where the configuration supports this type of examination to conclude with reasonable assurance that cracks are not approaching a critical size.

<u>Profile Examinations (PEs) will be performed on 100% of leaking components. The PEs consists of non-destructive examination of the leaking component for the presence of any visual crack identifications (Inside/outside diameter) and destructive examinations for microstructure, degree of dealloying, percent of dealloying through wall thickness and chemical composition (including aluminum content). When sufficient material is available for preparation of a test coupon, mechanical properties (ultimate strength, yield strength, and/or fracture toughness) will be obtained.</u>

<u>Pressure tests and bending tests (i.e. Analysis Confirmatory Tests (ACTs)) will be performed on leaking components to obtain maximum pressure and bending moment. The ACTs confirm that the analytical methodology used to calculate the load carrying capacity and structural integrity of the leak components is conservative.</u>

<u>ACTs will be performed on 100% of the leaking components until 3 confirmatory ACTs from 3 different component sizes have been tested. Following the 9 confirmatory ACTs, 20% of all removed leaking aluminum bronze components will be tested until the end of the Period of Extended Operation.</u>

If at least two leaking components are not identified two years prior to the end of each 10-year testing interval, a risk-ranked approach based on those components most susceptible to degradation will be used to identify candidate components for removal, and PE and ACT testing will be performed so at least two components are tested during the 10-year interval.

Destructive examination of each leaking component removed from service will be performed to determine the degree of dealloying until 10 percent of the susceptible components in the ECW system are examined. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.
Metallurgical testing of leaking aluminum bronze material components in the ECW system removed from service will be performed to update the structural integrity analyses, to confirm load carrying capacity and to determine the degree of dealloying by destructive examination. Metallurgical testing of the removed leaking component will be performed until at least three different size components of two samples each are tested, and at least nine total samples are tested. The metallurgical testing will include fracture toughness testing of test samples that include a crack in the dealloyed material where sufficient sample size supports bend testing. Additionally, the samples will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. Ultimate tensile strength will be trended and compared to the acceptance criterion. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.

Beginning 10 years prior to the period of extended operation for each 10-year interval, periodic metallurgical testing of aluminum bronze material components will be performed to update the structural integrity analyses, confirm load carrying capacity, and determine extent degree of dealloying. For each 10-year interval beginning 10 years prior to the period of extended operation, 20 percent of leaking above ground components removed from service, but at least one, will be tested every five years. Tensile test samples from a removed component will be tested to include both leaking and non-leaking portions of the component. If at least two leaking components are not identified two years prior to the end of each 10-year testing interval, a risk-ranked approach based on those components most susceptible to degradation will be used to identify candidate components for removal and testing so at least two components are tested during the 10-year interval. The samples will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. The samples will be destructively examined to determine the degree of dealloying and the presence of cracks. Ultimate strength, yield strength, and/or fracture toughness Ultimate tensile strength will be trended and compared to the acceptance criterion. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.

An engineering evaluation will be performed at the end of each PE and ACT testing interval to confirm the analytical methodology used to calculate the load carrying capacity and structural integrity of the leak components is conservative. determine if the sample size requires adjustment based on the results of the tests.

The acceptance criterion for ultimate tensile strength and yield strength values of dealloyed aluminum bronze material is greater than or equal to 30 ksi.

The acceptance criterion for the fracture toughness is greater than or equal to 65 ksi in$^{1/2}$ for non-dealloyed aluminum bronze castings and at welded joints in the heat affected zones. ~~The acceptance criterion for yield strength is equal to or greater than one-half of the ultimate strength.~~

If a criterion is not met, the condition will be documented in the corrective action program to perform a structural integrity analysis to confirm that the load carrying capacity of the tested material remains adequate to support the intended function of the ECW system through the period of extended operation.

B2.1.37 Selective Leaching of Aluminum Bronze

Program Description

The Selective Leaching of Aluminum Bronze program manages loss of material due to selective leaching for aluminum bronze (copper alloy with greater than eight percent aluminum) components exposed to raw water within the scope of license renewal. This plant-specific program will use requirements of the Selective Leaching of Materials program (B2.1.17) specifically relating to aluminum bronze components. The selective leaching of aluminum bronze is applied in addition to the Open-Cycle Cooling Water program (B2.1.9).

The Selective Leaching of Aluminum Bronze program is an existing program that is implemented by plant procedure. This procedure directs that every six months (not to exceed nine months), an inspection of aluminum bronze (copper alloy with greater than eight percent aluminum) components be completed.

STP has buried copper piping with less than eight percent aluminum content that is not susceptible to dealloying. However, there are welds in which the filler metal is copper alloy with greater than eight percent aluminum material. Therefore, the procedure directs that a yard walkdown be performed above the buried piping with aluminum bronze welds, from the intake structure to the unit and from the unit to the discharge structure to look for changes in ground conditions that indicate leakage.

Aluminum bronze (copper alloy with greater than 8 percent aluminum) components which are found to have indications of through-wall dealloying are evaluated, and scheduled for replacement by the corrective action program. Components with indications of through-wall dealloying~~, greater than one inch,~~ will be replaced by the end of the next ~~refueling~~ outage. Periodic destructive and non-destructive examinations of aluminum bronze material components will be performed to update the analytical methodology used to demonstrate structural integrity ~~analyses,~~ confirm load carrying capacity, and determine ~~extent~~ degree of dealloying.

Aging Management Program Elements

The results of an evaluation of each element against the 10 elements described in Appendix A of NUREG-1800, *Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants* are provided below.

Scope of Program (Element 1)

The Selective Leaching of Aluminum Bronze program manages loss of material due to selective leaching for aluminum bronze (copper alloy with greater than eight percent aluminum) pumps, piping welds and valve bodies exposed to raw water within the scope of license renewal. These aluminum bronze (copper alloy with greater than eight percent aluminum) components with raw water internal environments are susceptible to loss of material due to selective leaching (dealloying).

STP has analyzed the effects of dealloying and found that the degradation is slow so that rapid or catastrophic failure is not a consideration.

A structural integrity analysis performed when dealloying was first identified confirmed that 100 percent dealloyed aluminum bronze material retains sufficient load carrying capacity. This structural integrity analysis determined that the leakage can be detected before the flaw reaches a limiting size that would affect the intended functions of the essential cooling water and essential cooling water screen wash system.
~~Volumetric examinations of aluminum bronze material components that demonstrate external leakage will be performed where the configuration supports this type of examination to conclude with reasonable assurance that cracks are not approaching a critical size.~~

~~Destructive examination of each leaking component removed from service will be performed to determine the degree of dealloying until 10 percent of the susceptible components in the ECW system are examined. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.~~

~~Metallurgical testing of leaking aluminum bronze material components in the ECW system removed from service will be performed to update the structural integrity analyses, to confirm load carrying capacity and to determine the degree of dealloying by destructive examination. Metallurgical testing of the removed leaking component will be performed until at least three different size components of two samples each are tested, and at least nine total samples are tested. The metallurgical testing will include fracture toughness testing of test samples that include a crack in the dealloyed material where sufficient sample size supports bend testing. Additionally, the samples will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. Ultimate tensile strength will be trended and compared to the acceptance criterion. Degree of dealloying and cracking will be trended by comparing examination results with previous examination results.~~

~~As part of the testing described above, six samples from three aluminum bronze components removed from service in 2012 will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. The aluminum bronze samples exposed to ECW system raw water environment will come from a pump shaft line casing pipe and from two small cast valve bodies. The pump shaft line casing pipe was removed from service in 2012 and the two small cast valve bodies will be removed from service in 2012. The components to be sampled have been exposed to ECW system raw water environment since the ECW system entered service. Priority will be given to selecting 100% dealloyed component samples. STP will complete this testing prior to the end of 2012.~~

~~Beginning 10 years prior to the period of extended operation for each 10-year interval, periodic metallurgical testing will be performed to confirm that the load carrying capacity of aged dealloyed aluminum bronze material in the ECW system remains adequate to support the intended function of the system during the period of extended operation. For each 10-year interval beginning 10 years prior to the period of extended operation, 20 percent of leaking above ground components removed from service, but at least one, will be tested every five years. Tensile test samples from a removed component will be tested to include both leaking and non-leaking portions of the component.~~

~~If at least two leaking components are not identified two years prior to the end of each 10-year testing interval, a risk-ranked approach based on those components most susceptible to degradation will be used to identify candidate components for removal and testing so at least two components are tested during the 10-year interval. The component will be sectioned to size the inside surface flaws, if present, and/or mapping of the dealloyed surface areas for determining the extent degree of the dealloying. The samples will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. Ultimate tensile strength will be trended and compared to the acceptance criterion. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.~~

~~An engineering evaluation will be performed at the end of each test to determine if the sample size requires adjustment based on the results of the tests. The structural integrity analyses will be updated as required to validate adequate load carrying capacity.~~

~~Plant procedure directs that every six months (not to exceed nine months) an inspection of all susceptible aluminum bronze (copper alloy with greater than eight percent aluminum) above ground components be completed to identify any components that show evidence of dealloying. Aluminum bronze (copper alloy with greater than 8 percent aluminum) components which are found to have indications of through-wall dealloying are evaluated, and scheduled for replacement by the corrective action program. Components greater than one inch will be replaced by the end of the subsequent refueling outage.~~

STP has buried copper alloy piping with less than eight percent aluminum that is not susceptible to dealloying. However, there are welds in which the filler metal is copper alloy with greater than eight percent aluminum material. Therefore, the procedure directs that a yard walkdown be performed above the buried piping aluminum bronze welds, from the intake structure to the unit and from the unit to the discharge structure to look for changes in ground conditions that indicate leakage. If leaking below-grade welds are discovered by surface water monitoring or during a buried ECW piping inspection, a section of each leaking weld will be removed for destructive examination.

Preventive Actions (Element 2)

The Selective Leaching of Aluminum Bronze program does not prevent degradation due to aging effects but provides for inspections to detect aging degradation prior to the loss of intended functions, replacement of degraded components, and testing to confirm load carrying capacity of aged dealloyed aluminum bronze material .

The Open-Cycle Cooling Water program (B2.1.9) uses an oxidizing biocide treatment (sodium hypochlorite and sodium bromide) to reduce the potential for microbiologically influenced corrosion.

Parameters Monitored or Inspected (Element 3)

The Selective Leaching of Aluminum Bronze program includes visual inspections every six months (not to exceed nine months) for dealloying in all susceptible aluminum bronze (copper alloy with greater than eight percent aluminum) components.

Upon discovery of visual evidence of through-wall dealloying, components are evaluated against the analytical methodology used to calculate the load carrying capacity and structural integrity of the leak components to verify the continued use of the component until replaced. ~~During these inspections, if evidence of through-wall dealloying is discovered, the components are evaluated and scheduled for replacement by the corrective action program. Components, greater than one inch, will be replaced by the end of the next refueling outage.~~

Every 6 months, a walkdown is performed above the buried essential cooling water piping containing copper alloy welds with aluminum content greater than 8 percent. During the walkdown of the buried essential cooling water piping, the ground is observed for conditions that would indicate leakage due to selective leaching. Whenever aluminum bronze materials are exposed during inspection of the buried essential cooling water piping, the components are examined for indications of selective leaching. If leaking below-grade welds are discovered by surface water monitoring or during a buried ECW piping inspection, a section of each leaking weld will be removed for destructive examination.

Volumetric examinations of leaking aluminum bronze material components that demonstrate external leakage will be performed where the configuration supports this type of examination to conclude with reasonable assurance that cracks are not approaching a critical size.

Profile Examinations (PEs) will be performed on 100% of leaking components through the end of Period of Extended Operation. The PE consists of non-destructive examination of the leaking component for the presence of any visual crack identifications (inside/outside surfaces) and distractive examinations for microstructure, degree of dealloying, percent of dealloying through wall thickness and chemical composition (including aluminum content). When sufficient material is available for preparation of a test coupon, mechanical properties (e.g. ultimate strength, yield strength, and/or fracture toughness) will be obtained. The PE results provide the physical, metallurgical and mechanical properties used to trend the progression of dealloying and to confirm the acceptability of using the existing correlation of observed OD crack angle as the means by which STP projects internal degradation.

Pressure and bending moment tests (i.e. analysis Confirmatory Tests(ACTs)) will be performed on leaking components to obtain pressure and bending moment. The ACTs will be used to confirm the analytical methodology used to calculate the load carrying capacity and structural integrity of the leaking components is conservative. .The ACT confirms that the analytical methodology used to calculate the load carrying capacity and structural integrity of the leaking components is conservative.

ACTs will be performed on 100% of the leaking components until 3 confirmatory ACTs from 3 different component sizes have been tested. Following the 9 confirmatory ACTs, 20% of all removed leaking aluminum bronze components will have ACTs performed until the end of the Period of Extended Operation

If at least two leaking components are not identified two years prior to the end of each 10 year testing interval, a risk-ranked approach based on those components most susceptible to degradation will be used to identify candidate components for removal, and PE and ACT testing will be performed so at least two components are tested during the 10-year interval.

Detection of Aging Effects (Element 4)

The Selective Leaching of Aluminum Bronze program includes visual inspection of aluminum bronze (copper alloy with greater than eight percent aluminum) components to determine if selective leaching of these components is occurring.

~~Every six months (not to exceed nine months), an inspection of susceptible above ground aluminum bronze (copper alloy with greater than eight percent aluminum) components is completed to identify any components that show evidence of dealloying. Every 6 months, a walkdown is performed above the buried essential cooling water piping containing copper alloy welds with an Aluminum content greater than 8 percent. During the walkdown, the soil is observed to identify conditions that may be an indication of leakage due to selective leaching. Whenever aluminum bronze materials are exposed during inspection of the buried essential cooling water and ECW screen wash system piping, the components are examined for indications of selective leaching. If leaking below-grade welds are discovered by surface water monitoring or during a buried ECW piping inspection, a section of each leaking weld will be removed for destructive metallurgical examination.~~

~~Aluminum bronze (copper alloy with greater than 8 percent aluminum) components which are found to have indications of through-wall dealloying are evaluated, and scheduled for replacement by the corrective action program. Components, greater than one inch, will be replaced by the end of the next refueling outage.~~

Volumetric examinations, when configuration allows, of aluminum bronze material components that demonstrate external leakage will be used ~~performed where the configuration supports this type of examination~~ to conclude with reasonable assurance that cracks are not approaching a critical size.

The PE results provide the physical, metallurgical, and mechanical properties used to trend the progression of dealloying and to confirm the acceptability of using the existing correlation of observed outside diameter (OD) crack angle to project internal degradation.

The ACTs are used to confirm the analytical methodology used to calculate the load carrying capacity and structural integrity of the leak components is conservative.
~~Destructive examination of each leaking component removed from service will be performed to determine the degree of dealloying until 10 percent of the susceptible components in the ECW system are examined. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.~~

~~Metallurgical testing of leaking aluminum bronze material components in the ECW system removed from service will be performed to update the structural integrity analyses, to confirm load carrying capacity and to determine the degree of dealloying by destructive examination. Metallurgical testing of the removed leaking component will be performed until at least three different size components of two samples each are tested, and at least nine total samples are tested. The metallurgical testing will include fracture toughness testing of test samples that include a crack in the dealloyed material where sufficient sample size supports bend testing. Additionally, the samples will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. Ultimate tensile strength will be trended and compared to the acceptance criterion.~~

~~Degree of dealloying and cracking will be trended by comparing examination results with previous examination results.~~

~~As part of the testing described above, six samples from three aluminum bronze components removed from service in 2012 will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. The aluminum bronze samples exposed to ECW system raw water environment will come from a pump shaft line casing pipe and from two small cast valve bodies. The pump shaft line casing pipe was removed from service in 2012 and the two small cast valve bodies will be removed from service in 2012. The sample components have been exposed to ECW system raw water environment since the ECW system entered service. Priority will be given to selecting 100% dealloyed component samples. STP will complete this testing prior to the end of 2012.~~

~~Beginning 10 years prior to the period of extended operation for each 10-year interval, periodic metallurgical testing will be performed to confirm that the load carrying capacity of aged dealloyed aluminum bronze material in the ECW system remains adequate to support the intended function of the system during the period of extended operation. For each 10-year interval beginning 10 years prior to the period of extended operation, 20 percent of leaking above ground components removed from service, but at least one, will be tested every five years. Tensile test samples from a removed component will be tested to include both leaking and non-leaking portions of the component. If at least two leaking components are not identified two years prior to the end of each 10-year testing interval, a risk-ranked approach based on those components most susceptible to degradation will be used to identify candidate components for removal and testing so at least two components are tested during the 10-year interval. The component will be sectioned to size the inside surface flaws, if present, and/or to map the dealloyed surface areas for determining the extent degree of the dealloying. The samples will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. Ultimate tensile strength will be trended and compared to the acceptance criterion. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.~~

An engineering evaluation will be performed at the end of each PE and ACTs testing interval to confirm the analytical methodology used to calculate the load carrying capacity and structural integrity of the leak components is conservative. ~~test to determine if the sample size requires adjustment based on the results of the tests.~~

The analytical methodology used to demonstrate structural integrity will be updated as required to confirm that ~~to validate~~ the ~~adequate~~ load carrying capacity of the aluminum bronze material is adequate to support the intended function of the ECW system through the period of extended operation.

Monitoring and Trending (Element 5)

The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.

Ultimate strength, yield strength, and/or fracture toughness will be trended. The ultimate tensile strength results from the metallurgical aluminum bronze material testing will be monitored and trended. Trending provides monitoring of the degree of dealloying, the degree of cracking, and the ultimate tensile strength, yield strength and fracture toughness for aging aluminum bronze material through the period of extended operation.

Upon completion of each test, the data trended will be evaluated against the acceptance criteria. for ultimate tensile strength.

Acceptance Criteria (Element 6)

Dealloying of aluminum bronze components is a well known phenomenon at STP. A long term improvement plan was developed in May 1992. As a result of these analyses, aluminum bronze (copper alloys with greater than eight percent aluminum) components are visually inspected every six months (not to exceed nine months). Upon discovery of visual evidence of through-wall dealloying, components are evaluated, and scheduled for replacement by the corrective action program. Components, greater than one inch, will be replaced by the end of the next refueling outage. Due to the slow nature of dealloying, this replacement interval provides reasonable assurance that the systems and components within the scope of this program will continue to perform their intended functions consistent with the current licensing basis for the period of extended operation.

The ASME Code Section XI structural factors for the normal/upset conditions (2.77) as well as the emergency and faulted conditions (1.39) will be applied for acceptance of dealloyed conditions.

The acceptance criterion for ultimate tensile ultimate strength and yield strength values of dealloyed aluminum bronze material is greater than or equal to 30 ksi.

The acceptance criterion for the fracture toughness is greater than or equal to 65 ksi $in^{1/2}$ for non-dealloyed aluminum bronze castings and at welded joints in the heat affected zones. The acceptance criterion for yield strength is equal to or greater than one-half of the ultimate strength.

If an acceptance criterion is not met, the condition will be documented in the corrective action program and to perform a structural integrity analysis will be performed to confirm that the load carrying capacity of the tested material remains adequate to support the intended function of the ECW System through the period of extended operation.

Corrective Actions (Element 7)

Upon discovery of visual evidence of through-wall dealloying, components are evaluated against the analytical methodology used to calculate the load carrying capacity and structural integrity of the leak components, and components are scheduled for replacement by the next outage, and scheduled for replacement by the next outage.

When the ACT does not confirm the structural integrity analyses, STP follows its corrective action program as defined in the 10 CFR Part 50 Appendix B, to address emergent conditions to assure continued safe operation of the units.

A Operational Decision-Making Issue (ODMI) detailing specific steps based on identified conditions will be developed. These steps include notifying the control room of the condition, initiating a condition report and performing field walkdowns to determine compensatory action.

STP site QA procedures, review and approval process, and administrative controls are implemented in accordance with the requirements of 10 CFR 50 Appendix B and are acceptable in addressing corrective actions. The QA program includes elements of corrective action, and is applicable to the safety-related and nonsafety-related systems, structures and components that are subject to aging management review.

Confirmation Process (Element 8)

STP site QA procedures, review and approval process, and administrative controls are implemented in accordance with the requirements of 10 CFR 50 Appendix B and are acceptable in addressing confirmation processes and administrative controls. The QA program includes elements of corrective action, and is applicable to the safety-related and nonsafety-related systems, structures and components that are subject to aging management review.

Administrative Controls (Element 9)

See Element 8.

Operating Experience (Element 10)

A review of the STP plant-specific operating experience indicates that macrofouling general corrosion erosion-corrosion, and through-wall dealloying have been observed in a ECW system components. STP has concluded that the through-wall dealloying degradation is slow in aluminum bronze cast components therefore rapid or catastrophic failure is not likely to occur. STP has determined that the leakage can be detected before the flaw reaches a limiting size that would affect the intended functions of the essential cooling water and essential cooling water screen wash system. A long range improvement plan and engineering evaluation were developed to deal with the dealloying of aluminum bronze components when dealloying has been identified. Based on these analyses, the approach has been to evaluate components, and schedule replacement by the corrective action program. ~~Components with indications of through wall dealloying, associated with piping greater than one inch in diameter, will be replaced by the end of the next refueling outage.~~ A monitoring and inspection program provides confidence in the ability to detect the leakage.

Enhancements

Prior to the period of extended operation, the following enhancements will be implemented in the following program elements:

~~*Scope of Program (Element 1)*~~

~~Procedures will be enhanced to:~~

~~Perform volumetric examinations of aluminum bronze material components that demonstrate external leakage where the configuration supports this type of examination to conclude with reasonable assurance that cracks are not approaching a critical size.~~

~~Perform destructive examination of each leaking component removed from service to determine the degree of dealloying until 10 percent of the susceptible components in the ECW system are examined. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.~~

~~Prior to the period of extended operation, metallurgical testing of leaking aluminum bronze material components in the ECW system removed from service will be performed to update the structural integrity analyses, to confirm load carrying capacity and to determine the degree of dealloying by destructive examination. Metallurgical testing of the removed leaking component will be performed until at least three different size components of two samples each are tested, and at least nine total samples are tested. The metallurgical testing will include fracture toughness testing of test samples that include a crack in the dealloyed material where sufficient sample size supports bend testing. Additionally, the samples will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. Ultimate tensile strength will be trended and compared to the acceptance criterion. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.~~

~~As part of the testing described above, test six samples from three aluminum bronze components removed from service in 2012 for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. The aluminum bronze test samples exposed to ECW system raw water environment are to come from a pump shaft line casing pipe and from two small cast valve bodies. The pump shaft line casing pipe was removed from service in 2012 and the two small cast valve bodies will be removed from service in 2012. Priority shall be given to selecting 100% dealloyed component samples.~~

~~Beginning 10 years prior to the period of extended operation for each 10-year interval, periodically test samples of above ground ECW system components removed from service for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. For each 10 year interval beginning 10 years prior to the period of extended operation, 20 percent of leaking components removed from service, but at least one, will be tested every five years. Tensile test samples from a removed component shall be tested to include both leaking and non-leaking portions of the component. If at least two leaking components are not identified two years prior to the end of each 10-year testing interval, a risk-ranked approach will be used based on those components most susceptible to degradation to identify candidate components for removal and testing so at least two components are tested during the 10-year interval. The component will be sectioned to size the inside surface flaws, if present, and/or mapping of the dealloyed surface areas for determining the degree of the dealloying. The samples will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure.~~

Ultimate tensile strength will be trended and compared to the acceptance criterion. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.

Perform an engineering evaluation at the end of each test to determine if the sample size requires adjustment based on the results of the tests.
Perform a structural integrity analysis to confirm that the load carrying capacity of the tested material remains adequate to support the intended function of the ECW system through the period of extended operation.

Parameters Monitored and Inspected (Element 3)

Procedures will be enhanced to:

Indicate that whenever aluminum bronze materials are exposed during inspection of the buried essential cooling water piping, the components are examined for indications of selective leaching. If leaking below-grade welds are discovered by surface water monitoring or during a buried ECW piping inspection, a section of each leaking weld will be removed for destructive examination.

Perform volumetric examinations of leaking aluminum bronze material components that demonstrate external leakage where the configuration supports this type of examination to conclude with reasonable assurance that cracks are not approaching a critical size.

Perform Profile Examinations (PE) on 100% of leaking components. The PE consists of non-destructively examination of the leaking component for the presence of any visual crack identifications (Inside/outside diameter) and distractive examinations for microstructure, degree of dealloying, percent of dealloying through wall thickness and chemical composition (including aluminum content). When sufficient material is available for preparation of a test coupon, mechanical properties (ultimate strength, yield strength, and/or fracture toughness) will be obtained.

Perform pressure and bending tests (Analysis Confirmatory Tests) on leaking components to obtain maximum pressure and bending moment.

Require ACTs be performed on 100% of the leaking components until 3 confirmatory ACTs from 3 different component sizes have been tested. Following the 9 confirmatory ACTs then 20% of all removed leaking aluminum bronze components will have ACTs performed until the end of the Period of Extended Operation.

Require at least two components be tested (PEs and ACTs) during the each 10-year interval. If at least two leaking components are not identified two years prior to the end of each 10 year testing interval, a risk-ranked approach based on those components most susceptible to degradation will be used to identify candidate components for removal testing.

Detection of Aging Effects (Element 4)

Procedures will be enhanced to:

Indicate that whenever aluminum bronze materials are exposed during inspection of the buried essential cooling water piping, the components are examined for indications of selective leaching. If leaking below-grade welds are discovered by surface water monitoring or during a buried ECW piping inspection, a section of each leaking weld will be removed for destructive examination.

Perform volumetric examinations of leaking aluminum bronze ~~material~~ components ~~that demonstrate external leakage~~ where the configuration supports this type of examination to conclude with reasonable assurance that cracks are not approaching a critical size.

~~Perform destructive examination of each leaking component removed from service to determine the degree of dealloying until 10 percent of the susceptible components in the ECW system are examined. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.~~

~~Metallurgical testing of leaking aluminum bronze material components in the ECW system removed from service will be performed to update the structural integrity analyses, to confirm load carrying capacity and to determine the degree of dealloying by destructive examination. Metallurgical testing of the removed leaking component will be performed until at least three different size components of two samples each are tested, and at least nine total samples are tested. The metallurgical testing will include fracture toughness testing of test samples that include a crack in the dealloyed material where sufficient sample size supports bend testing. Additionally, the samples will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. Ultimate tensile strength will be trended and compared to the acceptance criterion. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.~~

~~As part of the testing described above, test six samples from three aluminum bronze components removed from service in 2012 for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. The aluminum bronze test samples exposed to ECW system raw water environment are to come from a pump shaft line casing pipe and from two small cast valve bodies. The pump shaft line casing pipe was removed from service in 2012 and the two small cast valve bodies will be removed from service in 2012. Priority shall be given to selecting 100% dealloyed component samples.~~

~~Beginning 10 years prior to the period of extended operation for each 10-year interval, periodically test samples of above ground ECW system components removed from service for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. For each 10 year interval beginning 10 years prior to the period of extended operation, 20 percent of leaking components removed from service, but at least one, will be tested every five years. Tensile test samples from a removed component shall be tested to include both leaking and non-leaking portions of the component.~~

~~If at least two leaking components are not identified two years prior to the end of each 10-year testing interval, a risk-ranked approach will be used based on those components most susceptible to degradation to identify candidate components for removal and testing so at least two components are tested during the 10-year interval. The component will be sectioned to size the inside surface flaws, if present, and/or mapping of the dealloyed surface areas for determining the degree of the dealloying. The samples will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure. Ultimate tensile strength will be trended and compared to the acceptance criterion. The degree of dealloying and cracking will be trended by comparing examination results with previous examination results.~~ Perform an engineering evaluation at the end of each PE and ACTs testing interval to confirm the analytical methodology used to calculate the load carrying capacity and structural integrity of the leak components is conservative. ~~test to determine if the sample size requires adjustment based on the results of the tests.~~

Update the analytical methodology used to demonstrate ~~Perform a~~ structural integrity ~~analysis~~ as required confirming ~~to confirm~~ that the load carrying capacity of the aluminum bronze material remains adequate to support the intended function of the ECW system through the period of extended operation.

Monitoring and Trending (Element 5)

Procedures will be enhanced to:

Trend the degree of dealloying and cracking by comparing examination results with previous examination results.

Trend ultimate ~~tensile~~ strength, yield strength, and/or fracture toughness results from the ~~metallurgical aluminum bronze material~~ PE testing.

Upon completion of each test, evaluate the data trended against the acceptance criteria ~~for ultimate tensile strength~~.

Acceptance Criteria (Element 6)

Procedures will be enhanced to:

Specify the ASME Code Section XI structural factors for the normal/upset conditions (2.77) as well as the emergency and faulted conditions (1.39).

Specify the acceptance criteria ~~criterion~~ for ultimate ~~tensile~~ strength and yield strength values of dealloyed aluminum bronze material is greater than or equal to 30 ksi.

Specify the acceptance criterion for fracture toughness is 65 ksi in$^{1/2}$ for non-dealloyed aluminum bronze castings and at welded joints in the heat affected zones.

~~Specify the acceptance criterion for yield strength is equal to or greater than one-half of the ultimate strength.~~

Initiate a corrective action document when the acceptance the criterion is not met.

Corrective Actions (Element 7)

Procedures will be enhanced to:

Specify that upon discovery of visual evidence of through-wall dealloying, components are scheduled for replacement by the next outage.

Specify that when the ACT does not confirm the structural integrity analyses, STP will follow its corrective action program as defined in the 10 CFR 50 Appendix B, to address emergent conditions to assure continued safe operation of the units. Specify that a ODMI detailing specific steps based on identified conditions will be developed. These steps include notifying the control room of the condition, initiating a condition report, and performing field walkdowns to determine compensatory action.

Conclusion

The continued implementation of the Selective Leaching of Aluminum Bronze program provides reasonable assurance that aging effects will be managed such that the systems and components within the scope of this program will continue to perform their intended functions consistent with the current licensing basis for the period of extended operation.

Enclosure 3

Regulatory Commitments

A4 LICENSE RENEWAL COMMITMENTS

Table A4-1 identifies proposed actions committed to by STP for STP Units 1 and 2 in its License Renewal Application. These and other actions are proposed regulatory commitments. This list will be revised, as necessary, in subsequent amendments to reflect changes resulting from NRC questions and STP responses. STP will utilize the STP commitment tracking system to track regulatory commitments. The Condition Report (CR) number in the Implementation Schedule column of the table is for STP tracking purposes and is not part of the amended LRA.

Table A4-1 License Renewal Commitments

Item #	Commitment	LRA Section	Implementation Schedule
39	Enhance the Selective Leaching of Aluminum Bronze procedure to: • examine aluminum bronze materials exposed during inspection of the buried essential cooling water piping for evidence of selective leaching, • ~~perform periodic metallurgical testing of aluminum bronze material components to update the structural integrity analyses, confirm load carrying capacity, and determine degree of dealloying as follows:~~ ~~o Above ground ECW System components removed from service will be tested as follows:~~ ~~• For each 10-year interval beginning 10 years prior to the period of extended operation, 20 percent of leaking components removed from service, but at least one, will be tested every five years.~~ ~~• Tensile test samples from a removed component will be tested to include both leaking and non-leaking portions of the component.~~ ~~• If at least two leaking components are not identified two years prior to the end of each 10-year testing interval, a risk-ranked approach based on those components most susceptible to degradation will be used to identify candidate components for removal and testing so at least two components are tested during the 10-year interval.~~ ~~• The samples will be tested for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure.~~ ~~• Trend ultimate tensile strength and compare to the acceptance criterion.~~ ~~• Determine degree of dealloying and presence of cracks by destructive examination. Trend the degree of dealloying and cracking by comparing~~	B2.1.37	Complete no later than six months prior to the period of extended operation. Inspections to be complete no later than six months prior to the PEO or the end of the last refueling outage prior to the PEO, whichever occurs later. CR 11-28986

Table A4-1 License Renewal Commitments

Item #	Commitment	LRA Section	Implementation Schedule
	~~examination results with previous examination results.~~ • ~~Perform an engineering evaluation at the end of each test to determine if the sample size requires adjustment based on the results of the tests.~~ • ~~The acceptance criterion for ultimate tensile strength value of aluminum bronze material is greater than or equal to 30 ksi. The acceptance criterion for yield strength is equal to or greater than one-half of the ultimate strength.~~ • ~~Initiate a corrective action document when the acceptance criterion is not met.~~ • and, if a leak from below-grade welds is discovered by surface water monitoring or during a buried ECW piping inspection, a section of each leaking weld will be removed for destructive examination.		
44	Enhance the Selective Leaching of Aluminum Bronze procedure to update the structural integrity analyses, confirm load carrying capacity, and determine degree of dealloying as follows: • Perform volumetric examinations of leaking aluminum bronze components where the configuration supports this type of examination to conclude with reasonable assurance that cracks are not approaching a critical size. • Perform Profile Examinations (PE) on 100% of leaking components. The PE consists of non-destructive examination of the leaking component for the presence of any visual crack identifications (Inside/outside surfaces) and distractive examinations for microstructure, degree of dealloying, percent of dealloying through wall thickness and chemical composition (including aluminum content). When sufficient material is available for preparation of a test coupon, mechanical properties (ultimate strength, yield strength, and/or fracture toughness) will be obtained. • Perform pressure and bending tests (Analysis Confirmatory Tests (ACTs) on leaking components to obtain pressure and bending moment. • Require ACTs be performed on 100% of the leaking components until 3 confirmatory ACTs from 3 different component sizes have been tested. Following the 9 confirmatory ACTs then 20% of all removed leaking aluminum bronze components will have ACTs performed until the end of the Period of Extended Operation. • Require at least two components be tested (PEs and ACTs) during the each 10-year interval.	B2.1.37	July 31, 2014 (revised per NOC-AE-14003090) CR 12-22150

Table A4-1 License Renewal Commitments

Item #	Commitment	LRA Section	Implementation Schedule
	If at least two leaking components are not identified two years prior to the end of each 10 year testing interval, a risk-ranked approach based on those components most susceptible to degradation will be used to identify candidate components for removal testing. • Perform an engineering evaluation at the end of each PEs and ACTs testing interval to confirm the analytical methodology used to calculate the load carrying capacity and structural integrity of the leak components is conservative. • Update the analytical methodology used to demonstrate structural integrity used to demonstrate structural integrity as required confirming that the load carrying capacity of the aluminum bronze material remains adequate to support the intended function of the ECW system through the period of extended operation. • Trend the degree of dealloying and cracking by comparing examination results with previous examination results. Trend ultimate strength, yield strength, and/or fracture toughness results from the PE testing. • Upon completion of each test, incorporate new test data updating existing trend to evaluate impact on the acceptance criteria. • Specify the ASME Code Section XI structural factors for the normal/upset conditions (2.77) as well as the emergency and faulted conditions (1.39). • Specify the acceptance criteria criterion for ultimate tensile strength and yield strength values of dealloyed aluminum bronze material is greater than or equal to 30 ksi. Specify the acceptance criterion for fracture toughness is 65 ksi in1/2 for non-dealloyed aluminum bronze castings and at welded joints in the heat affected zones. • Initiate a corrective action document when the acceptance the criterion is not met. • Specify that upon discovery of visual evidence of through-wall dealloying, components are scheduled for replacement by the next outage. • Specify that when the ACTs does not confirm the structural integrity analyses, o The corrective action program as defined in 10 CFR Part 50 Appendix B will be followed to address emergent conditions to assure continued safe operation of the units.		

Table A4-1 License Renewal Commitments

Item #	Commitment	LRA Section	Implementation Schedule
	o That a Operational Decision-Making Issue (ODMI) detailing specific steps based on identified conditions will be developed. These steps include notifying the control room of the condition, initiating a condition report and performing field walkdowns to determine compensatory action. ~~Structural integrity analyses will be updated and testing will be conducted to confirm that methodologies and assumptions based on past information remain valid.~~ • ~~Six samples from three aluminum bronze components recently removed from service will be tested.~~ • ~~The samples will be tested for chemical composition including aluminum content, mechanical properties (such as fracture toughness, yield and ultimate tensile strengths) and microstructure.~~ • ~~The acceptance criterion for ultimate tensile strength value of aluminum bronze material is greater than or equal to 30 ksi. The acceptance criterion for fracture toughness is 65 ksi in$^{1/2}$ for aluminum bronze castings and at welded joints in the heat affected zones. The acceptance criterion for yield strength is equal to or greater than one-half of the ultimate strength.~~ • ~~Trend ultimate tensile strength and compare to the acceptance criterion.~~ • ~~Determine degree of dealloying and presence of cracks by destructive examination. Trend the degree of dealloying and cracking by comparing examination results with previous examination results.~~ • ~~The structural integrity analyses will be updated, as required.~~ • ~~The results of the testing and any required changes to the structural integrity analyses will be completed and sent to the NRC staff for review.~~		
45	~~Enhance the Selective Leaching of Aluminum Bronze procedures to:~~ • ~~Volumetrically examine aluminum bronze material components in the ECW system that demonstrate external leakage where the configuration supports this type of examination,~~ • ~~Destructively examine each aluminum bronze material component in the ECW system that demonstrates external leakage for the presence or absence of internal cracks and for the degree of dealloying. Profiling will continue until 10 percent of susceptible components are examined to validate the input parameters to the structural integrity analyses.~~ o ~~Trend the degree of dealloying and cracking by comparing examination results with previous examination results.~~	~~B2.1.37~~	~~July 31, 2014 (revised per NOC-AE-14003090)~~ All items incorporated into Item # 44 by NOC-AE-14003135 CR 12-26987

Table A4-1 License Renewal Commitments

Item #	Commitment	LRA Section	Implementation Schedule
	~~• Metallurgically test aluminum bronze material components in the ECW system that demonstrate external leakage until the following population of components is tested:~~ ~~o At least three different size components of two samples each are tested, and~~ ~~o At least nine total samples are tested.~~ ~~o Perform fracture toughness testing of test samples that include a crack in the dealloyed material where sufficient sample size supports bend testing.~~ ~~o Trend ultimate tensile strength and compare to the acceptance criterion.~~ ~~o Test samples for chemical composition including aluminum content, mechanical properties (such as yield and ultimate tensile strengths) and microstructure.~~ ~~o Determine the degree of dealloying by destructive examination.~~ ~~o Trend the degree of dealloying and cracking by comparing examination results with previous examination results.~~ ~~• The acceptance criterion for ultimate tensile strength value of aluminum bronze material is greater than or equal to 30 ksi. The acceptance criterion for fracture toughness is 65 ksi $in^{1/2}$ for aluminum bronze castings and at welded joints in the heat affected zones. The acceptance criterion for yield strength is equal to or greater than one-half of the ultimate strength.~~ ~~• Perform an engineering evaluation at the end of each test to determine if the sample size requires adjustment based on the results of the tests.~~ ~~• Update the structural integrity analyses as required to validate adequate load carrying capacity.~~		
46	Leak rates that could occur upstream of any individual component supplied by the ECW system will be determined to validate the maximum size flaw for which piping can still perform its intended function. • A summary of the results of these leak rates will be provided to the NRC for review.	N/A	July 31, 2014 by this Letter NOC-AE-14003135 CR 12-27257