Nuclear Operating Company

South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

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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 Request for Additional Information for the
Review of the South Texas Project, Units 1 and 2,
License Renewal Application – Set 31 (TAC Nos. ME4936 and ME4937)

References:

1. Letter; G. T. Powell to USNRC Document Control Desk; "License Renewal Application;" NOC-AE-10002607; dated October 25, 2010 (ML103010257)
2. Letter; J. W. Daily to G. T. Powell; "Request for Additional Information for the Review of the South Texas Project, Units 1 and 2, License Renewal Application – Set 31 (TAC Nos. ME4936 and ME4937);" AE-NOC-15002670; dated May 28, 2015 (ML15131A272)

By Reference 1, STP Nuclear Operating Company (STPNOC) submitted a License Renewal Application (LRA). By Reference 2, the NRC staff requested additional information (RAI) for their review of the STP LRA. The RAI is related to STP's Aging Management of the Selective Leaching of Aluminum Bronze Program. STPNOC's response to the RAI 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.

Regulatory commitment item 44 in LRA Table A4-1 is revised and depicted as line-in/line-out pages provided in Enclosure 3. There are no other commitments in this letter.

A147

STI: 34162945

If there are any questions, please contact 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 July 29, 2015
Date

G. T. Powell
Site Vice President

amr

Enclosures:

1. STPNOC Response to RAI
2. STPNOC LRA Changes with Line-in/Line-out Annotations
3. STPNOC Regulatory Commitments

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Enclosure 1

STPNOC Response to RAI

RAI B.2.1.37-6-1, Monitoring and Trending, and Acceptance Criteria AMP Elements

Background

As amended by letter dated July 31, 2014, the "monitoring and trending" Aging Management Program (AMP) element of the Selective Leaching of Aluminum Bronze Program states that the degree of dealloying and cracking, ultimate strength, yield strength, and/or fracture toughness will be trended throughout the period of extended operation. The "acceptance criteria" program element of the Selective Leaching of Aluminum Bronze Program states an acceptance criterion for ASME Code structural factors, ultimate tensile strength, yield strength, and as-received fracture toughness. The following documents illustrate the use of various input parameters:

- AES-C-1964-1, "Calculation of Critical Bending Stress for Dealloyed Aluminum-Bronze Castings in the ECW System," uses as-received material properties (i.e., ultimate strength, yield strength, fracture toughness) to establish critical bending stresses for select sizes of piping.
- RC 9890, "Stress Summary for Large Bore ECW Piping (2-1/2-inch and above)," uses a 100 percent dealloyed ultimate strength to demonstrate that ASME Code components have adequate structural integrity.
- AES-C-1964-5, "Evaluation of the Significance of Dealloying and Subsurface Cracks on Flaw Evaluation Method," uses the percent average internal dealloying and 100 percent dealloyed ultimate strength and yield strength to conclude that average dealloying up to 60 percent through-wall, accompanied by a crack within a region of through-wall dealloying, will meet allowable stress limits. It also includes a correlation between the observed outside flaw length to project the average dealloyed angle in order to demonstrate that structural integrity is met when a through-wall leak is detected.

Issue

It is not clear to the staff that the currently proposed parameters to be monitored and trended are adequate because the percent of average internal dealloying and flaw size correlation are critical parameters used in AES-C-1964-1 and AES-C-1964-5 to demonstrate structural integrity when a through-wall leak is detected and they are not included in the list of parameters to be trended. It is not clear as to whether 100 percent dealloyed material properties used in these calculations will be monitored and trended because the program uses the term "and/or" for trending these parameters. In addition, it is not clear as to why there are no acceptance criteria for percent average dealloying and verification of the flaw size correlation to Figure 4-1 of AES-C-1964-5.

Request

1. State the basis for not monitoring and trending the percent of average internal dealloying and data related to the flaw size correlation in Figure 4-1 of AES-C-1964-5. In addition, state whether 100 percent dealloyed material properties will be monitored and trended.

2. In light of the use of the term "and/or," provide justification as to why there are no acceptance criteria for percent average dealloying and verification of the flaw size correlation in Figure 4-1 of AES-C-1964-5.

3. If a 100 percent dealloyed or other parameter that should be monitored and trended or have an acceptance criterion because it has been used as an input value (except as-received values) in analyses used to demonstrate structural integrity is not addressed in the above two requests, state the parameter and whether it will be monitored and trended and its acceptance criterion.

STP Response

1. The percent average dealloying depth, the ratio of maximum to average dealloying depth, and the area equivalent dealloyed through-wall (TW) angle are trended. These parameters are determined from each Profile Exam (PE) and plotted with past results (see responses to RAI's B.2.1.37-6-2 and B.2.1.37-6-3). When sufficient volume of material is available from removed leaking components to fabricate fully dealloyed test specimens, testing is performed to trend the mechanical properties at 100% dealloyed (DA).
2. The term "and/or" is revised to "and". Both the percent average dealloying depth and the area equivalent dealloyed through-wall (TW) flaw angle are trended using the destructive examination results from PE's. Acceptance of the percent average dealloying depth is determined by Analysis Confirmatory Test (ACT) where comparison of actual stress applied to the component is determined to be greater than the critical bending stress predicted by the model.

   Verification of Figure 4-1 of AES-C-1964-5 is performed on a continual basis through PE results. The acceptance criterion used to bound the trending data for percent average dealloying depth is 60%. The area equivalent dealloyed through-wall (TW) length shall be less than or equal to 110% of the allowable flaw length determined in the structural integrity analysis.
3. The 100% DA tensile properties are trended to validate the 30 ksi value for ultimate tensile strength as used in the ASME Section III stress allowable ratios. Any 100% DA tensile properties less than 30 ksi will be evaluated to confirm structural integrity by ACT or by detailed analytical calculations.

   The percent average dealloying depth and area equivalent TW flaw angle are trended from PE results. The 60% average dealloying depth is currently established by ACT (see AES-C-1964-4). Any components exhibiting average dealloying depths greater than 60% will be verified by ACT or by detailed analytical calculations.

LRA Appendix A1.37, Appendix B2.1.17, Table A4-1 and the AMP basis document PSALBZ, Selective Leaching of Aluminum Bronze is revised to state: Ultimate strength, yield strength, and fracture toughness will be trended and compared to acceptance criteria. Percent average dealloying depth, the ratio of maximum to average dealloying depth, and the area equivalent dealloyed through-wall (TW) flaw angle will be trended by comparing examination results with previous examination results.

The acceptance criterion used to bound the trending data for percent average dealloying depth is 60%. The area equivalent dealloyed through-wall (TW) length shall be less than or equal to 110% of the allowable flaw length determined in the structural integrity analysis.

Enclosure 2 provides the line-in/out revision to LRA Appendices A1.37 and B2.1.27.

Enclosure 3 provides the line-in/out revision to LRA Table A4-1 Commitment 44.

RAI B.2.1.37-6-2, Percent Average Dealloying Inspection Results

Background

The staff reviewed several reports that show average dealloying values that exceed the 60 percent input used in AES-C-1964-5 during the audit in March of 2015. These values range from approximately 64 to 74 percent, as documented in report numbers MT-3383, "Investigation of Leaks in Aluminum Bronze Flange from South Texas Project to Determine Extent of Dealloying," MT-4907, "Mapping of Dealloying in Aluminum Bronze Pipe to Flange Weld Bend Test," MT-3047-2, "Investigation of Dealloying in 6-Inch Aluminum Bronze Flange and Cracking of this Flange welded to Wrought Pipe at South Texas Project Unit 1," and MT-3923, "Evaluation of [6-inch] Aluminum Bronze Flange from South Texas Project Unit 2 Essential Cooling Water System."

Issue

The staff cannot conclude that the applicant's existing structural integrity calculations remain valid when some inspections have revealed average dealloying values that exceed the 60 percent value used in the current analysis.

Request

Explain how structural integrity is demonstrated when inspections have revealed average dealloying values that exceed 60 percent.

STP Response

The distribution of dealloying has been observed to vary significantly in both the through-thickness (radial) and around the cross-section (circumferential), making the determination of percent average dealloying depth (t^*_{ave}/t) sensitive to the number of measurement points on the cross-section. The dealloying profiles cited in the RAI include MT-3923, MT-3047-2, and MT-3383 are based on only 8 measurements made at uniform spacing around the circumference resulting in the percent average dealloying depth for these examples being overstated due the limited coverage of the degraded area.

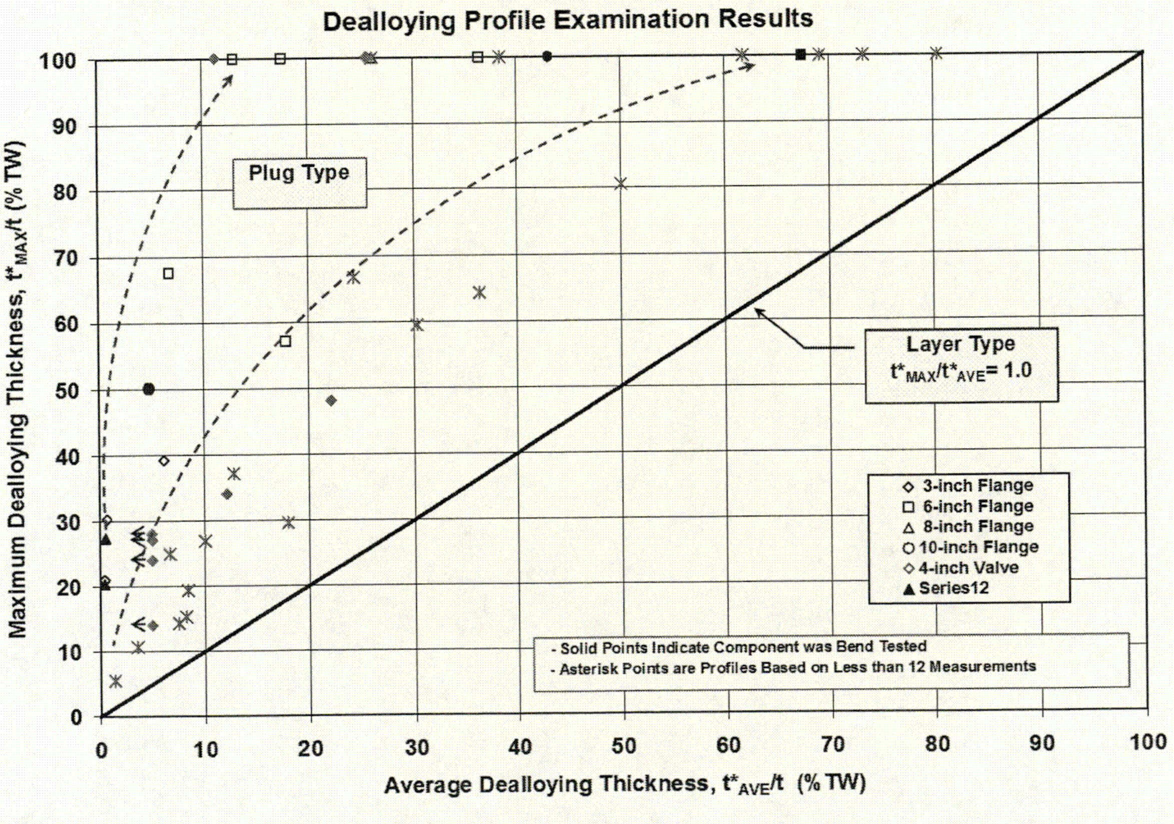
Figure 1 below shows a plot of the current PE data where the maximum dealloying depth is plotted against the percent average dealloying depth. The current data base of PE data support the profile shapes are plug-like (localized TW penetration) rather than layered type (uniform TW penetration). There are five PEs that show percent average depths greater than 60%, four, shown as red asterisks, are PEs determined from only 8 data points at 45-degree uniform spacing. The remaining PE had a percent average dealloying depth of 67% which was from a 6-inch flange where an ACT was performed. This flange had a bending capacity that exceeded the integrity model prediction, with margin, providing evidence that the flaw evaluation method is conservative for t^*_{ave}/t of a percent average dealloying thickness of at least 60%.

Confirmation of structural integrity is achieved through the analysis confirmation testing (ACT) and PEs which are performed on leaking components removed from service. The ACT is composed of hydrotesting the component to internal pressure exceeding the design pressure and three-point bend testing to a high proof load. The solid points in Figure 1 are the components that received ACTs. The 60% value is used as the current benchmark for the analytical methodology. This value is trended as additional ACT data is generated from future removed leaking components.

Basis for acceptability of 60% benchmark:

- The five PEs >60% are from components with short in-service periods (startup - 1990's)
- Four of five PEs utilized 8 point data points
- There are zero instances of PEs with observed beyond 60% since 1992, demonstrating that STP is now effectively identifying leakage earlier:
    - Since 1999, Preventive Maintenance Inspections have been established and proceduralized
    - Inspections are consistently performed by the System Engineer with experience identifying external signs of through wall leakage.
- Compiled data confirms that plug-type dealloying is the major contributing profile.
- The average dealloying depth is established by ACT (AES-C-1964-4, and AES-C-1964-5), where fracture stress margin was 1.21 and analytical model prediction margin was 1.05 for the 67% TW sample.
- Ongoing trending of percent average through wall depth with review action if it exceeds 60% provides reasonable assurance that corrective actions can be implemented prior to the identification of any in-service condition which could challenge structural integrity margins.

Figure 1- Summary of PE Results for Maximum and Average Dealloying Depths



RAI B.2.1.37-6-3, Inspection Results Demonstrating the Acceptability of the Flaw Size Correlation

Background

Figure 4-1 of AES-C-1964-5 contains a flaw-sizing curve which is used to relate the size of an indication found on the outside surface of a pipe to the amount of dealloying that has occurred on the inside of the pipe. This figure is based on data gathered in the 1990's from examinations of dealloyed pipes with through-wall cracks. During the audit the staff reviewed AES 13078445-2Q1, "Structural Testing of 3-inch, 8-inch and 10-inch Aluminum Bronze Flanges Removed from the Essential Cooling Water System." The staff independently confirmed that for the 10-inch flange, this test provides one more data point that supports the flaw size correlation.

Issue

During the audit, the staff found that other piping specimens that exhibited dealloying and through-wall cracks have since been tested; however, the new examination data from these tests has not been used to update or justify the continued use of Figure 4-1 of AES-C-1964-5.

Request

Plot the data for all of the more-recent tests of dealloyed specimens with through-wall cracks onto Figure 4-1 of AES-C-1964-5. Justify the continued use of this figure if the new data points fall outside the existing relationship established between crack angle and dealloying angle. Provide a list of all the data points referenced to their source document.

STP Response

Currently, there are 13 PEs performed on components where through-wall (TW) leakage was observed. From the PEs, the shape (inside and outside variation in TW penetration) of 10 leak locations were estimated from the physical measurements.

AES-C-1964-5, Figure 4-1 was updated with the data to date shown in Table 1 below. The updated Figure 4-1 is attached as Figure 1 to this response. Figure 1 correlates the angle of the assumed TW flaw for input to the analytical integrity evaluation with the outside surface length measurements determined from field inspections. The definition for TW flaw angle was revised from the average of the inside and outside dealloying measurements to one based on the equivalent degraded area of the TW dealloyed region. In this revised definition, the angle of the assumed TW flaw provides the same area loss as the local dealloying (plug) region that has penetrated through the wall. This definition has a physical basis in that it is a direct measure of the local area loss and conservatively assumes no load carrying capacity of the dealloyed metal. The local dealloyed area is calculated by numerically integrating the profile depth measurements from each PE.

The original curve for the TW size correlation is shown in Figure 1 as the thin dotted red line connecting with the solid red line. The newly added data fall below the original curve so no adjustments to the original curve were needed. This is the case whether average dealloyed angle or equivalent area angle definitions were used in the correlation. However, for small outside surface degradation (i.e., less than 8 degrees), the thin dotted red line was deleted and the solid red line was extended horizontally to the vertical axis. So for surface measurements less than or equal to 28 degrees of outside circumference, the assumed TW flaw length to be

used in the integrity analysis is 40 degrees. This is both conservative and practical when small pin-hole leaks are detected.

Table 1

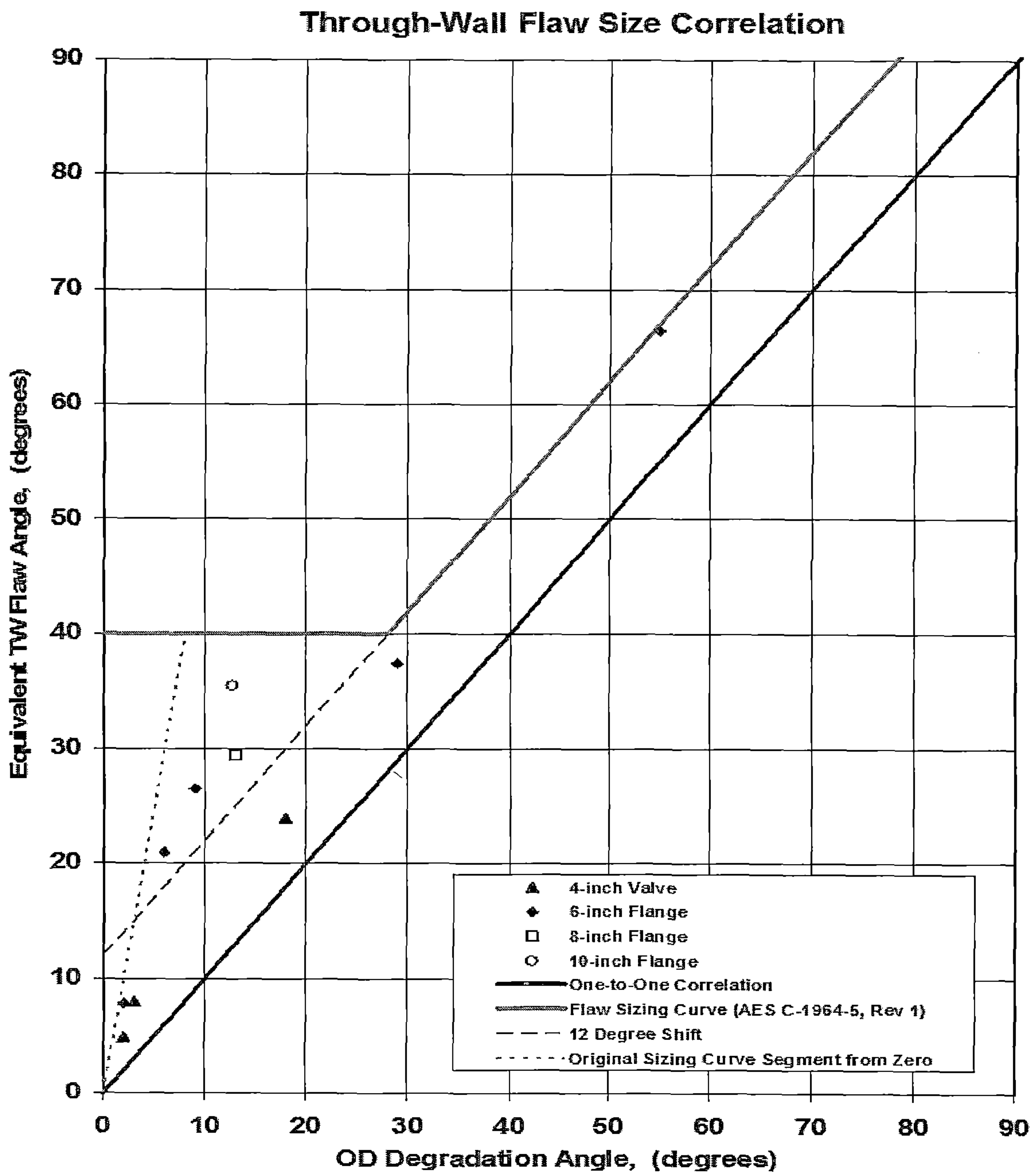
Summary of Through-Wall Dealloy Flaw Data (Degrees)

Component	Size (NPS)	ID	Location[2]	Outside Surface Dealloying Angle, $2q_{OD}$ (degs)	Inside Surface Dealloying Angle, $2q_{ID}$ (degs)	Equivalent TW Flaw Angle, $2q_{TW}$ (degs)	Source[3]
Valve [1]	4	V-6936	Inlet	2	6	4.9	AES 12048100-2Q-3
Valve [1]	4	V-6936	Inlet	3	10	8.0	AES 12048100-2Q-3
Valve [1]	4	V-6937	Inlet	18	26	23.9	AES 12048100-2Q-3
Flange	6	EW 2208/FS3452	WR	29	52	37.4	MT-3840
Flange	6	EW 2209/FS3451	BR	11	Insufficient Data[4]		MT-3840
Flange	6	EW 1308/FS4044	BR	6	Insufficient Data [4]		MT-3047-2
Flange	6	EW 2106/FW3489	BR	2	12	7.8	MT-4046
Flange [1]	6	EW1125/FS4350	BR	55	80	66.4	MT-4907
Flange [1]	6	EW1125/FS4350	BR	6	24	20.9	MT-4907
Flange	6	EW2206	WR	9	63	26.5	MT-5369
Flange	6	EW 2309/FS3453	WR	6	Insufficient Data[4]		MT3923
Flange	6	EW 2309/FS3453	BR	6	Insufficient Data[4]		MT3923
Flange	6	EW2208	BR	7	Insufficient Data [4]		MT3383
Flange	8	EW2384/FS10445	WR	13	31	29.4	MT-2727
Flange [1]	10	F-054	BR	12.7	59.2	35.4	AES 13078445-2Q-2

Notes:

(1) Components that underwent ACT (pressure and bend testing)
(2) WR = weld root, BR = backing ring edge
(3) AES numbered reports are documents prepared by Intertek. The MT reports are laboratory reports prepared by HL&P
(4) Profiles based on less than eight measurements uniformly spaced around the circumference.

Figure 1- Updated Figure 4-1 from AES-C-1964-5



RAI B.2.1.37-6-4, Substantiation of 100 Percent Dealloyed Tensile Specimens

Background

Page 12 of Enclosure 1, dated July 31, 2014, states that the dimensional degree of dealloying for mechanical test specimens is determined by an optical analysis that digitalizes an image of the fractured surface. The digital image distinguishes between the as-received and dealloyed material conditions based on the appearance of the fractured surface and the ratios of the areas to calculate the percent of dimensional dealloying for mechanical test specimens. The inherent assumption in this analysis is that, on an engineering scale, the alloys susceptible to selective leaching only exist in two discrete conditions: (1) the as-received condition and (2) fully dealloyed. This same assumption that the susceptible alloys only exist in two discrete conditions, was reinforced in discussions with plant and consultant staff during the supplemental audit of the Selective Leaching of Aluminum Bronze Program in March of 2015. This optical analysis method was used to determine the percent dealloyed for all the mechanical test data presented in Enclosure 1 of letter dated July 31, 2014, including the 100 percent dealloyed properties. The 100 percent dealloyed properties were then used in structural integrity calculations.

Page 14 of Enclosure 1, dated July 31, 2014, states that some mechanical test specimens were selected and elemental analysis was performed on the fractured surfaces. Qualitative elemental measurement, for Al, Fe, and Cu, were taken in a manner that traversed the fractured surface spanning areas of both as-received and dealloyed material. An example of one of those traverses taken on a fracture toughness specimen was provided on page 14 of Enclosure 1. The traverse shows a region of the fractured surface with a chemistry representative of as-received material and a region with reduced level of aluminum and iron.

Issue

The staff has not been provided with a technical basis to substantiate the assumption that alloys susceptible to selective leaching only exist in two discrete conditions. The staff cannot conclude that the susceptible material only exists in two discrete conditions or that the dealloying process has gone to completion in a region of reduced aluminum/iron based on a single traverse taken on a single specimen. The staff recognizes that material in the fully dealloyed condition will still have measureable amounts of aluminum and iron because not all of the phases present in the alloys are affected by the dealloying process. It is unclear to the staff if conclusions being drawn from Energy Dispersive Spectroscopy (EDS) traverses in dealloyed regions are based on elemental levels, degree of stability of the composition over a given length, or some other factor.

In addition, the elemental composition of the 100 percent dimensionally dealloyed tensile specimen (10x10x6 tee, piece number 3, Alloy CA952) has not been evaluated to determine if the dealloying process has gone to completion. This tensile specimen was used to produce the only yield strength value for 100 percent dimensionally dealloyed material measured to date, as shown in the plots on page 6 of Enclosure 1.

Request

1. Provide the technical basis used to substantiate the assumption that the alloys (C95400 and C95200) susceptible to selective leaching only exist in two discrete conditions; the as-received condition and fully dealloyed. Provide the technical references and experimental data used to support the technical basis, as applicable.

2. Demonstrate that the dealloying process has gone to completion in the tensile specimen (10x10x6 tee, piece number 3, Alloy CA952) used to produce the 100 percent dimensionally dealloyed yield strength value plotted on page 6 of Enclosure 1.
3. Provide, in tabular form, all the specimens that were tested in the 100 percent dealloyed condition. Provide a short description to identify each specimen including the component it was extracted from and alloy. Provide the mechanical properties that were measured from conducting the test. Provide the method used to establish that the specimen was 100 percent dealloyed. If neither the optical method discussed above nor direct elemental evaluation was used to establish that the test specimen was 100 percent dealloyed, provide a justification to substantiate the condition of the material.

STP Response

1. The two separate material conditions represent dealloyed and undealloyed Aluminum Bronze (Al-Brz) regions relative to the fracture surface of test specimens of both CA952 and CA954 alloys. It is important to note that the two discrete material conditions are with reference to the plane of the fracture surface. The dealloying across the component thickness is preferential creating multiple planes of a bi-metallic structure on a macro-scale. The corrosion process progresses along a network of the intergranular eutectoid structure containing the susceptible transformed phases until such time a continuous leak path is created through the wall thickness.

   The failure of the test specimen reveals the weakest plane across the specimen section for the given degraded state. For a partially dealloyed section, two distinct fracture regions are observed, dealloyed area and undealloyed area.

   The corrosion process first attacks the transformed material phases at local spots at the wetted surface of the component. The corrosion process causes aluminum (Al) and iron (Fe) to dissolve and then to leach out being carried away by the cooling water. The basic premise is that before the corrosion process can continue its advance through the thickness, the path up to the deepest point of penetration is essentially devoid of susceptible material (i.e., the corrosion process has gone to completion along that grain-boundary network). Fractographic and microstructural evidence that support this premise for both CA954 and CA952 are presented below.

   a) The visual appearance of the fracture surface shows two separate and distinct regions. The region of dealloyed Al-Brz is a reddish brown color. The region of undealloyed Al-Brz is a golden yellow color.

   b) The corrosion process progresses through the thickness like a moving wave. The boundary of the penetration follows the interconnecting network transformed material between the non-susceptible alpha grains. There is a distinct and abrupt change in material surface composition between the two regions. This can be seen in Figure 1 for CA952 and Figure 2 for CA954.

   c) There is a distinct change in failure mode between the two regions. The dealloyed region is an intergranular fracture along eutectoid boundaries that exhibit corrosion degradation with measureable reduced levels of Al and Fe, and the creation of voids within the transformed material.

   d) Surface chemistries in each region were determined by from Energy Dispersive Spectroscopy (EDS). The determination for the existence of two discrete material conditions, or that the dealloying process has gone to completion in a region of

reduced aluminum/iron, is not based on a single traverse taken on a single specimen. In the EDS study, multiple 1 mm^2 surface area scans were performed on four fracture surfaces; five traverses per specimen with up to twelve 1 mm^2 area measurements per traverse. This gave approximately 200 representative measurement points on the fracture surfaces; ~140 in CA952 material and ~60 in CA954 material. So a significant database of the variation of surface chemistries has been generated which provides the technical basis for supporting the dealloyed and undealloyed material conditions.

e) Examples of typical results are shown in Figures 1 and 2. Figure 1a confirms the surface chemistry within the undealloyed region is consistent with the virgin material since the aluminum (Al) and Iron (Fe) content is close to the chemistry material test report (CMTR) values reported for this CA952 heat. Figure 1b shows the reduced Al and Fe contents within the dealloyed region and the return to virgin composition values in the undealloyed layer. Figure 2 illustrates the same behavior for dealloyed and undealloyed material for CA954.

f) The depleted Al and Fe content along the fracture surface is significant up to the transition point between corroded and uncorroded (virgin) material. The transition between the two regions is seen as a step-like change. The depleted levels of both Al and Fe are approximately uniform across the dealloyed region suggesting the corrosion process has significantly slowed or arrested (i.e., the network of eutectoids forming the fracture surface are fully dealloyed). The tested samples are from components which have been in-service for multiple years. The uniform level of reduced alloy content over the long operating period indicates any time-dependent nature of the dealloying has attenuated and the corrosion process has gone to completion on the fracture plane.

2. Surface chemistries and local microstructure of the 100% DA tensile specimen (10x10x6-inch tee, Specimen #3-3) were evaluated for confirmation of a fully dealloyed condition. The results from five surface scans performed on the tensile fracture surface are plotted in Figures 3 and 4. For comparison, the results from the crack tip opening displacement (CTOD) specimen from the same material heat are also shown. Only the measurements within the dealloyed region are plotted. The multiple scans (inside diameter (ID) to outside diameter (OD) and transverse directions) provide a complete survey of the material composition. The depleted Al and Fe levels are at similar levels and uniform in all directions for both specimens. This indicates that the same extent of dealloying has occurred in both specimens which represent different locations within the 10x10x6-inch tee. As discussed in response 1) above, the uniform distribution of Al and Fe within the dealloyed region suggests time-dependent corrosion process is completed and a final dealloyed state has been achieved along the fracture path. Figure 4 shows the elevation in Copper (Cu) on the fracture surface is also uniform and similar for both specimens. The elevation in Cu occurs on a wt% basis since the Al and Fe has been reduced leaving mainly pure Cu and voided areas within the eutectoid.

   To further investigate the question of the state of the corrosion process near the fracture surface, the tensile specimen was sectioned axially and the microstructure in the vicinity of the fracture plane was evaluated at several locations. The fracture surface of the 100% DA tensile specimen was examined with optical light microscopy and interrogated in the Scanning Electron Microscope (SEM) using EDS. The sample was then sectioned along its central axis in the direction that was determined to be representative of the through

component thickness. The sample was etched to reveal the microstructure and location marks were indented to allow the SEM and light microscopy images to be directly compared. Selected areas on the cut plane immediately beneath the fracture surface were then imaged and analyzed using backscattered imaging and EDS.

The microstructure of CA952 material differs from the C954 material in a number of ways, most markedly being the volume fraction of transformed β eutectoid. An important observation of the transformed β morphology is that it consists of thinner transformed regions with areas of small secondary alpha (α_s) grains scattered throughout. During the dealloying process, the susceptible phases are attacked by the service water. It is reported that the chemically susceptible transformed phases are completely dissolved and pure copper is then redeposited back onto the surrounding microstructure. The advancement of the dealloying process is dependent upon the available network of susceptible material and the formation of voids to move the corrosive solution through the microstructure. After the dealloying process is completed, the CA952 displays a network of large primary alpha (α_p) grains (unaffected by corrosion) with a mixture of αs, pure copper, and voids at the triple points and along the grain boundaries.

The results of the metallurgical analysis are shown in Figure 5. The light micrograph at the top of figure shows that the SEM and light microscopy are directly comparable. It was determined that the visual assessment of the microstructure can be correlated to the chemistry results produced using EDS when a copper colored phase is present in the microstructure. The light micrograph shows a microstructure of α_p – grains in a network of dealloyed eutectoid (α_s, copper and voids). Copper is seen as pinkish color material and voids are visible as black holes within the eutectoids.

The following locations were evaluated with EDS:

Location	**Microstructure Feature**
1	Alpha grain
2	Eutectoid
3	Eutectoid-near alpha boundary
4	Iron rosette precipitate

The loss in Al in these regions is approximately 8 wt%. It has been measured in previous work and can be determined from the equilibrium phase diagram that the eutectoid phase has ~12.5 wt% aluminum present. The current work measures the Al content to be ~4 wt% after the dealloying process has occurred. The chemistry results from the EDS show a slightly increased level of Al present in the dealloyed regions due to the scale and morphology of the susceptible phases and presence of αs at these locations. The sensitivity of the EDS technique is also limited due to the inherent interaction volume of the electrons.

In summary, a consistent reduced level of aluminum is found close to fracture surface in the dealloyed regions through the thickness of the sample (ID to OD). This is indicative of a fully completed corrosion process in the sampled plane.

3. There were three tensile test specimens and one CTOD fracture test specimen showing a fully dealloyed condition over the fracture surface (i.e. 100% DA). A summary of these tests is given in Table 1, below.

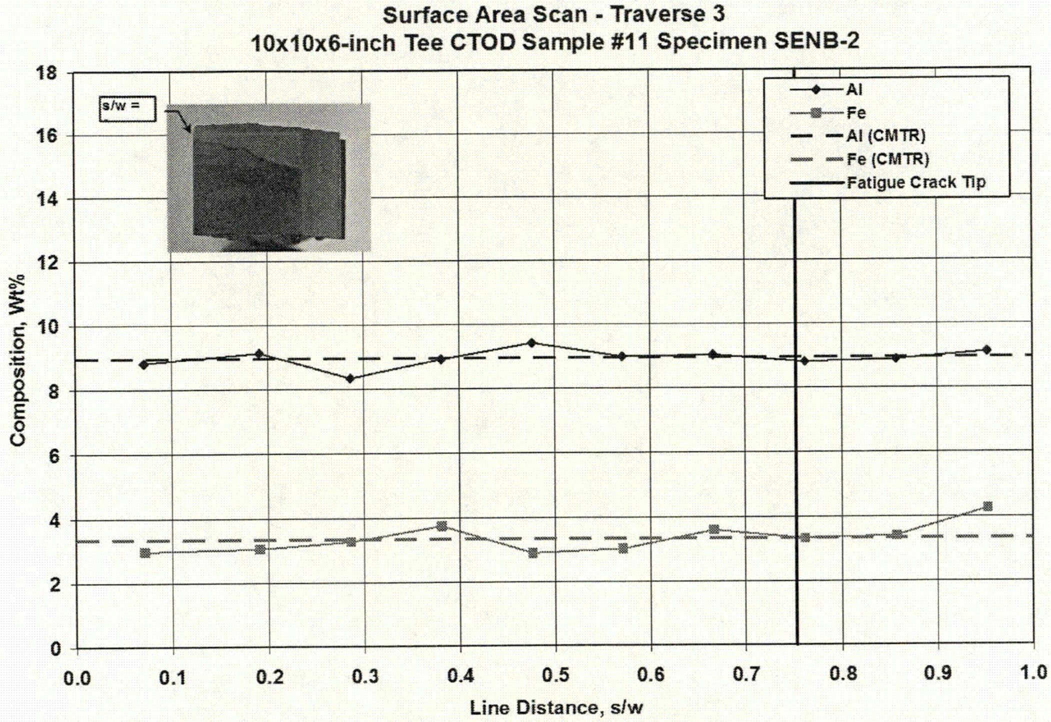
Table 1
Summary of Al-Brz Specimens Used for 100% Dealloying Testing

Component	Material	Heat	Specimen ID	0.2% OS Yield (ksi)	0.5% EUL Yield (ksi)	Ultimate Tensile (ksi)	K_{CTOD} (ksi in$^{1/2}$)	Dealloying Determination Method (1)
Small Bore Fitting (2)	CA954	-	1	-	-	31.7	-	SCM (3)
Small Bore Fitting (2)	CA954	-	5	-	-	28.9	-	SCM (3)
10x10x6-inch Tee, Piece #3	CA952	D-5921-2	3-3	27.2	28.0	28.9	-	Optical EDS Surface Chemistry Microstructure
10x10x6-inch Tee, Piece #4	CA952	D-5921-2	A1	-	-	-	26.7	Optical

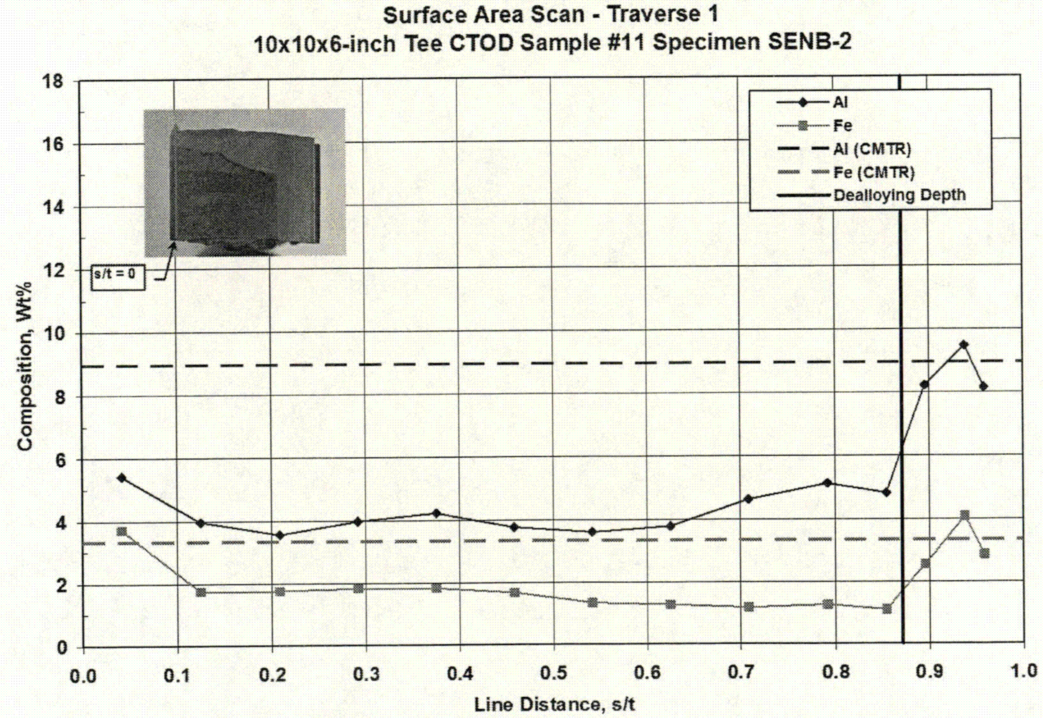
Notes:

1) The three methods of determination of 100%DA condition are a) optical (fracture surface appearance is reddish brown in color and intergranular over the 100% of the fracture area), b) surface chemistry scans (reduced Al and Fe content to confirmed facture surface is 100%DA), and c) microstructural evaluation of transformed phase to confirm fully dealloyed condition (presence of pure Cu and voids in the eutectoids).
2) Samples believed to be taken from one or two 2-inch valves removed from service.
3) Method used was stated in the Bechtel Report 8804-06 FA, Rev. 3, August 1988, as "SCM of the tensile fracture surface." No description of the method was given. This was most likely done in an SEM, and SCM probably indicates surface chemistry measurements by EDS were used to determine dealloyed condition.

Figure 1 - Typical Surface Area Scan Chemistry Results for CA952 CTOD Specimen



a) Traverse across Undealloyed Region



b) Traverse across Dealloyed Region and into Undealloyed Region

Figure 2 - Typical Surface Area Scan Chemistry Results for CA954 CTOD Specimen

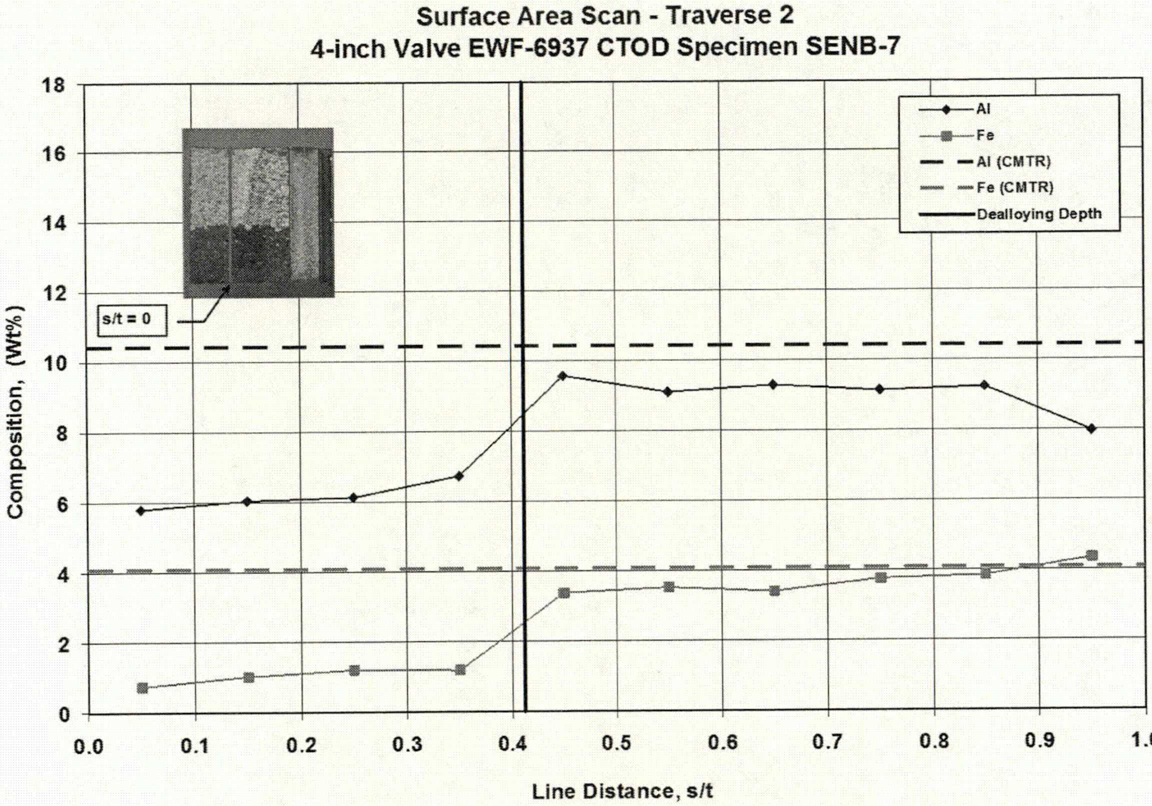
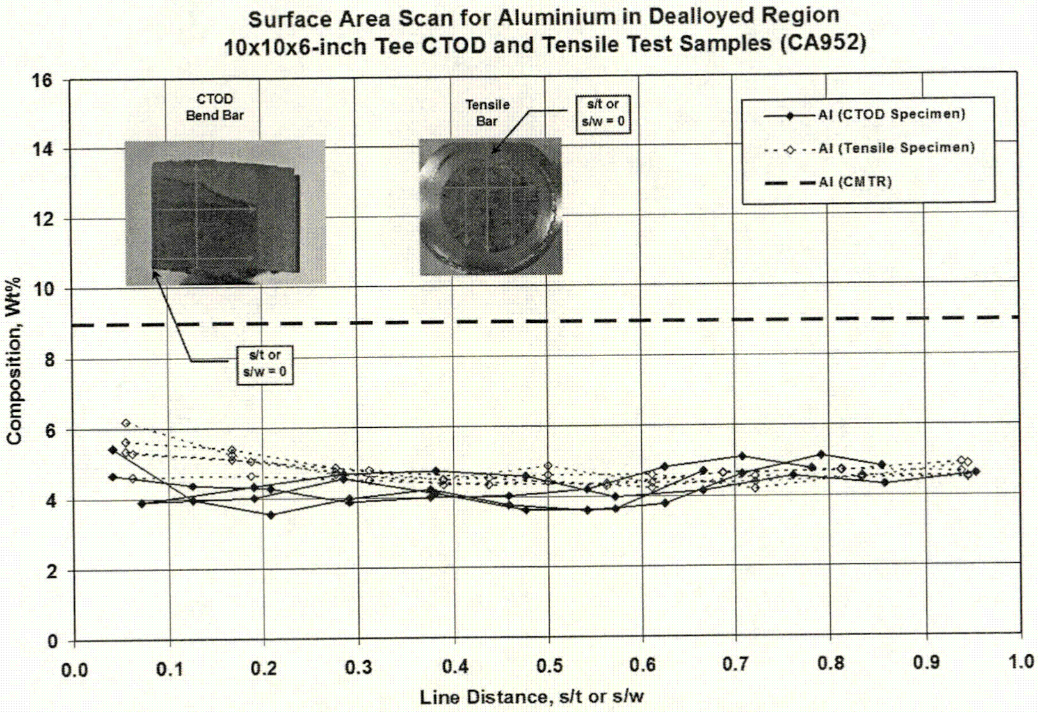
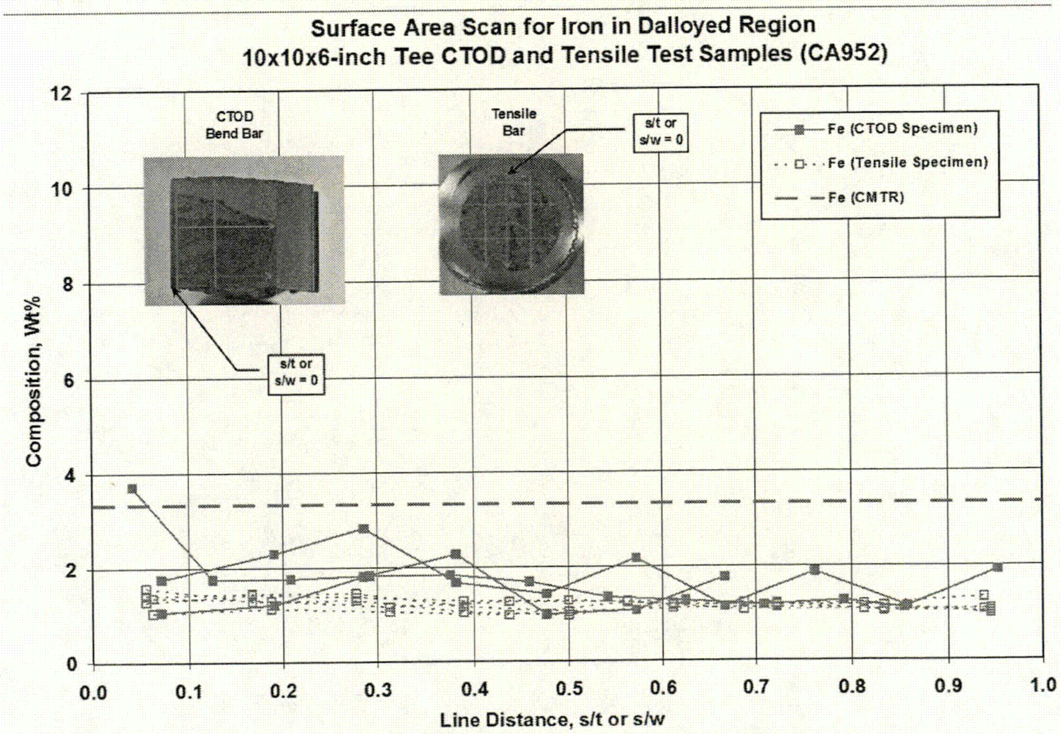


Figure 3 - Comparison of Aluminum and Iron Content in Al-Brz Test Specimens



a) Aluminum Content in the Dealloyed Region of CTOD and Tensile Specimens



b) Iron Content in the Dealloyed Region of CTOD and Tensile Specimens

Figure 4 - Elevation of Copper Content (Wt%) in the Dealloyed Region of Al-Brz Test Specimens

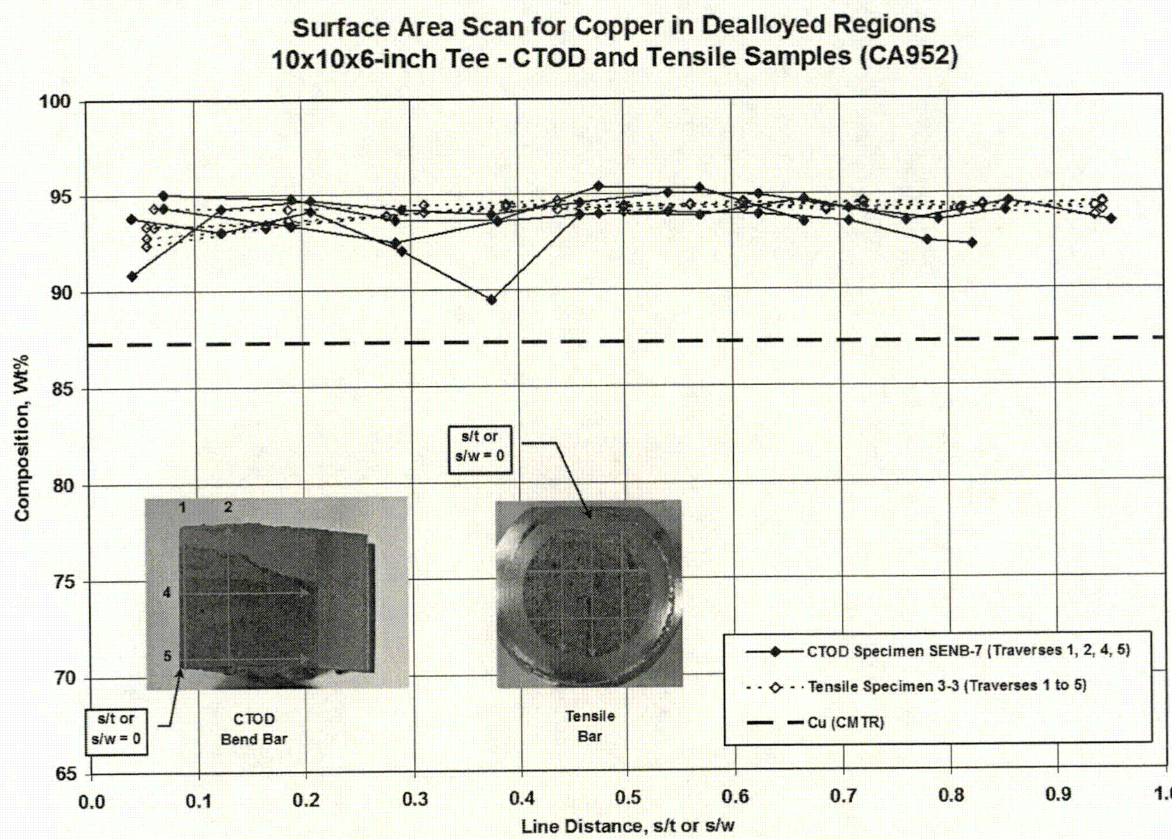
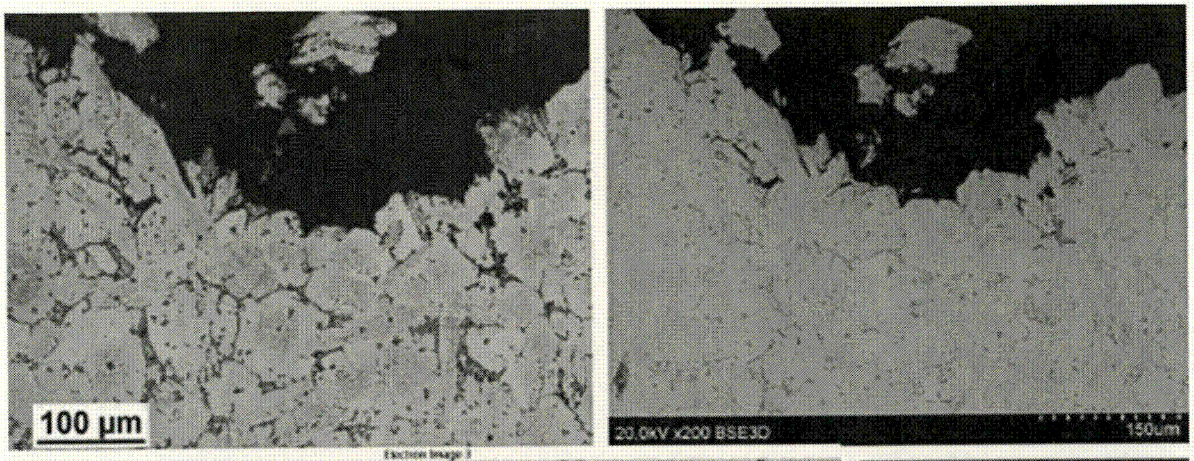
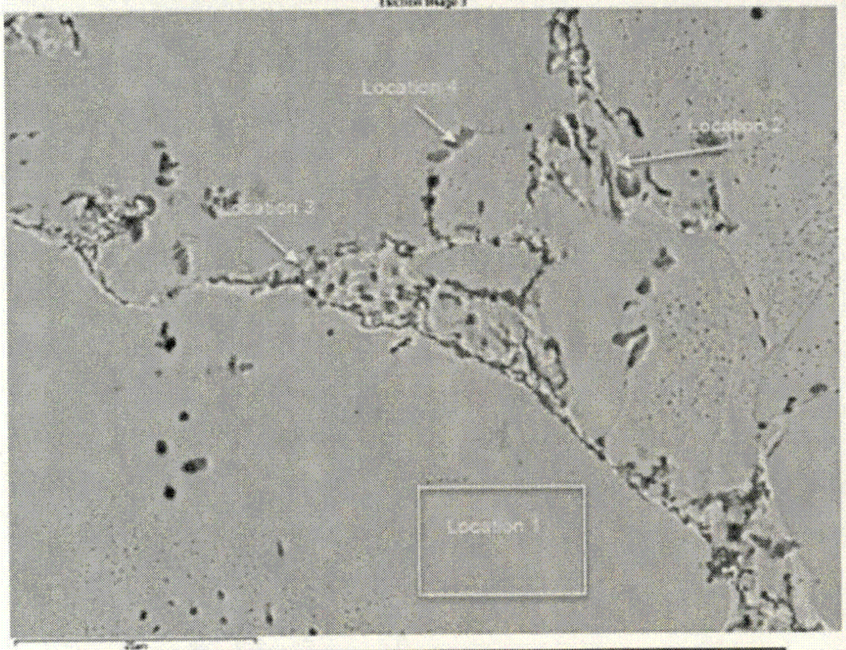
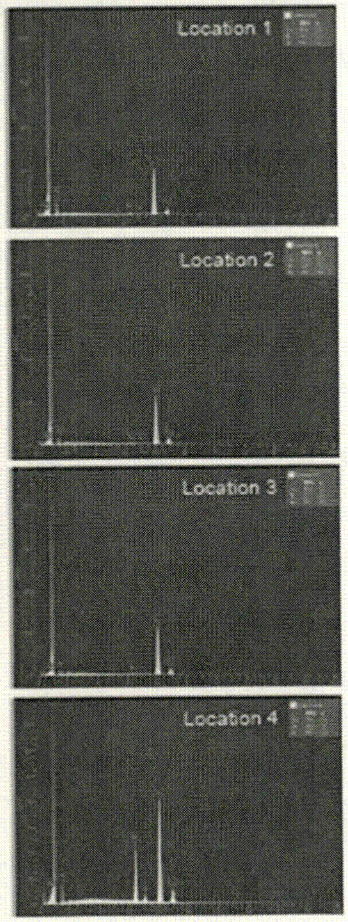


Figure 5 - Image Showing Side-View of Fracture Surface of Tensile Specimen (10x10x6 -inch Tee, Specimen #3-3, CA952)







	Location 1	Location 2	Location 3	Location 4
Element	Wt%	Wt%	Wt%	Wt%
Al	9.02	3.79	2.68	3.98
Fe	1.59	0.60	0.51	19.50
Cu	89.39	95.61	96.81	76.52
Total:	100.00	100.00	100.00	100.00

RAI B.2.1.37-6-5, Strength vs. Percent Dealloyed Curves

Background

The staff has reviewed publically available tensile yield strength and ultimate tensile strength values for aluminum bronze alloys C95200 and C95400 [references 1-7, listed below]. The results of the staff's review are shown below in Table 1.

Table 1: Publically available strength data for alloys C95200 and C95400

	Minimum Values		Typical values	
Alloy	Yield (Ksi)	Tensile (Ksi)	Yield (Ksi)	Tensile (Ksi)
C95200	25	65	27	80
C95400	30	75	35	85

The tensile yield strength and ultimate tensile strength values for the C95200 and C95400 alloys tested by STP are provided in RAI Response Set 26, Enclosure 1, dated July 31, 2014. The strength values are plotted on pages 5 and 6 of Enclosure 1. The yield strength values are plotted using both the standard 0.2 percent offset method and the 0.5 percent Extension-Under-Load (EUL) method.

A regression analysis of the strength data has been performed on each plot. The staff's estimate of the STP values plotted on pages 5 and 6 of the Enclosure are shown in Table 2 below.

Table 2: Estimate of strength values plotted on pages 5 & 6 of Enclosure 1, dated July 31, 2014

Alloy	Percent Dealloyed	Minimum Values		Minimum Values	
		Yield (Ksi)	Tensile (Ksi)	Yield (Ksi)	Tensile (Ksi)
C95200	0%	~32	~65	---**	---**
	100%	~28	~29	---**	---**
C95400	0%	~26	~73	~35	~80
	100%	---**	---**	---**	---**
C954/2*	0%	~26	~65	~35	~80
	100%	~28	~29	---**	---**

* C954/2 denotes treating the C95200 and 95400 data sets as a single data set.
** Insufficient quantity of data for the staff to estimate a value.

The staff has made the following three observations based on their review of Tables 1 and 2:

- The range of strength values of the aluminum bronze alloys at STP are representative of the range of strength values expected from a sampling of the commercial industry for alloys C95200 and C95400. The STP values span the expected minimum to maximum range with the typical values being comparable to those reported by others.
- As-received (0 percent dealloyed) yield strength values bound the dealloyed yield strength values reported by STP. The lowest as-received yield strength value reported by STP is for alloy C95400 which is the stronger of the two alloys.
- Approximate decrease in ultimate tensile strength is 60 percent while the approximate decrease in tensile yield strength does not appear to be measureable.

References:

[1] ASME BPVC, Section IIB-2013, SB-148, Table 3

[2] ASTM B148-14, Standard Specification for Aluminum-Bronze Sand Castings

[3] ASTM B763/B763M-14, Standard Specification for Copper Alloy Sand Castings for Valve Applications

[4] QQ-C-390B, Federal Specification for Copper Alloys Castings

[5] Material Data Sheets at http://www.eriebronze.com/alloys/ accessed on April 10, 2015

[6] Material Data Sheets at http://www.spba.net/ accessed on April 10, 2015

[7] Copper Development Association Inc. at http://www.copper.org/resources/properties accessed on April 10, 2015

Issue

(1) The plots on pages 5 and 6 of Enclosure 1 have multiple data sets for alloys C95200 and C95400. Each plot also has a single regression curve plotted. It is unclear to the staff if the data within each plot is being treated as a single data set or multiple data sets when determining strength values as a function of percent dealloying.

(2) It appears that linear regression analysis was used to determine the relationship between yield strength and percent dealloying while a nonlinear regression analysis was used to determine the relationship between ultimate tensile strength and percent dealloying. It is unclear to the staff why different types of regression analysis were used for the different data sets. The R-squared value for the curves has not been provided. It is also unclear to the staff if each data point is weighted equally in the analysis.

(3) It is unclear to the staff why the yield strength is being determined by both the 0.2 percent offset and the 0.5 percent EUL methods for all alloys and material conditions. It is also unclear if the values determined by the two different methods are being used for two different purposes. Depending on what the yield strength values are being used for, the appropriateness of determining the tensile yield strength using the 0.5 percent EUL method is uncertain.

(4) Tensile testing of material in the zero percent dealloyed condition has produced lower yield strength values than the material tested in the 100 percent dealloyed condition. Also, material tested in the less than 10 percent dealloyed condition produced comparable yield strength values as the material tested in the 100 percent dealloyed condition. Given the degree of scatter and statistical uncertainty in the yield strength values plotted on page 6 of Enclosure 1, it is not clear to the staff that the single yield strength data point for the 100 percent dealloyed material bounds the lower limit which could exist for the susceptible components in operation.

Request

Respond to the following requests to the extent applicable to the aging management, structural integrity, and operability of aluminum-bronze components. If the data is not being used to support these activities, state that it is not applicable and no further discussion is needed.

(1) Clarify if the data sets, within each plot on pages 5 and 6 of Enclosure 1, are being treated as a single data set or multiple data sets when determining strength values as a function of percent dealloying. If the data sets within each plot are treated as a single data set, state and justify how this ensures that the strength values are conservatively bounded given that: (a) there are values for two different alloys; (b) the data sets are comprised of more C95400 data points than the lower strength C95200 alloy; and (c) the only material condition where values are available for both alloys is the as-received condition.

(2) State and justify the basis for the type of regression analysis used to determine the relationship between strength and percent dealloying for each plot on pages 5 and 6 of Enclosure 1, addressing why different types were used. Clarify if any data points were excluded or weighed unequally in the analysis. Provide the R-squared value for each fit on pages 5 and 6 in Enclosure 1.

(3) Clarify if and how the different yield strength values, determined by the 0.2 percent offset method and the 0.5 percent EUL method, are being used. If the 0.5 percent EUL yield

strength values are being used for structural integrity, provide and justify the ductility criteria used to establish when this method will be used. Provide the lowest percent elongation value measured for C95200 and C95400, at any level of dealloying. If the 0.5 percent EUL yield strength values are being used for structural integrity calculations to support operability evaluations state and justify the basis for using this method.

(4) Provide the lowest yield strength and ultimate tensile strength values measured to date, at any level of dealloying. Clarify what numerical yield strength value is being used for the 100 percent dealloyed material in the structural integrity calculations to support operability evaluations. State and justify the basis used to conclude that the 100 percent dealloyed yield strength value being used for the structural integrity calculations to support operability evaluations is bounding for the susceptible components in operation.

STP Response

(1) The tensile test data sets for CA954 and CA952 were treated as one population for the regression analysis for 0.5% EUL and 0.2% OS yield strengths (σ_y), ultimate tensile strength (σ_u) and modulus of elasticity (E). This approach was followed because:

a. Limited test data were available especially at the higher levels of dealloying (i.e., greater than 80%DA). Therefore, combining data sets provided for a continuous distribution of data to be fitted and avoids extrapolating to 100% dealloyed condition.

b. CMTR and tensile test data for the tested components suggest the supplied heats for the CA952 material were at comparable strength levels as the CA954 material in the test plan.

c. As the test specimens approached fully dealloyed conditions over the cross-section, the tensile properties for the two alloys become similar. The strengthening from the eutectoid structure decreases with %DA and approaches the same limiting value. It appears that the reduced strength as the alloys becomes 100% DA is not strongly influenced by the original strength condition.

The strength values for non-dealloyed condition are based on Code specified minimum properties for CA952. The test data for 0%DA are not used in the structural integrity calculations in the procedures of Calculations AES-C-1964-1 and AES-C-1964-5. Use of Code specified minimum values are conservative and not dependent on the regression analysis relationship for %DA.

(2) The fitting of the tensile test data followed standard engineering practice for performing regression data analysis and error minimization. A linear regression model was used to fit the measured test results for yield and ultimate tensile strengths and modulus of elasticity. It was clear from the ultimate tension strength data that a non-linear equation would be needed for that property. An exponential equation was used to fit the data to capture the concave shape for the observed reduction in strength with the amount of dealloying in the test specimen. The same functional form was used for 0.2% OS and 0.5% EUL yield strength data. A simple quadratic function was used to fit the Modulus of Elasticity data. Least squares regression was used in the regression analysis to develop the best fit to the data. The correlation of determination for each fit as measured by the R^2 is given below:

Parameter	Number of Data Points	Number of Excluded Data Points	R^2 Regression Value
0.2% OS Yield, σ_y	20	1	0.46
0.5% EUL Yield, σ_y	18	0	0.55
Ultimate Tensile, σ_u	26	0	0.92
Modulus of Elasticity, E	19	0	0.42

All data points were equally weighted (1.0) in the regression analysis except for the one test value for 0.2% OS yield which was judged to be an outlier as discussed in (4) below. Although not reflected in the overall fit as described by R^2, the data fits are very good over most of the range. The lower R^2 values are bias by the large variation in data near 0%DA.

(3) The 0.5% EUL yield strength is used in defining the flow stress of the material when calculating the limit load capacity of the component. The use of the 0.5% EUL yield is justified since the specified minimum yield strength given in the ASTM SB-148 for acceptance of AL-Brz product, as tabulated in ASME Section III Section II, Part D, is based on the load achieved at 0.5% strain. The 0.5% EUL yield value defines the stress allowable limits to be used in design of Al-Brz nuclear piping components.

The 0.2% OS yield strength is used in the calculation of crack tip opening displacement (CTOD) from the clip-gage test data and in the correlation of fracture toughness (K_{CTOD}) from the CTOD test result. The regression equations for 0.2% OS yield and modulus of elasticity are used in the calculation of K_{CTOD} for the corresponding %DA for each test result.

The lowest measured elongation for CA952 is less than 1% at 100%DA. The lowest measured elongation for CA954 is 3% at 53%DA.

(4) The lowest measured tensile strength values to date are listed below:

Alloy	Property	Casting	Condition	Measured Value
CA952	0.5 EUL Yield Strength	10x10x6 Tee	100%DA	28.0 ksi
	0.2% Offset Yield Strength	10x10x6 Tee	100%DA	27.2 ksi
	Ultimate Tensile Strength	10x10x6 Tee	100%DA	28.9 ksi
CA954	0.5 EUL Yield Strength	4" Valve Body	53%DA	33.7 ksi
	0.2% Offset Yield Strength	4" Valve Body	53%DA	30.7 ksi
	0.2% Offset Yield Strength	Small Bore Valve	0%DA	26.8 ksi**
	Ultimate Tensile Strength	Small Bore Valve	100%DA	28.9 ksi

** Test result is believed to be an outlier since it falls outside the expected code specified minimum range for virgin material (see Figure 1). This test was performed in 1988 with no recorded test stress-strain data available.

Figures 1 and 2 compare CMTR data with tensile tests results produced by STP. In general, there is good agreement between the test data and reported CMTR values for the tested components. There are a few cases where the ultimate tensile strengths fell on the low side of the specified minimum values for the specification. Two of the specimens showed casting imperfections on the fracture plane typical of solidification flaws. Such small imperfections can have a noticeable impact on test results derived from sub-size specimens.

There is one test result for CA954 in the virgin condition that produced a 0.2% OS yield value that is lower than the tensile results at 100% DA condition. This result is listed in the table above (and plotted in Figure 1) where it is noted that this test result is suspected to be an outlier for the following reasons. First, the yield value falls below the specified minimum yield for CA954 yet it exhibited a high value for ultimate tensile strength. This appears to be inconsistent for CA954 which obtains its strength from larger amounts of transformed material. Second, the determination of 0.2% OS requires an accurate estimate of modulus of elasticity. Variability in E for low modulus materials like Al-Brz can cause significant scatter in 0.2% OS yield values. If an upper value for E was assumed, then the yield strength will be underestimated. In either case, the 0.2% OS yield strength is not directly used in the flaw evaluation of in-service dealloyed castings.

The value of yield strength for 100% DA condition is 28 ksi. This value is the measured test result for the 0.5% EUL yield strength for CA952 and bounds the regression fit.

Calculations AES-C-1964-1 and C-1964-5 have been revised to use 28 ksi instead of 30 ksi in the determination of flow stress. The fully dealloyed flow stress is used in the assessment of critical bending stress for the postulated fully dealloyed cross-section condition.

Figure 1 - CMTR and Test Specimen Data for SB-148 CA954

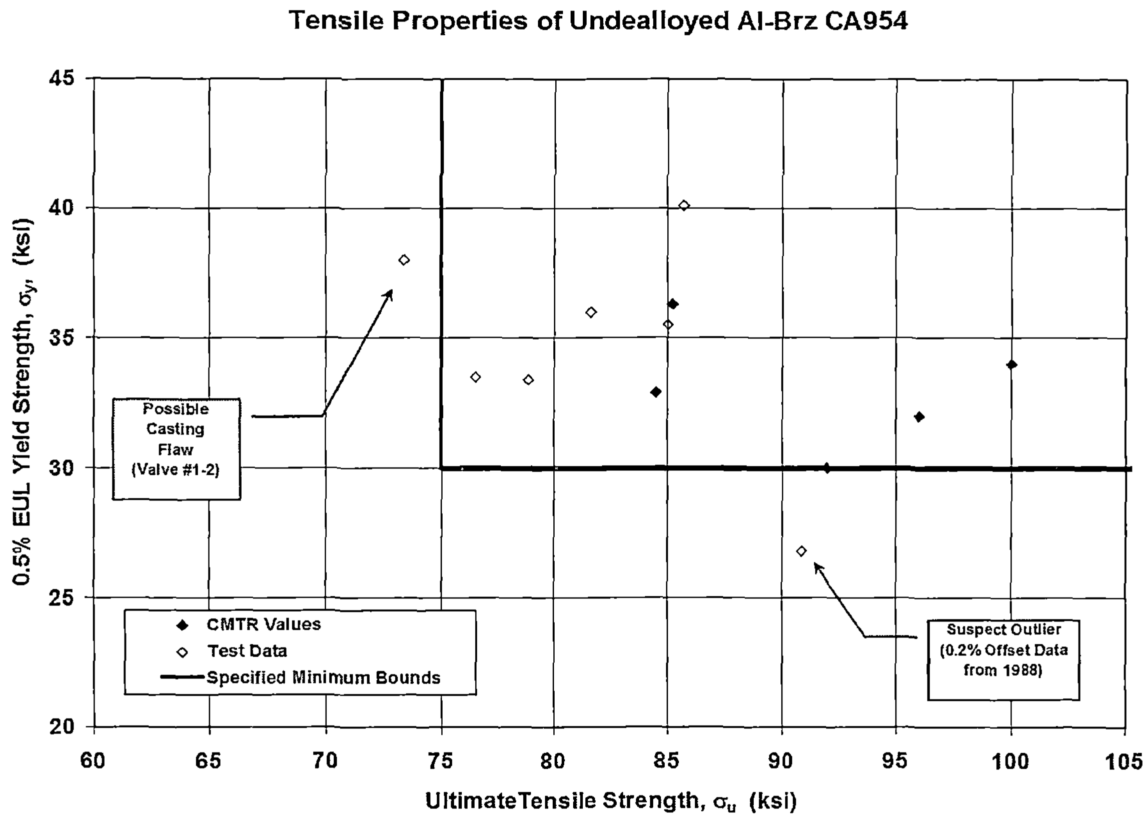
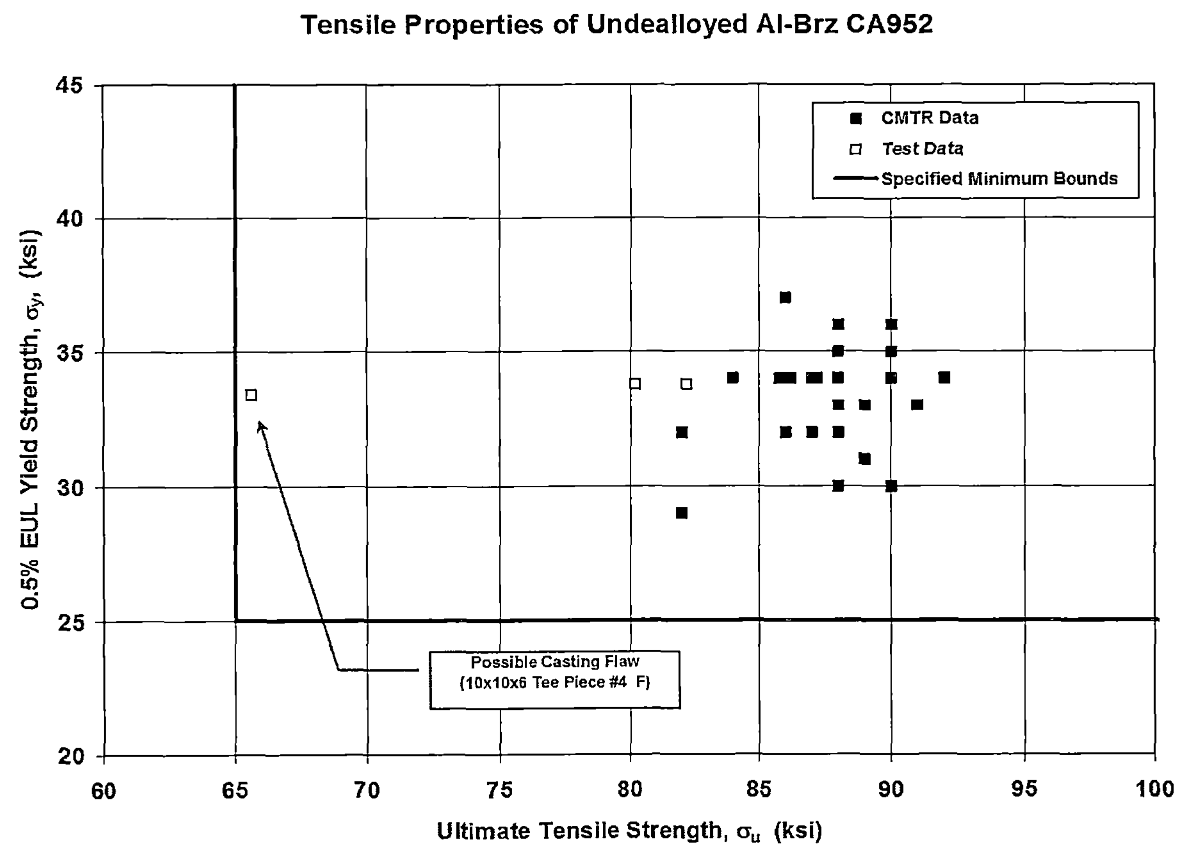


Figure 2 - CMTR and Test Specimen Data for SB-148 CA952



RAI B.2.1.37-6-6, AMP Acceptance Criteria for Strength

Background

The "acceptance criteria" program element of the Selective Leaching of Aluminum Bronze Program states that 30 ksi is the acceptance criteria for both ultimate tensile strength and yield strength. RAI Response Set 26, dated July 31, 2014, has three strength vs. percent dealloyed plots on pages 5 and 6 of Enclosure 1. The three plots all have strength values below 30 ksi.

Issue

It is unclear to the staff how acceptance criteria of 30 ksi can be established for ultimate tensile strength and yield strength properties when current plant-specific data shows values below the acceptance criteria.

Request

State the basis and justify how the 30 ksi acceptance criteria can be established for ultimate tensile strength and yield strength properties when current test data shows values below the acceptance criteria. If 30 ksi is not the appropriate acceptance criteria for yield strength and ultimate tensile strength, state the revised acceptance criteria and basis used to establish the values. If the acceptance criterion for yield strength or ultimate tensile strength is revised, provide a summary of the results of each structural integrity calculation to reflect lower acceptance criteria.

STP Response

The ASME Section III design allowable stress is based on ultimate tensile strength. In the 1994 Bechtel integrity assessment, a value of 30 ksi was used based on an average value for ultimate tensile strength from two test specimens reflecting 100% dealloyed condition. Current work is consistent with the testing performed in 1994 and an additional measurement of tensile strength at 100% dealloyed condition has been obtained. The regression analysis of all available data suggests 30 ksi still remains a reasonable asymptotic limit. The average of three tests at 100% dealloying is 29.8 ksi. The use of 30 ksi as a limit for 100% dealloyed material is still appropriate and will be trended over the extended operating period.

The yield strength for 100% dealloyed material is not used in the code calculations or the flaw analysis evaluation of AES-C-1964-1. Further, the 100% dealloyed ultimate tensile strength is not used in the structural integrity calculations. So the yield and ultimate tensile strengths for 100% DA conditions are not required for determining operability when leakage is detected. This places less emphasis on knowing the precise material strength for 100%DA conditions.

The 100% DA properties are used in the evaluation of the significance of any subsurface degradation as documented in AES-C-1964-5. There were no test data for yield strength when that calculation was originally prepared. A value of 30 ksi for yield strength was assumed on the basis that both yield strength and ultimate tensile strength will approach the same limit as ductility is reduced. From the current testing, a yield strength (0.5% EUL) value of 28.0 ksi was measured from a 100% DA specimen. Calculation C-1964-5 has been updated to define material flow stress using 28 ksi as the yield strength. The change in the results was not significant. The flow stress in C-1964-5 changed from 30 ksi to 29 ksi and the limit load bending stress for a fully dealloyed cross-section changed from 38 ksi to 36.7 ksi.

RAI B.2.1.37-6-7, Basis for Use of the Average Dealloying Angle in Structural Integrity Analyses

Background

The response to RAI B.2.1.37-5, part f, dated July 31, 2014, cites Generic Letter 90-05, "Guidance for Performing Temporary Non-Code Repair of ASME Code Class 1, 2, and 3 Piping," and ASME Code Section XI, Appendix H, "Evaluation of Procedures for Flaws in Piping Based on Use of a Failure Analysis Diagram," as the basis for use of the average through-wall dealloying angle instead of the inside wall dimension in AES-C-1964-5.

Issue

The staff cannot conclude that ASME Code Section XI, Appendix H (a methodology used to evaluate partial through-wall indications) provides a basis for use of an average through-wall dealloying angle because it lacks specificity to demonstrate acceptance of an average flaw size. Generic Letter 90-05 cites a flaw length, 2a, which is based on the dimensions of the flaw at the minimum pipe wall thickness. However, Generic Letter 90-05 is based on a process where the flaw can be characterized by volumetric measurements. In the case of selective leaching of castings, it is unlikely that volumetric characterization of the flaw would be possible, and if it were possible, the flaw-sizing correlation from Figure 4-1 of AES-C-1964-5 would not be necessary. A sufficient basis for use of the average dealloying angle has not been provided.

Request

State and justify the basis for use of an average through-wall dealloying angle as the output of the flaw-sizing correlation in Figure 4-1 of AES-C-1964-5.

STP Response

The original definition for the TW flaw for input to the integrity analysis used physical measurements of the circumferential extent of dealloying on the inside and outside surface. The average of the inside and outside lengths (angle) was used as a reasonable assumption for defining the TW flaw (postulated crack) to conservatively represent the dealloyed metal. The technical basis of this assumption was that TW dealloying typically varied linearly with circumferential distance so that averaging the lengths would account for both dealloyed and undealloyed material in the local plug-type leak region. An alternate definition is now being used for defining an equivalent TW flaw with a justified physical technical basis. This definition equates the area of the local dealloyed region to the postulated size of the flaw for the integrity analysis. The equivalent flaw would have the same area of penetration as the degraded section associated with the TW leak.

The flaw sizing correlation of Figure 4-1 is now based on this equivalent area method. This definition will result in TW flaw sizes comparable or more conservative than GL 90-05 since t_{min} for the ECW piping is relatively small. Using the dealloying angle measured at t_{min} in accordance with GL 90-05 would bias the assumed TW flaw length towards the length measured on the outside surface.

Figure 1 in RAI B.2.1.37-6-3 response below show the new Figure 4-1. Both the "average TW flaw and "equivalent area" TW flaw are very similar. Figure 2 below compares the two definitions. Past evaluations using Figure 4-1 remain valid and conservative.

Figure 1 - Updated Figure 4-1 from AES-C-1964-5

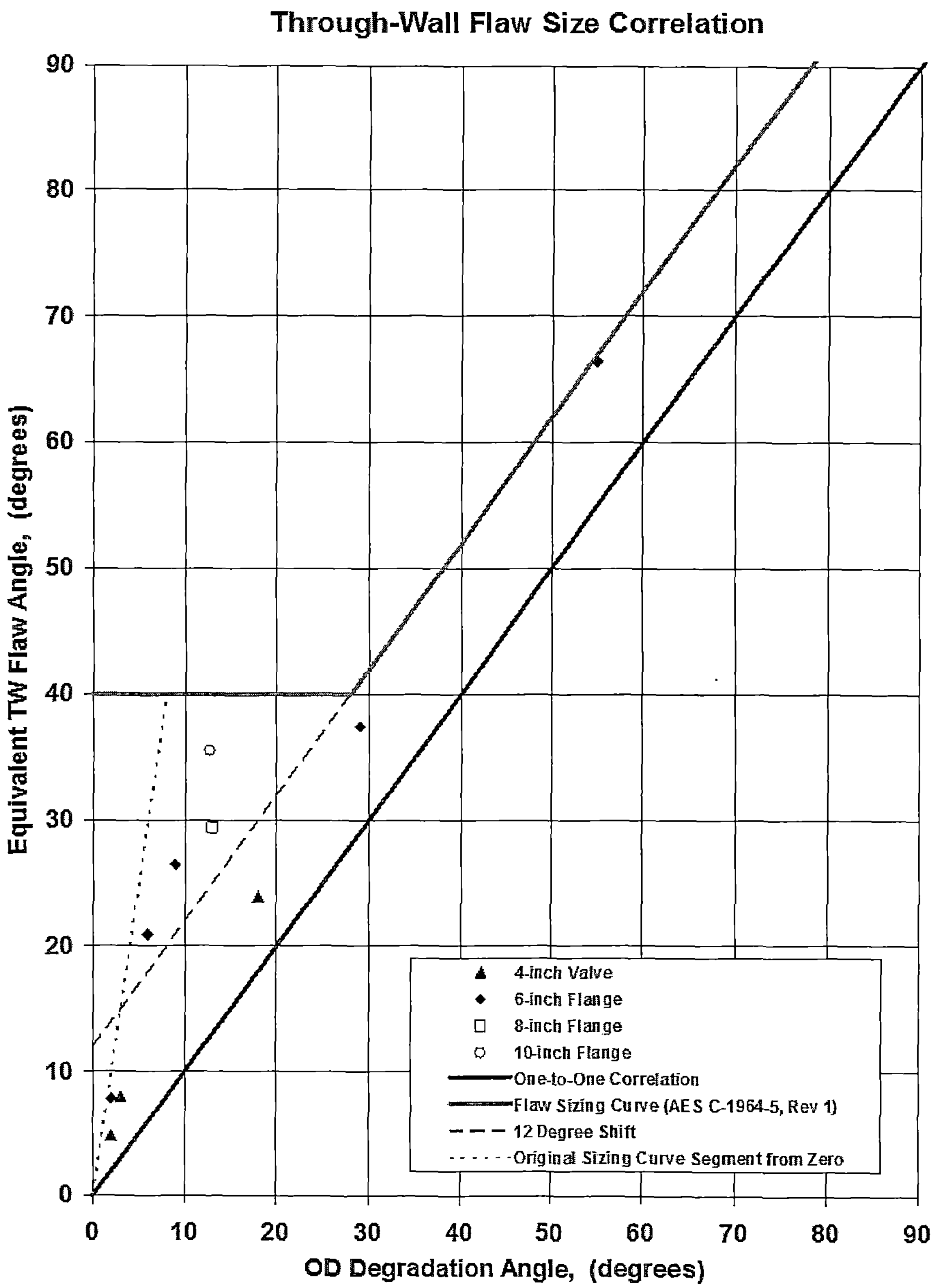
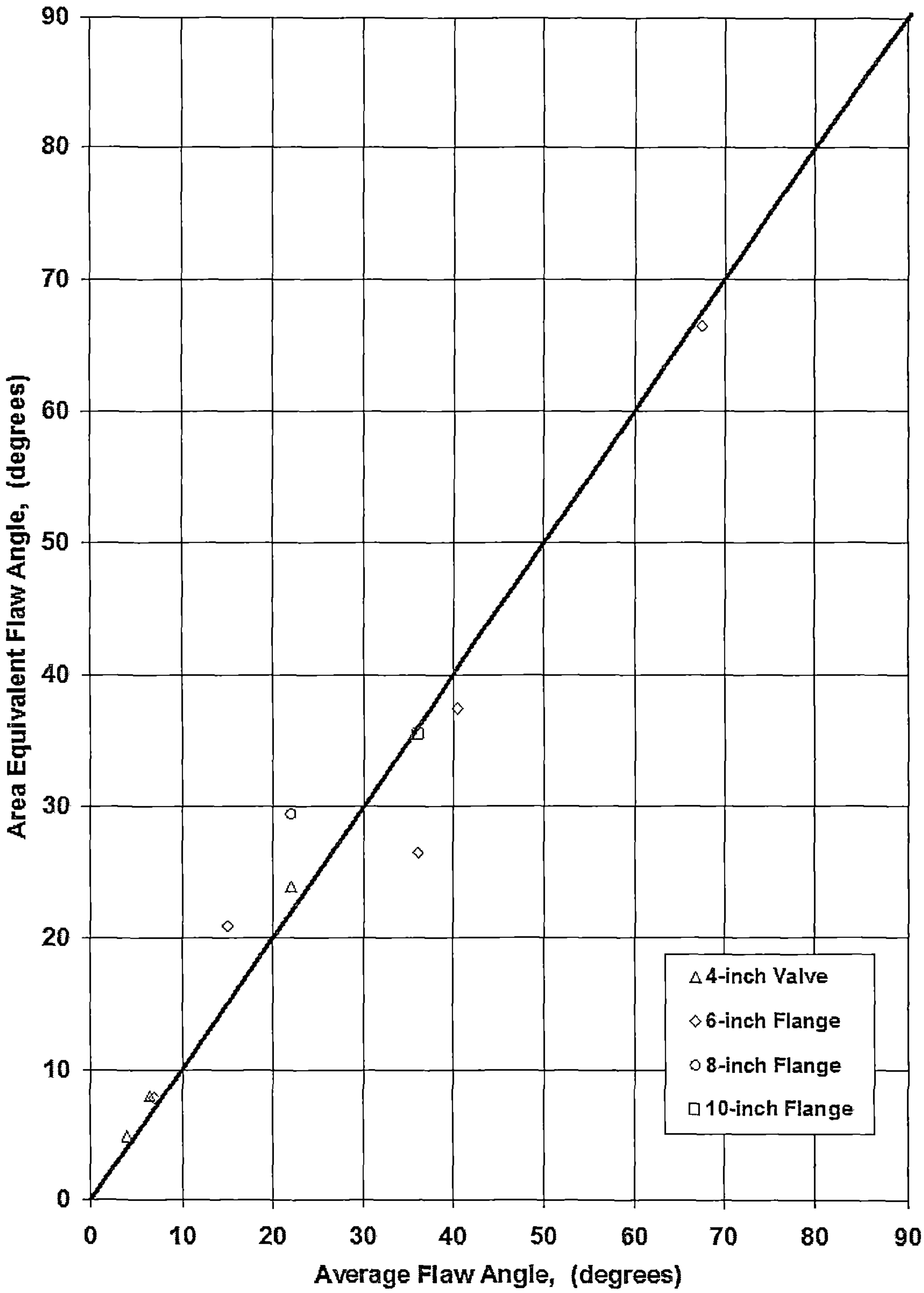


Figure 2 - Comparison of Equivalent Area Flaw Angle with Average Flaw Angle



RAI B.2.1.37-6-8, Implementing Procedures Related to System Walkdowns and Design Verification of As-Found Conditions

Background

During the supplemental audit of the Selective Leaching of Aluminum Bronze Program the staff reviewed PMWO SEM-1-9100041 and PMWO SEM-2-9100045, "ECW and ECW Screen Wash System – Visual Inspection System Piping."

UFSAR Appendix 9A states:

> Leaks that are detected are treated as non-conforming to the ASME Code, Section XI, i.e., as temporary non-code conditions in accordance with Generic letter 90-05. Relief Requests are submitted to the NRC for such leaks (except for repairs in accordance with Code completed during LCO conditions, or leaks detected and repaired during an outage, or leaks in lines 1 inch or under which are exempt from ASME Code Section XI replacement rules).

During the supplemental audit, the staff reviewed 0PGP04-ZA-0148, "Aluminum Bronze Dealloying Management Program." Section 5.5.1, "Relief Request," states that based on the use of Code Case N-513-3, "Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping," components with flaws a short distance from the weld do not require a relief request. The staff also reviewed the 50.59 screen, 33915401, dated May 22, 2014, performed for this procedure change.

During the supplemental audit, the staff reviewed calculation 14-EW-003, "Flood and Leak Rate Analysis for a Circumferential Crack in Aboveground ECW Piping," dated March 11, 2014. This calculation supports the closure of Commitment No. 46 which states, "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." The calculation yielded results of crack sizes that would limit the leakage rate to below administrative limits ranging from 7.9 inches for 30-inch components to 6.0 inches for 3-inch components.

Issue

1. Based on its review of PMWO SEM-1-9100041 and PMWO SEM-2-9100045 and an interview with a system engineer who has conducted system walk downs to detect potential leaking susceptible aluminum bronze components, it is not clear that all susceptible components are listed in the PMWO.
2. The staff cannot conclude that the change to 0PGP04-ZA-0148 to allow the use of ASME Code Section XI Code Case N513-3 is acceptable. Code Case N-513-3, states, "[t]he flaw geometry shall be characterized by volumetric inspection methods or by physical measurement. The full pipe circumference at the flaw location shall be inspected to characterize the length and depth of all flaws in the pipe section." In most if not all cases, the internal flaw size cannot be characterized by volumetric or physical measurements.
3. It is not clear to the staff that the range of crack sizes that would limit the leakage rate to below administrative limits have been determined to be less restrictive than allowable flaw sizes that are determined meet structural integrity using AES-C-1964-1. In addition, 0PGP04-ZA-0148 has not been updated to reflect this potential further limit on allowable flaw size.

Request

1. State whether all susceptible components or description of components are listed in PMWO SEM-1-9100041 and PMWO SEM-2-9100045. If not, explain why all of the susceptible components are not identified in these inspection tasks.
2. State and justify the basis for use of Code Case N-513-3 to determine the acceptability of components exhibiting through-wall flaws.
3. State whether there are any flaw sizes that would be acceptable from a structural integrity basis but not acceptable to ensure that the leakage rate from a degraded component is below administrative limits. If this is the case, state how the leakage rate flaw size acceptance criteria will be incorporated into the program.

STP Response

1. Preventive Maintenance Work Orders (PMWO) SEM-1-9100041 and PMWO SEM-2-9100045 were reviewed to ensure all susceptible components or description of components are listed in these inspection tasks. The PMWO's are updated to include 1" valves and now assures description of all susceptible components are addressed.
2. 0PGP04-ZA-0148 will be updated to remove the use of ASME Code Section XI Code Case N513-3 unless the ASME Code committee endorses specific applicability of an indirect sizing method that bounds the area of degradation in lieu of a volumetric method.
3. Because of the relatively low design stresses for the ECW system piping, acceptable flaw sizes for dealloyed Al-Brz castings in general are very large. Based on operating experience, leak rates from local TW dealloyed regions are not significant and are typically only visible as weepage on the surface. Leak detection capabilities are sufficient to find TW dealloyed locations well before the administrative leakage limits are reached. Inspections are performed by ECW System subject matter experts to identify evidence of TW leakage such as wet spots, residual surface deposits, and discoloration of the metal.

   Once leakage is detected, the leak rates are monitored so that corrective action can be implemented if any significant increase in leak rates is observed prior to scheduled component replacement.

   There are no flaw sizes for dealloyed uncracked Al-Brz castings that would be acceptable from a structural integrity basis but not acceptable to ensure that the leakage rate from a degraded component is below administrative limits.

RAI B.2.1.37-6-9, Scope Expansion Criteria

Background

RAI B.2.1.37-5 Request (e), dated December 18, 2012, postulates a series of six degraded conditions and requests the specific actions to be taken in response to these conditions and the basis for those actions. The response includes a series of decision trees and extent of condition testing that would be conducted based on the severity of the degraded condition.

The staff reviewed the RAI response presented in RAI Response Set 26 dated July 31, 2014, and discussed the examples with station staff during the supplemental audit of the Selective Leaching of Aluminum Bronze Program. The staff recognizes that in several of the scenarios, the severity of the degraded condition will not be known until the degraded component has been replaced and subjected to subsequent profile examinations and analysis confirmation testing. In that case, the specific nonconforming component will no longer be in service. However, the purpose of extent of condition testing is to determine whether there are any other components in the system that are in an equally degraded condition. For example Generic Letter 90-05 contains recommendations for augmented inspections.

The staff concluded that differentiating the number of extent of condition tests depending on the severity of the degraded condition is a good practice. For example, discovery of a component that is inoperable either based on the size of the outside diameter evidence of through-wall leakage or as a result of follow-on testing should result in a larger extent of condition population than discovering that some aspect of the analytical methodology used to demonstrate structural integrity is not bounded, but the components can be demonstrated to be operable after revising the calculations.

Issue

With respect to the "corrective actions" program element, SRP-LR Section A.1.2.3.7 states that actions to be taken when the acceptance criteria are not met should be described in appropriate detail or referenced to source documents. However, the "corrective actions" program element of the Selective Leaching of Aluminum Bronze Program does not describe the extent of condition testing that will be conducted when degraded components are detected.

Request

State how the number of additional PEs and/or ACTs that will be conducted (beyond those stated in the "detection of aging effects" program element) when indications of through-wall leakage are discovered in susceptible aluminum bronze components will be addressed in the Selective Leaching of Aluminum Bronze Program and licensing basis.

STP Response

The following actions outline the overall strategic actions for test or inspection results not meeting acceptance criteria:

- Perform operability determinations of all leaking components left in service, thereby assuring their structural integrity.
- Assess immediate extent of condition for each case by:
  1) Performing immediate walkdown of all ECW systems in both units for identifying leaking components;
  2) Increasing frequency of monitoring based on severity of condition;

3) Implementing daily operator's walkdown;
4) Scheduling 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).
5) If ASME Safety Factors are not met, performing extent of condition expanded scope of ACTs and PEs.

The process that is common to all actions is described below:

Process for Results Outside of Acceptance Criteria

When acceptance criteria are not met an immediate determination of operability, and an assessment of the extent of condition is performed.

Non-conforming ACT and PE conditions require reevaluating 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. If structural integrity cannot be demonstrated, the affected components are repaired or replaced within STP Technical Specification requirements

If the average measured crack length is greater than 110% of the average crack length used in analysis and ASME Appendix H or C Safety Factors are not met, 1 additional ACT and 3 additional PE are performed to determine extent of condition.

If the ACT results are less than acceptance curve (AES-C-1964-5 Fig 4-2) and ASME Appendix H or C Safety Factors are not met, 3 additional ACT and 5 additional PE are performed to determine extent of condition.

If the material properties (ultimate strength, yield strength or, fracture toughness) are less than 15% of the average trend values and ASME Appendix H or C Safety Factors not met, 3 additional ACT and 5 additional PE are performed to determine extent of condition.

LRA Appendix A1.37, Appendix B2.1.17, Table A4-1 and the AMP basis document PSALBZ, Selective Leaching of Aluminum Bronze is revised to include the extent of condition determination listed above.

Enclosure 2 provides the line-in/out revision to LRA Appendices A1.37 and B2.1.27.

Enclosure 3 provides the line-in/out revision to LRA Table A4-1 Commitment 44.

RAI B.2.1.37-6-10, Clarification of Licensing Basis Related to Use of Partially Dealloyed Material Properties

Background

Pages 5 through 7 of Enclosure 1 of RAI Response Set 26 dated July 31, 2014, show material property data for ultimate tensile strength, yield strength, and fracture toughness for various amounts of dimensional dealloying.

Issue

As a result of the staff's review of these plots and interviews with the applicant's personnel, the staff lacks sufficient information to validate the accuracy of the partially dealloyed mechanical properties. The staff notes that no partially dealloyed material properties have been used in the calculations that support the technical basis for the Selective Leaching of Aluminum Bronze Program, including AES-C-1964-5 and RC 9890. However, it is not clear whether partially dealloyed material properties might be used in the future.

If partially dealloyed materials were to be used the staff will require additional information to determine the validity of partially dimensionally dealloyed toughness values and the statistical significance of the partially dimensionally dealloyed strength values if they will be used to demonstrate structural integrity.

Request

Clarify whether partially dimensionally dealloyed mechanical properties (i.e., ultimate tensile strength, yield strength, and fracture toughness) will be used during the period of extended operation to demonstrate the structural integrity of aluminum-bronze components. If partially dealloyed material properties will not be used during the period of extended operation, state how this will be addressed in the licensing basis.

STP Response

The mechanical properties for ultimate tensile strength, yield strength, and fracture toughness generated for partially dimensionally dealloyed mechanical properties will not be used during the period of extended operation to demonstrate the structural integrity of aluminum-bronze components. The data were developed in the study of mechanical property behavior to confirm that there is a systematic trend in properties with %DA and the data are for information only. Structural integrity determination utilizes Code specified minimum values when evaluating mechanical properties.

LRA Appendix A1.37, Appendix B2.1.17, Table A4-1 and the AMP basis document PSALBZ, Selective Leaching of Aluminum Bronze is revised to state: Partially dimensionally dealloyed mechanical properties (ultimate strength, yield strength, and fracture toughness) are not used during the period of extended operation to demonstrate the structural integrity of aluminum-bronze components.

Enclosure 2 provides the line-in/out revision to LRA Appendices A1.37 and B2.1.27.

Enclosure 3 provides the line-in/out revision to LRA Table A4-1 Commitment 44.

Enclosure 2

STPNOC 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 a 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 will be replaced by the end of the 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.

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.

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.

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.

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.

Ultimate strength, yield strength, and/or fracture toughness will be trended and compared to the acceptance criterion. The percent average degree of dealloying depth, the ratio of maximum to average dealloying depth, and the area equivalent through-wall (TW) flaw angle cracking will be trended by comparing examination results with previous examination results. The acceptance criterion used to bound the trending data for percent average dealloying depth is 60% and the area equivalent dealloyed TW length shall be less than or equal to 110% of the allowable flaw length determined in the structural integrity analysis.

An engineering evaluation will be performed at the end of each PE and ACT to confirm the analytical methodology used to calculate the load carrying capacity and structural integrity of the leaking components is conservative.

The acceptance criterion for 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.

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.

If 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 Plan of Action 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. Non-conforming ACTs and PEs conditions require reevaluating 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, the affected components are either repaired or replaced within STP Technical Specification requirements.

If the average measured crack length is greater than 110% of the average crack length used in analysis and ASME Appendix H or C Safety Factors are not met, 1 additional ACT and 3 additional PE are performed to determine extent of condition.

If the ACT results are less than the acceptance curve (AES-C-1964-5 Fig 4-2) and ASME Appendix H or C Safety Factors are not met, 3 additional ACT and 5 additional PE are performed to determine extent of condition.

If the material properties (ultimate strength, yield strength or, fracture toughness) are less than 15% of the average trend values and ASME Appendix H or C Safety Factors not met, 3 additional ACT and 5 additional PE are performed to determine extent of condition.

Partially dimensionally dealloyed mechanical properties (ultimate strength, yield strength, and fracture toughness) are not used during the period of extended operation to demonstrate the structural integrity of aluminum-bronze components.

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 will be replaced by the end of the next outage. Periodic destructive and non-destructive examinations of aluminum bronze material components will be performed to update the 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.

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 leaking components to verify the continued used of the component until replaced.

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~~ 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 (e.g. ultimate strength, yield strength, and/or fracture toughness) will be obtained.

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 leak 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.

Volumetric examinations, when configuration allows, of aluminum bronze material components that demonstrate external leakage will be used 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 leaking components is conservative.

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.

The analytical methodology will be updated as required to confirm that the 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 percent average ~~degree of~~ dealloying depth, the ratio of maximum to average dealloying depth, and the area equivalent dealloyed through-wall (TW) flaw angle ~~cracking~~ will be trended by comparing examination results with previous examination results.

Ultimate strength, yield strength, and~~/or~~ fracture toughness will be trended. Trending provides monitoring of the degree of dealloying, the degree of cracking, the ultimate 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.

Acceptance Criteria (Element 6)

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 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 used to bound the trending data for percent average dealloying depth is 60%. The area equivalent dealloyed through-wall (TW) length shall be less than or equal to 110% of the allowable flaw length determined in the structural integrity analysis.

If an acceptance criterion is not met, the condition will be documented in the corrective action program and 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 leaking components. C~~, and c~~omponents are scheduled for replacement by the next outage~~, and scheduled for replacement by the next outage~~.

When acceptance criteria are not met an immediate determination of operability and an assessment of the extent of condition is performed.

If ~~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 Plan of Action 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. Non-conforming ACTs and PEs conditions require reevaluating 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, the affected components are either repaired or replaced within STP Technical Specification requirements.

If the average measured crack length is greater than 110% of the average crack length used in analysis and ASME Appendix H or C Safety Factors are not met, 1 additional ACT and 3 additional PE are performed to determine extent of condition.

If the ACT results are less than the acceptance curve (AES-C-1964-5 Fig 4-2) and ASME Appendix H or C Safety Factors are not met, 3 additional ACT and 5 additional PE are performed to determine extent of condition.

If the material properties (ultimate strength, yield strength or, fracture toughness) are less than 15% of the average trend values and ASME Appendix H or C Safety Factors not met, 3 additional ACT and 5 additional PE are performed to determine extent of condition.

Partially dimensionally dealloyed mechanical properties (ultimate strength, yield strength, and fracture toughness) are not used during the period of extended operation to demonstrate the structural integrity of aluminum-bronze components.

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. 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:

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~~ 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.

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 components where the configuration supports this type of examination to conclude with reasonable assurance that cracks are not approaching a critical size.

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.

Update the structural integrity analysis 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.

Monitoring and Trending (Element 5)

Procedures will be enhanced to:

Trend the percent average ~~degree of~~ dealloying, the ratio of maximum to average dealloying depth, and the area equivalent dealloyed through-wall (TW) flaw angle ~~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, evaluate the data trended against the acceptance criteria.

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 for ultimate 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.

The acceptance criterion used to bound the trending data for percent average dealloying depth is 60%. The area equivalent dealloyed through-wall (TW) length shall be less than or equal to 110% of the allowable flaw length determined in the structural integrity analysis.

~~Initiate a corrective action document w~~When the acceptance ~~the~~ criterion is not met~~.~~ initiate a corrective action document, perform an immediate determination of operability, and an assessment of the extent of condition.

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.

State, if the average measured crack length is greater than 110% of the average crack length used in analysis and ASME Appendix H or C Safety Factors are not met, 1 additional ACT and 3 additional PE are performed to determine extent of condition.

State, if the ACT results are less than acceptance curve (AES-C-1964-5 Fig 4-2) and ASME Appendix H or C Safety Factors are not met, 3 additional ACT and 5 additional PE are performed to determine extent of condition.

State, if the material properties (ultimate strength, yield strength or, fracture toughness) are less than 15% of the average trend values and ASME Appendix H or C Safety Factors not met, 3 additional ACT and 5 additional PE are performed to determine extent of condition.

State that partially dimensionally dealloyed mechanical properties (ultimate strength, yield strength, and fracture toughness) are not used during the period of extended operation to demonstrate the structural integrity of aluminum-bronze components.

Enclosure 3

STPNOC Regulatory Commitments

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,	B2.1.37	No later than the date the renewed operating licenses are issued CR 11-28986
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~~ 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. • 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. 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 leaking components is conservative.	B2.1.37	~~Completed~~ ~~NOC-AE-13003135~~ No later than the date the renewed operating licenses are issued CR 12-22150

Table A4-1 License Renewal Commitments

Item #	Commitment	LRA Section	Implementation Schedule
	• 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 percent average ~~degree of~~ dealloying depth, the ratio of maximum to average dealloying depth, and the area equivalent dealloyed through-wall (TW) flaw angle ~~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 nondealloyed aluminum bronze castings and at welded joints in the heat affected zones. • Specify the acceptance criterion used to bound the trending data for percent average dealloying depth is 60%. The area equivalent dealloyed through-wall (TW) length shall be less than or equal to 110% of the allowable flaw length determined in the structural integrity analysis. • 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
	○ 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. • State, if the average measured crack length is greater than 110% of the average crack length used in analysis and ASME Appendix H or C Safety Factors are not met, 1 additional ACT and 3 additional PE are performed to determine extent of condition. • State, if the ACT results are less than acceptance curve (AES-C-1964-5 Fig 4-2) and ASME Appendix H or C Safety Factors are not met, 3 additional ACT and 5 additional PE are performed to determine extent of condition. • State, if the material properties (ultimate strength, yield strength or, fracture toughness) are less than 15% of the average trend values and ASME Appendix H or C Safety Factors not met, 3 additional ACT and 5 additional PE are performed to determine extent of condition. • State that partially dimensionally dealloyed mechanical properties (ultimate strength, yield strength, and fracture toughness) are not used during the period of extended operation to demonstrate the structural integrity of aluminum-bronze components.		
45			
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	Completed Results submitted in NOC-AE-43003135 CR 12-27257