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Dominion®

August 24, 2009

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

Serial No.	09-506
NSSL/WDC	R0
Docket No.	50-423
License No.	NPF-49

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3
RELIEF REQUEST IR-3-04, RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION FOR ALTERNATIVE BRAZED JOINT ASSESSMENT METHODOLOGY

As a part of the inservice inspection (ISI) program, Dominion Nuclear Connecticut, Inc. (DNC) submitted a letter dated April 28, 2009 requesting approval to use an alternative brazed joint assessment methodology for the resolution of nonconforming conditions on American Society of Mechanical Engineers Boiler and Pressure Vessel (ASME) Code Class 3, moderate energy system piping with brazed joints at Millstone Power Station Unit 3 (MPS3). The April 28, 2009 letter requested authorization to allow the deferral of repair/replacement activities for degraded brazed joints in the Class 3 Service Water System in lieu of the requirements of the ASME Code, Section XI, 2004 Edition, No Addenda. In a letter dated July 27, 2009, the NRC transmitted a request for additional information (RAI). NRC requested that DNC respond to the RAI by August 25, 2009.

Enclosure 1 provides Revision 1 of Relief Request IR-3-04. Revision 1 incorporates changes to the relief request in response to the NRC RAI dated July 27, 2009. Enclosure 2 provides DNC response to the NRC RAI addressing Questions 1 through 3. Enclosure 3 provides updates to the original responses in DNC letters dated September 14, 2006 and January 2, 2007, for consistency with the final methodology and the current request. Enclosure 3 is provided in response to the NRC RAI, Question 1. Enclosure 4 provides an example of the application of the previously approved brazed joint assessment methodology during the third ISI interval as requested in NRC RAI, Question 3.

If you should have any questions regarding this submittal, please contact Wanda Craft at (804) 273-4687.

Sincerely,

Leslie N. Hartz
Vice President – Nuclear Support Services

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NRR

Enclosures:

1. Revision 1 of Relief Request IR-3-04
2. Response to the request for additional information in the letter dated July 27, 2009
3. Updates of the original responses provided in the requests for additional information in NRC letters dated September 14, 2006 and January 2, 2007
4. Example of the application of the previously approved brazed joint assessment methodology during the third ISI interval

Commitments made in this letter:

1. None

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Millstone Power Station

Serial No.09-506
Docket No. 50-423

ENCLOSURE 1

10 CFR 50.55a REQUEST NUMBER IR-3-04, REV. 1

(10 CFR 50.55a(a)(3)(i) REQUEST IR-3-04, TAC NO. ME1256)

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

Proposed Alternative

In Accordance with 10 CFR 50.55a(a)(3)(i)

--Alternative Provides Acceptable Level of Quality and Safety--

1. ASME Code Components Affected

ASME Code Class:	Code Class 3
References:	ASME Section XI, IWA-4000, IWA-5250 and IWD-3000
Examination Category:	N/A
Item Number:	N/A
Description:	Alternative Brazed Joint Assessment Methodology
Components:	Service Water System Brazed Piping Joints, three inches Nominal Size and Smaller

Figure 1 in Attachment A shows a typical brazed joint. Attachment B provides additional details concerning applicable brazed joint materials, configuration and brazing.

2. Applicable Code Edition and Addenda

ASME Section XI, 2004 Edition (No Addenda)

3. Applicable Code Requirement

If leakage of a Class 3 brazed connection is discovered during the course of normal operation, IWA-4000, Repair/Replacement Activities, applies and the joint must be repaired or replaced in accordance with that article. However, if the leakage is discovered during a scheduled leak test, the joint must be evaluated and repaired in accordance with IWD-3000 as clarified by the following:

- IWD-3000 does not have acceptance criteria for Class 3 components. IWD-3500, "ACCEPTANCE STANDARDS" refers to IWC-3500, "ACCEPTANCE STANDARDS". IWC-3516, "Examination Category C-H, All Pressure Retaining Components" states, "These standards are in the course of preparation. The standards of IWB-3522 may be applied."
- IWB-3522.1 establishes the acceptance standard for Visual Examination, VT-2, in which leakage of non-insulated and insulated piping is listed as a relevant condition. IWB-3522.1 states that such relevant conditions that may be detected during the conduct of system pressure tests shall require correction to meet the requirements of IWB-3142 and IWA-5250 prior to continued service.
- IWA-5250, "Corrective Action," in the context of a system leak test, requires identification of the source of leakage for evaluation of its corrective action which may include repair/replacement activities.

- IWB-3142, "Acceptance", permits acceptance of visually identified conditions under the requirements of IWB-3142.2, "Acceptance by Supplemental Examination."
- IWB-3200, "SUPPLEMENTAL EXAMINATIONS", permits supplemental surface or volumetric examinations to determine the extent of the unacceptable conditions and the need for corrective measures, repairs, analytical evaluation, or repair/replacement activities.

4. Reason for Request

In the course of plant operation, brazed joints are sometimes observed to be leaking at very low rate ("weepage") through a defect in the braze bond between the pipe and fitting. Applicable Code requirements depend on whether the leak is discovered in the course of normal plant operation or during a scheduled leak test.[1]

Section XI and Section III of the ASME Code do not have rules applicable to evaluation of weepage through brazed joints caused by defects in braze bonding between piping and fittings. Section XI, IWD-3000, has no acceptance standards and refers to the rules of IWB-3000. However, IWB-3000 has no rules pertaining to brazed joints. Therefore, Section XI does not have rules specific to examination and acceptance of relevant conditions observed in brazed joints. Lacking such rules, the leaking joint must be repaired in accordance with IWA-5250(a)(3) if found during a Code required system leakage test or IWA-4000 during any other mode of system operation.

A safe alternative to the requirement to immediately repair a brazed joint with leakage can include a deferred, but planned, repair/replacement activity that permits continued plant operation based on an evaluation of continued acceptable integrity and functionality of the brazed joint. With this approach, sections of piping containing brazed joints can be replaced with welds or flanges in a systematic and planned manner without unnecessary unavailability of safety related systems or components as well as unnecessary plant shutdowns.

5. Proposed Alternative and Basis for Use

It is proposed that in lieu of the immediate repair requirement of IWA-5250 or IWA-4000, DNC perform a supplemental ultrasonic test (UT) examination and comparison with alternative acceptance criteria. The UT examination will establish the extent of braze bond within the joint. The UT results will be compared with pre-established brazed joint bond levels required for structural integrity of the specific piping under consideration that accounts for the design basis loadings applicable to the condition. This will establish the basis for determining joint integrity to the extent required for system operability.

[1] ASME Code Interpretation XI-1-92-19

The lack of full braze bonding originates from construction, or fabrication, and is not progressive over time. However, the proposed methodology provides for continued monitoring until a resolution of the nonconforming condition (e.g., weepage) occurs through repair/replacement activities. Periodic monitoring of the joint and its leakage verifies that assumptions used for the assessment remain valid. The overall methodology has been validated by performance of physical testing on an array of simulated bond configurations, as well as several brazed joints salvaged from MPS3 piping. Consequently the request provides an acceptable level of quality and safety commensurate with the original licensing and design basis of MPS3 as well as the provisions of 10 CFR 50.55a(a)(3)(i).

5.1 SCOPE

The alternative is limited to brazed service water piping (typically constructed of copper-nickel or Monel piping and cast bronze fittings) or on-skid equipment piping that has a design pressure of 150 psig or less and a design temperature of 150 degrees Fahrenheit or less. The piping nominal size is limited to three inches maximum.

Basis:

The limitation of pipe sizes to three inches or less ensures that the alternative is applied to piping for which it was intended, and is comparable to the range of pipe sizes (two and three inches) included in the physical testing described in Attachment D. The limitation to service water systems ensures that the operating pressure and temperature are well within the moderate energy range. The fluid contents of the piping are comparable to those examined for potential corrosion effects.

5.2 EXAMINATION

As permitted by IWB-3200, "Supplemental Examinations," the brazed joint will be examined by UT using a straight beam technique that monitors the relative strengths of signals returned from the internal diameter (ID) of the pipe and the fitting. This technique was derived from and is consistent with the technique standardized by the U.S. Navy for use on brazed shipboard piping.[2]

The UT procedure in Attachment E is provided for reference only and is subject to change. The UT procedure will require that technicians be certified in accordance with ANSI / ASNT CP-189, 1995 Edition. Only Level II or III certified technicians may perform or review the braze readings and they must be familiar with brazed joint geometry and signal response characteristics. As a prerequisite the examination surface must be suitably prepared to obtain satisfactory sound transmission. The joint circumference is marked at a number of locations such that they are spaced no greater than one inch apart. For the actual examination

[2] NAVSEA 0900-LP-001-7000, "Fabrication and Inspection of Brazed Piping Systems", dated January 1, 1973.

a straight beam longitudinal wave signal is required. At each marked location the percent bond is recorded based on the relative strengths of signals received from the pipe ID and fitting ID. The procedure provides instructions to distinguish between fittings of the "face fed" and "insert" type, the latter of which have an internal groove in which a ring of braze filler material is inserted before brazing.

The MPS3 UT procedure will provide for documentation of the braze bond readings on suitable data sheets which also include the calibration data. The data sheets are reviewed by a certified Level II or III reviewer. The data sheets are then forwarded to Engineering for assessment.

Basis for Nondestructive Examination Technique:

The alternative UT examination is based on requirements for UT examination contained in the U.S. Navy standard for brazed piping. It uses basic straight beam UT technology, and was utilized to confirm the quality of critical piping systems in the submarine fleet of the U.S. Navy. A brazed joint is considered acceptable without further evaluation by the standard if the average bond is 60 percent or more.

Consistent with the reference standard, the MPS3 procedure will require this work to be performed by certified UT technicians, using calibrated equipment and approved couplants. It will require examination at multiple locations around the circumference of the fitting. It will require review of the data by a Level II or III technician. The UT procedure will be reviewed and approved by a Level III technician in accordance with Dominion quality requirements.

Previous trial demonstrations show that individual bond readings at a location on the fitting may vary, but the average reading is consistent among qualified examiners.

5.3 ASSESSMENT

An assessment of the joint using this methodology includes the following considerations:

- system performance and indirect effects assessments,
- adjustment of bond readings to account for uncertainties,
- a review of design basis stress analysis of the piping to determine required joint strength, and
- comparison of the adjusted bond readings with the prequalified bond levels that have been shown empirically by physical testing to assure structural integrity.

5.3.1 SYSTEM EFFECTS

As a prerequisite to structural assessment, knowledgeable engineering personnel assess the effect of the leak on the system and other nearby equipment. Typically a brazed joint with a defect in the braze material bonding will leak only drops per minute. The actual leak rate will be estimated and compared to service water system margins for loss or diversion of flow. In addition, a walkdown will be performed to identify any nearby equipment that may be affected by dripping or impingement spray from the leak. If required, a drip collection device or spray shield will be installed and maintained for the duration that the leak continues.

Basis:

ASME Code, Section XI Code Cases such as N-513-2 permit continued operation of low energy systems with minor leakage when justified by evaluation of system performance. Similarly, the proposed alternative permits continued operation provided that the leakage rate will not adversely affect required flows and the leakage or spray will not adversely affect safety related equipment. Typical flow from a weeping brazed joint is in terms of drops per minute. Even in a theoretical worst case of a joint having a total lack of braze material, the close tolerance between the pipe and fitting prevents significant flow. The total diametric clearance of a braze joint is about 0.005 inches. For a three inch pipe, the maximum possible flow area would be nominally 0.027 square inches (e.g., 3.14 x 3.5 x 0.0025) through which the upper bound flow rate at 100 psig would be about 6 gpm, a very small rate in comparison to service water pump capacity. More realistic estimates and actual leak rates would be much lower. Therefore, the maximum potential for braze joint leakage is very small. In addition, the proposed alternative requires a specific evaluation to assure that leakage does not unacceptably reduce system margins. Therefore, the system will meet all functional requirements and maintain an equivalent level of quality and safety.

5.3.2 ACCEPTANCE THRESHOLD AND ADJUSTMENT OF BOND READINGS

If the average measured bond reading is 60 percent or above, then no further assessment is required since the bond strength exceeds piping strength. If the average is less than 60 percent, then the bond readings as documented in the UT procedure are adjusted downwards on a sliding scale, such that all readings at 10 percent and below are assumed to be zero, and readings above 10 percent are adjusted using the following formula:

$$b_{adj} = 100 \times (\text{reading} - 10)/(100 - 10) \qquad \text{units of percent}$$

For example, a 50 percent UT reading would be adjusted to 44 percent bond level for assessment purposes. For simplicity, the adjustment may be applied to the average of the UT readings, or alternatively to each of the UT readings prior to averaging. The average of the adjusted readings is then used for assessment purposes. For bond readings that are significantly non-uniform around the circumference of the braze, an effective (lower) bond is computed based on the equivalent moment of the adjusted bond areas.

If the average adjusted bond reading is above 55 percent, then the joint strength is considered equal to or better than the piping, and steps 5.3.3 and 5.3.4 below are skipped.

Basis for acceptance threshold and adjustments of readings:

Acceptance of average UT bond readings of 60 percent or more is the same as the acceptance criteria in the U.S. Navy standard that has been used for critical shipboard piping systems. The U. S. Navy criteria are applicable to systems rated 300 psig and greater. The 60 percent threshold criterion is therefore conservative for systems with design conditions 150 psig or less. For further confirmation of the 60 percent threshold, testing has shown that if true bond in the joint exceeds 30 percent then the piping collapse load occurs before any bond failure. The testing performed for MPS3 is described in Attachment D. There is no braze bond failure mode because the piping deforms plastically to relieve the imposed load, and this occurs at loads greater than the maximum load permitted by the licensing basis analysis of the piping. The downward adjustment of bond readings, beyond what is required by the U.S. Navy standard, is an introduced conservatism used to help correlate the data from actual piping samples and accounts for uncertainties in bond readings.

5.3.3 CONSTRUCTION CODE QUALIFICATION STRESS ANALYSIS REVIEW

The Construction Code qualification stress analysis of record is reviewed to determine design basis loadings at the subject braze joint. Pressure, deadweight, and safe shutdown earthquake (SSE) loadings are included. The loads are either used directly or expressed in terms of equivalent pipe stress so that stress analysis outputs may be used directly. The stress intensification factor (SIF) that may have been applied in Construction Code stress analysis is not required to be included in the summation of nominal stresses used for assessment.

Basis for Stress Analysis Review:

The review of stress analysis required by this proposal is a data gathering activity required to determine the primary loads imposed on the brazed joint. The primary loads consist of maximum operating pressure, deadweight, SSE seismic, and any transient dynamic loads that have been defined for the piping. Since the stress analysis is the calculation of record for qualifying the piping in accordance with licensing basis requirements, it is an acceptable source of input for assessing the structural integrity of brazed joints.

The use of Construction Code stress values implicitly treats piping torsion loads as equivalent to bending moments. This is conservative because in the bonded joint, the torsional shear is actually half that calculated on an equivalent pipe stress basis.

5.3.4 COMPARISON OF ADJUSTED BOND TO REQUIRED BOND

Equation 3 in Figure 2 of Attachment A was developed to give the allowable loading for an equivalent bond level. The equation is used for a comparison that is needed only when the average bond is less than 60 percent. When an equivalent adjusted bond of a brazed joint is determined, as described in Section 5.3.2, an allowable loading ($S_{max}(b_{adj})$) can be obtained from the equation. This is the safe loading level that the joint can withstand. If the joint load demand that has been determined in Section 5.3.3, multiplied by a safety factor of 1.5, is less than the allowable ($1.5\ S_{eq} < S_{max}(b_{adj})$), then the brazed joint is concluded to have adequate structural integrity for continued service. The comparison is quantified as shown in Figure 2.

An example of a structural assessment performed for a hypothetical leaking brazed joint is included in Attachment C. The example is for a joint with 55 percent average measured bond, which is adjusted to an effective minimum bond of 43 percent for bending loads. This effective bond level results in a joint load capability of 16.5 ksi nominal pipe stress. The 16.5 ksi load capability is adequate for the design basis loads of this example since the joint load demand, including a 1.5 factor of safety, is only 6.6 ksi. Therefore, the example structural assessment concludes the joint can be left in service provided it is monitored until its permanent repair/replacement activity is completed.

If a joint does not have adequate bond by this assessment, this comparison for determining the adequacy of structural integrity of the joint is not applicable. Prompt repair/replacement of the joint, or temporary non-Code repairs subject to NRC review and approval may be an option, consistent with considerations in Regulatory Issue Summary 2005-20 for the resolution of degraded and nonconforming conditions.

<u>Basis for Comparison of an Adjusted to Required Bonding:</u>

Brazed joints with reduced bond levels can retain a significant strength that is adequate for the structural integrity of the joint. Dominion has sponsored tests at an independent testing facility to demonstrate the correlation between reduced bond levels and joint strength. The tests and their results are described in Attachment D.

The correlation developed by the testing conservatively determines a required bond level for a given intensity of joint loading. The results of these tests support the use of the comparison shown in Figure 2 of Attachment A for the structural integrity analysis.

The estimated joint strength obtained using Equation 3 in Figure 2 is confirmed conservative by test results. Each of the tested joints achieved a collapse load above that which would be predicted for a 7.5 ksi braze shear strength. This also confirms the acceptability of the 7.5 ksi maximum braze shear stress assumption that is used as an input to the Equation 3, shown in Figure 2. Additional basis for acceptability of this value is contained in Enclosure 3.

With the adjustment of bond readings imposed by this methodology, and a joint load capacity that is based on a 7.5 ksi shear stress, in conjunction with an imposed safety factor of 1.5 on loads and pressure, the tests demonstrate that a margin of greater than 1.5 exists between test results and estimated allowable joint load capacity from the actual piping removed from plant service. This margin provides an equivalent factor of safety (FS) to that provided by the ASME Code, Sections III and XI.

The ASME Code, Section III, Appendix F has been accepted by the NRC for evaluation of degraded conditions.[3] Appendix F, paragraph F-1331.1 (a) permits primary stress at levels up to $0.7S_u$ and in paragraph (c) it permits primary membrane plus bending stress at levels up to $(1.5)(0.7S_u) = 1.05S_u$. The maximum FS resulting from these comparisons is 1.4 relative to ultimate strength. In shear across a section, paragraph F-1331.1 (d) limits shear to $0.42S_u$ for a FS of 1.37 relative to $(1 / \sqrt{3})S_u$. The 7.5 ksi shear limit used at the braze bond is well below this Appendix F limit of $0.42S_u$ for the pipe and fitting materials.

The ASME Code, Section XI permits acceptance of planar flaws for which Appendix C in paragraph C-2621 requires a safety factor of 1.4 for circumferential flaws, and paragraph C-2622 requires a safety factor of 1.3 for axial flaws for faulted loads. These same safety factors in Appendix C are also incorporated by reference in Code Case N-513-2, which has been accepted by the NRC for evaluation of flaws.

Considering the ASME Code references described above, a FS of 1.5 for design basis loadings in ductile materials provides an equivalent and acceptable level of safety as compared to the plant design basis and permitted methodologies for evaluation of flaws.

5.4 MONITORING

The proposed alternative assessment methodology requires periodic monitoring to assure that the assumptions of the assessment remain valid. This monitoring will be in addition to the normal daily plant operator rounds during which

[3] Generic Letter 91-18, Rev. 1, "Information to Licensees Regarding NRC Inspection Manual Section on Resolution of Degraded and Nonconforming Conditions," October 8, 1997.

personnel are observant for signs of leakage. The monitoring will be by visual observation of the appearance of the joint and its leak rate, plus re-examination of the joint by UT to reconfirm the percent bonding. The frequency of the monitoring will be approximately once every three months. The monitoring will continue as described until the joint is repaired or replaced. If there are changes in the nonconforming condition of an evaluated brazed joint with weepage that may impact its assessment for adequate structural integrity or its functionality, a Condition Report will be generated in accordance with the Millstone Power Station Corrective Action Program and the UT readings on the joint will be repeated and reassessed.

Monitoring Basis:

The degree and frequency of periodic monitoring is conservative because the braze defect that permits this form of leakage stems from original construction, or fabrication, and is not the result of a progressive degradation mechanism. Conditions that are applicable to the use of this methodology stem from defects in braze material inside a socket joint and will have a very low leak rate. Leakage is commonly considered weepage, at drops per minute or simply the appearance of moisture and salt deposits.

In MPS3 operating experience, there have been no conditions where the piping disengaged from brazed fitting sockets. Consequently, no conditions have been observed that would have impacted the ability to maintain adequate system flow. This positive operating experience is due to the inherent structural integrity of brazed joints in service water systems.

To further address the potential for degradation, a search and review of external operating experience was performed. Braze failures in closed loop and electrical cooling systems such as generator stator cooling have been attributed to corrosion. However, there was no operating experience indicating progressive failure for open loop seawater systems. To confirm the conclusion that no progressive failure mechanism applies, DNC disassembled and examined two specimens that had already been removed from Millstone Power Station seawater service, and that were reported to have low bonding. The surface examination of the separated fitting and pipe surfaces did not reveal evidence of braze metal corrosion product. Since these examined joints are typical of plant construction and have seen nearly 20 years of service with no degradation of the bond, it is concluded that periodic visual monitoring of leak rate for this condition is acceptable, and monitoring may be scheduled on a quarterly basis. The specified response to altered conditions such as increased weepage will ensure that degradation to system functional margins does not occur.

5.5 REPAIR / REPLACEMENT

If the assessment can conclude that a brazed joint with leakage retains adequate structural integrity and functionality, an operability determination can be used to document an operable but not fully qualified status. A timely repair/replacement activity can be planned, commensurate with safety, and in accordance with 10 CFR Part 50, Appendix B. Consistent with the Millstone Power Station Corrective Action Program, the permanent Code repair/replacement for this nonconforming condition will be considered timely when completed during the next cold shutdown of sufficient duration, or the next refueling outage, whichever comes first.

If a joint does not have adequate bond by this assessment, the methodology for determining the adequacy of structural integrity of the joint is not applicable. Prompt repair/replacement of the joint, or temporary non-Code repairs subject to NRC review and approval may be an option, consistent with considerations in Regulatory Issue Summary 2005-20 for the resolution of degraded and nonconforming conditions.

Basis:

The bases for continued operation prior to repair of the joint are: system functionality is maintained as justified in Section 5.3.1 above, structural integrity of the joint is maintained as justified in Section 5.3.4, and there is no progressive braze bond failure mechanism that would alter these conclusions over time. Compensatory actions for the condition are administratively controlled under the Millstone Power Station Corrective Action Program. These include, but are not limited to, the periodic monitoring of leakage for the condition or housekeeping measures to contain weepage from affected piping. The application of this methodology will be consistent with considerations of Regulatory Issue Summary 2005-20 for the resolution of degraded and nonconforming conditions. The permanent repair/replacement of the brazed joint assessed using this methodology will be in accordance with ASME Code, Section XI, IWA-4000.

5.6 AUGMENTED EXAMINATION:

Up to five similar brazed joints will be selected for augmented leakage examination. The additional joints will be selected based on consideration of adjacency, opposite train, fitting type, or other factors that may be evident from the specific condition. Selected joints for augmented examination will be consistent with ASME Code Case N-513-2. If leakage is observed in similar joints, the resolution of each nonconforming condition will be evaluated in accordance with the Millstone Power Station Corrective Action Program, and the extent of condition will be documented and addressed.

Basis:

The examination of the additional joints is consistent with current practice for the resolution of degraded and nonconforming conditions, (e.g., application of ASME Code Case N-513-2). Augmented examinations provide information regarding the extent of condition being evaluated and are consistent with current Millstone Power Station procedures for responding to leakage in service water piping.

6. Duration of Proposed Alternative

This proposal requests approval for the use of an alternative brazed joint assessment methodology for the third 10-year Inservice Inspection (ISI) interval, which began on April 23, 2009, and is scheduled to be completed on April 22, 2019.

7. Precedents

A similar request for relief was granted in the Second Interval (Relief Request IR-2-38) per letter 07-0153 dated February 28, 2007, ADAMS Accession No. ML070580514.

FIGURES

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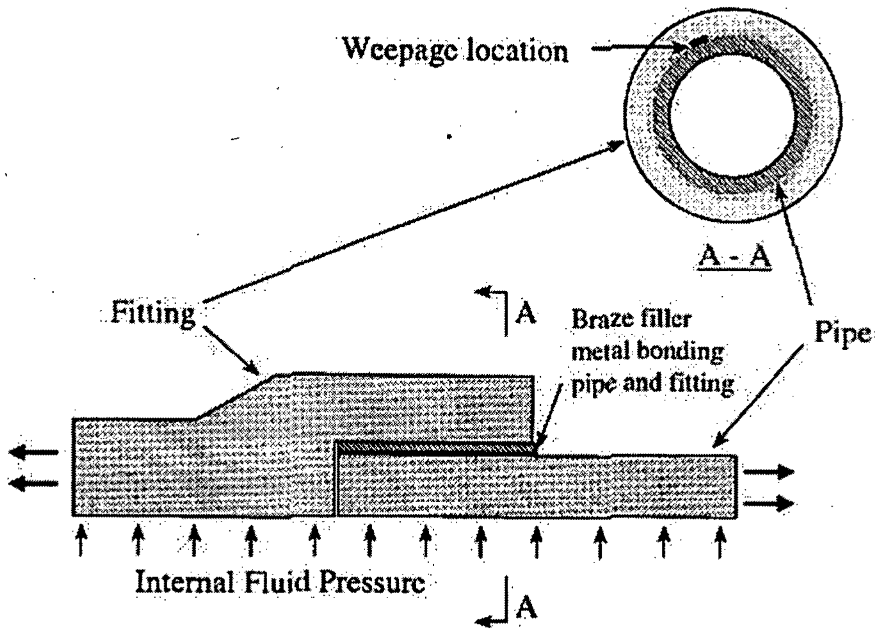


Figure 1: Typical Brazed Joint Configuration

$$1.5 \cdot S_{eq} < Smax\left(b_{adj}\right) \qquad (1)$$

$$S_{eq} = S_{lp} + S_{dl} + S_{sse} + S_{dyn} \qquad (2)$$

S_{lp} = longitudinal pressure stress

S_{dl} = deadload stress

S_{sse} = SSE seismic stress

S_{dyn} = dynamic stress (if defined)

Unintensified pipe stresses from Code qualification analysis

$$S_{max}\left(b_{adj}\right) = \frac{\pi}{4} \cdot \frac{D^2 \cdot L_{ins} \cdot \tau_{max}}{Z_{pipe}} \cdot b_{adj} \qquad (3)$$

D = pipe outside diameter

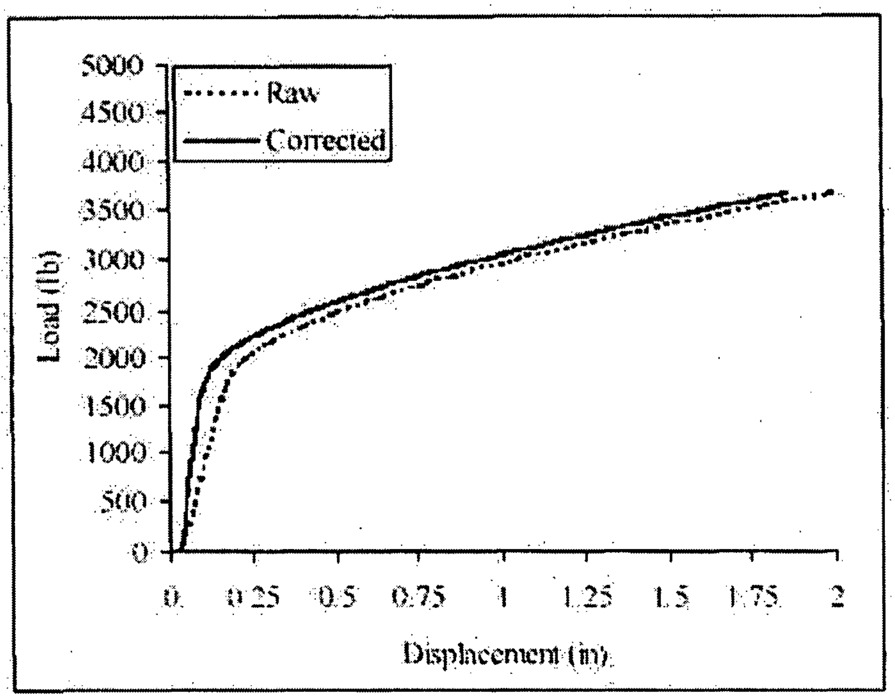
L_{ins} = depth of fitting socket excluding any insert groove

Z_{pipe} = piping section modulus

τ_{max} = 7500 psi (maximum braze shear stress)

b_{adj} = adjusted effective bond

Figure 2: Equations for Brazed Joint Assessment Comparison of Brazed Joint Load vs. Capacity



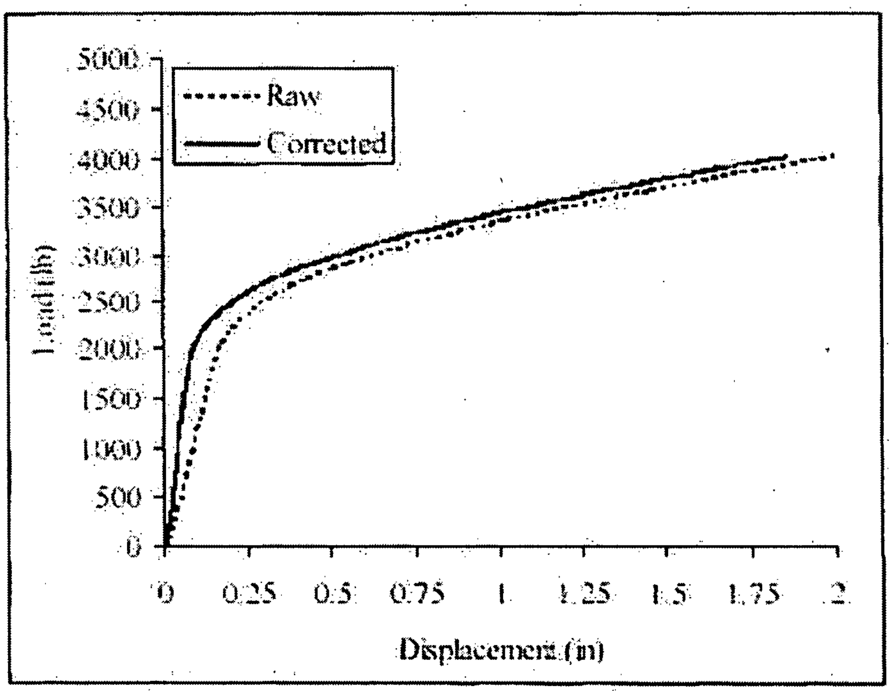
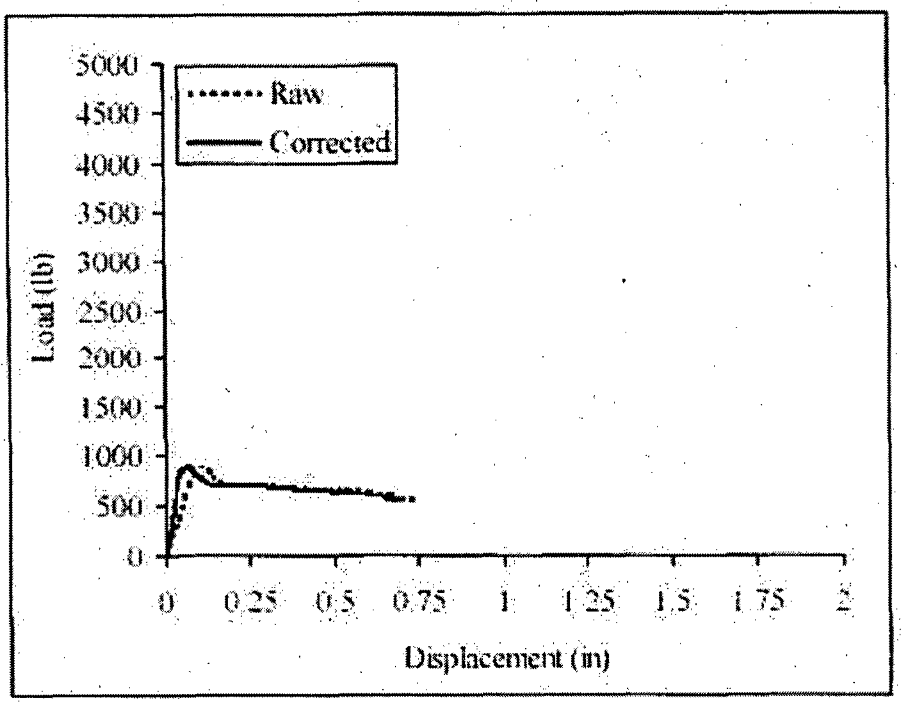


Figure 3: Two Inch Couplings: Fabricated Samples at (a) 30% (above) and (b) 60% bond



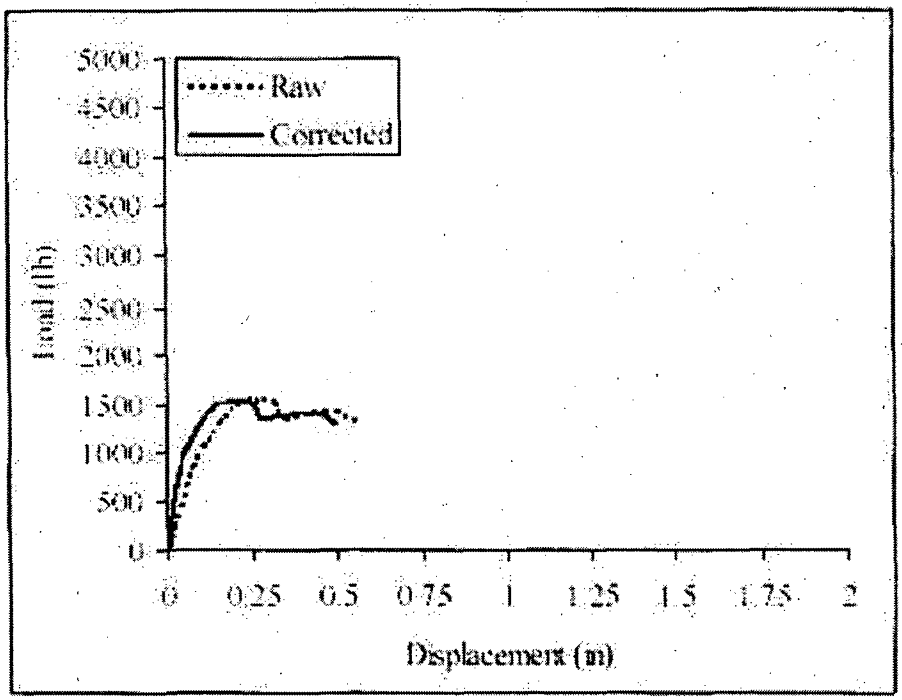


Figure 4: Two Inch Joints: Two Fabricated Samples with 12% Bond

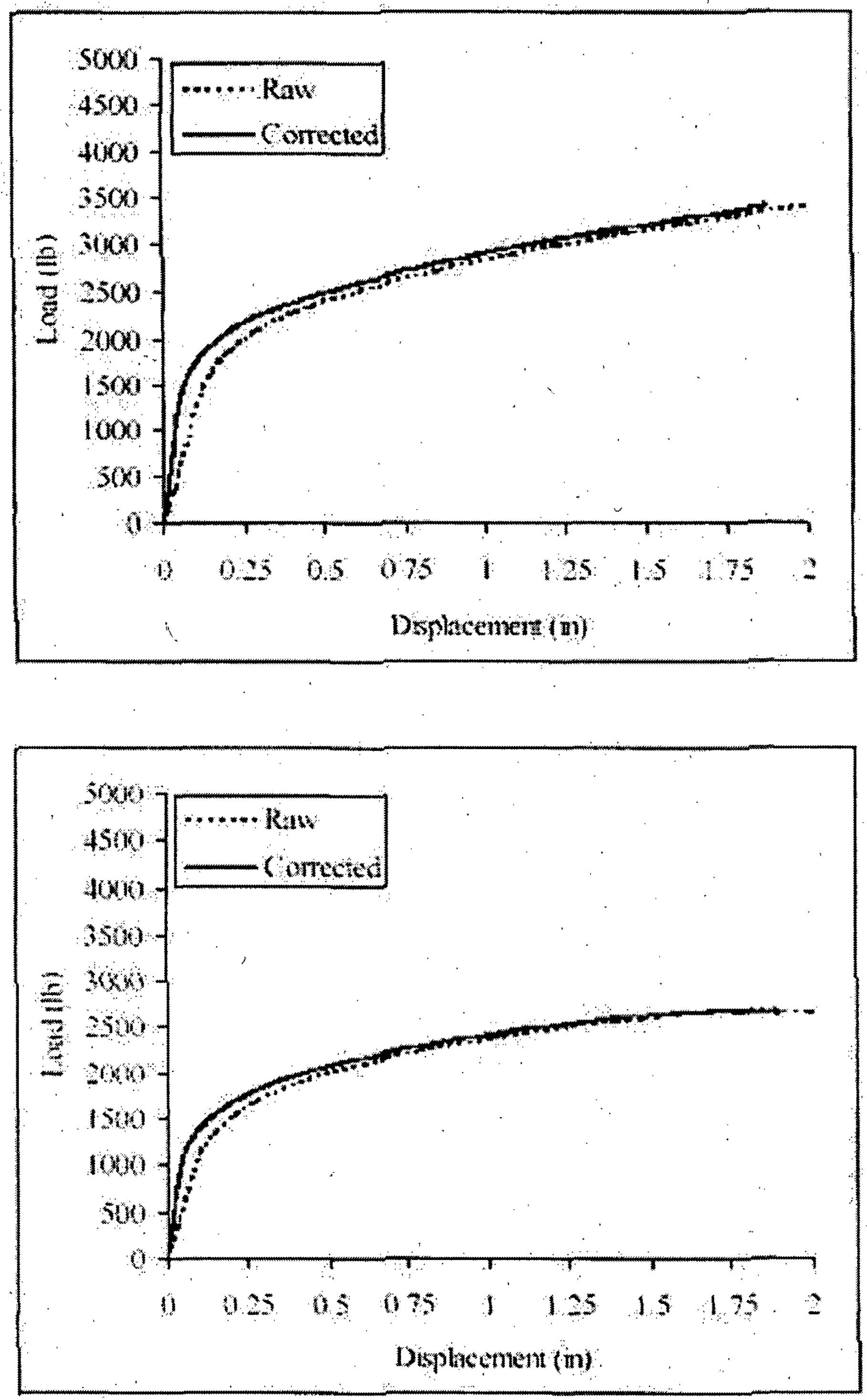


Figure 5: Arc Segment Disbondment, (a) 90 (above) and (b) 126 Degrees Arc

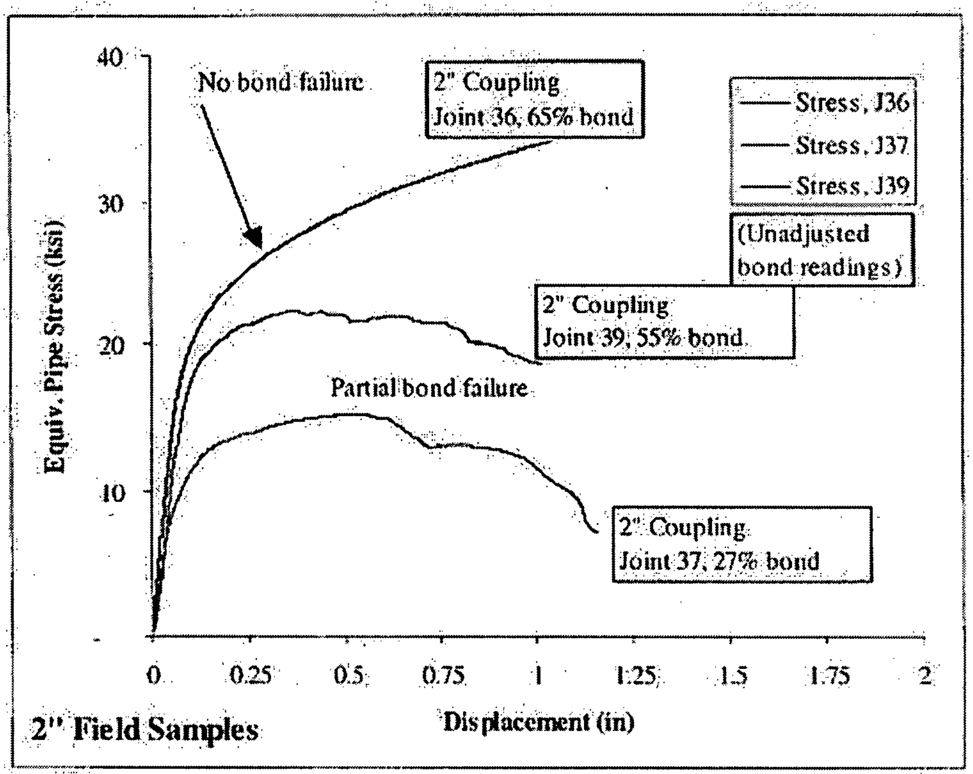


Figure 6: Two Inch Braze Field Sample Test Curve

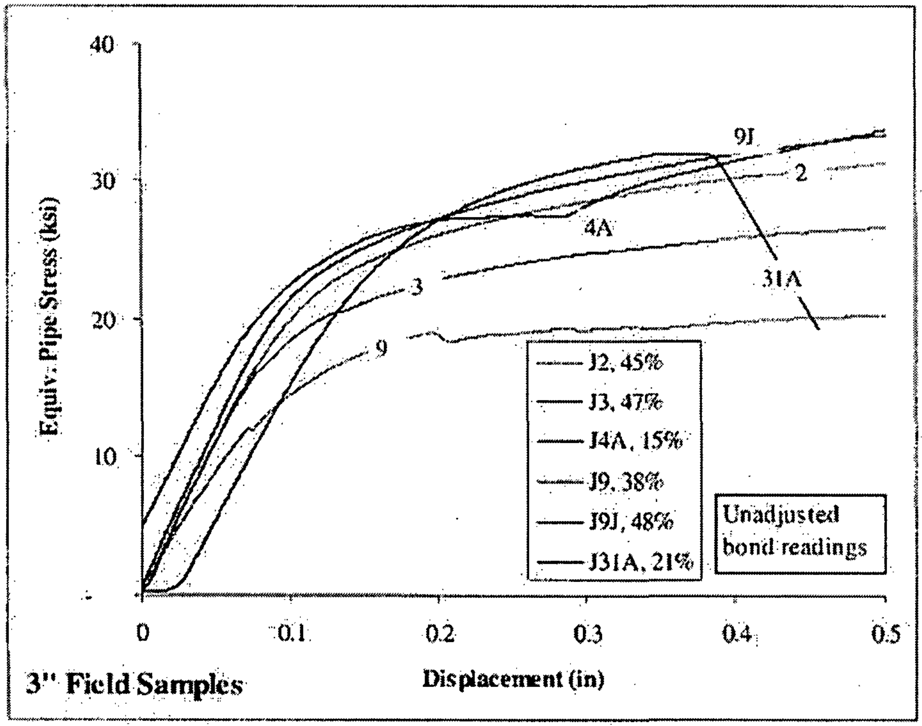


Figure 7: Three Inch Braze Field Sample Test Curve

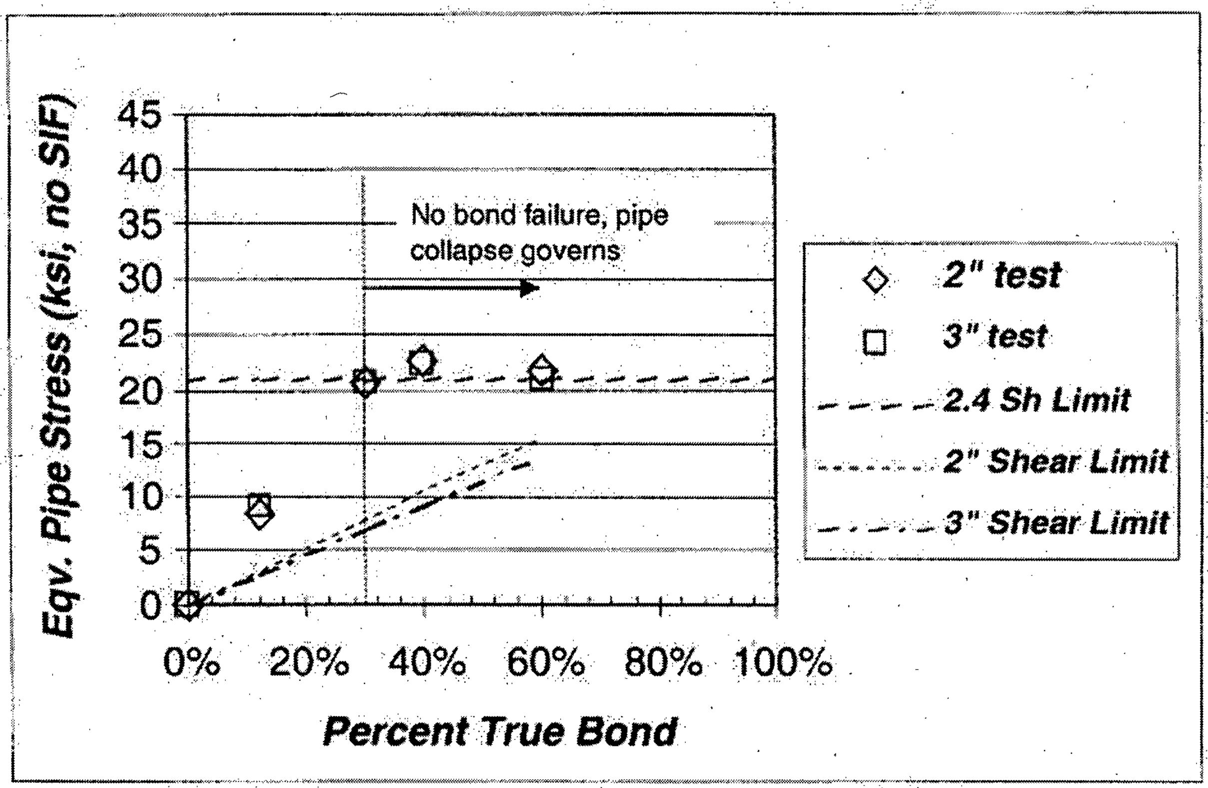


Figure 8: Test Results for Specially Fabricated Joints

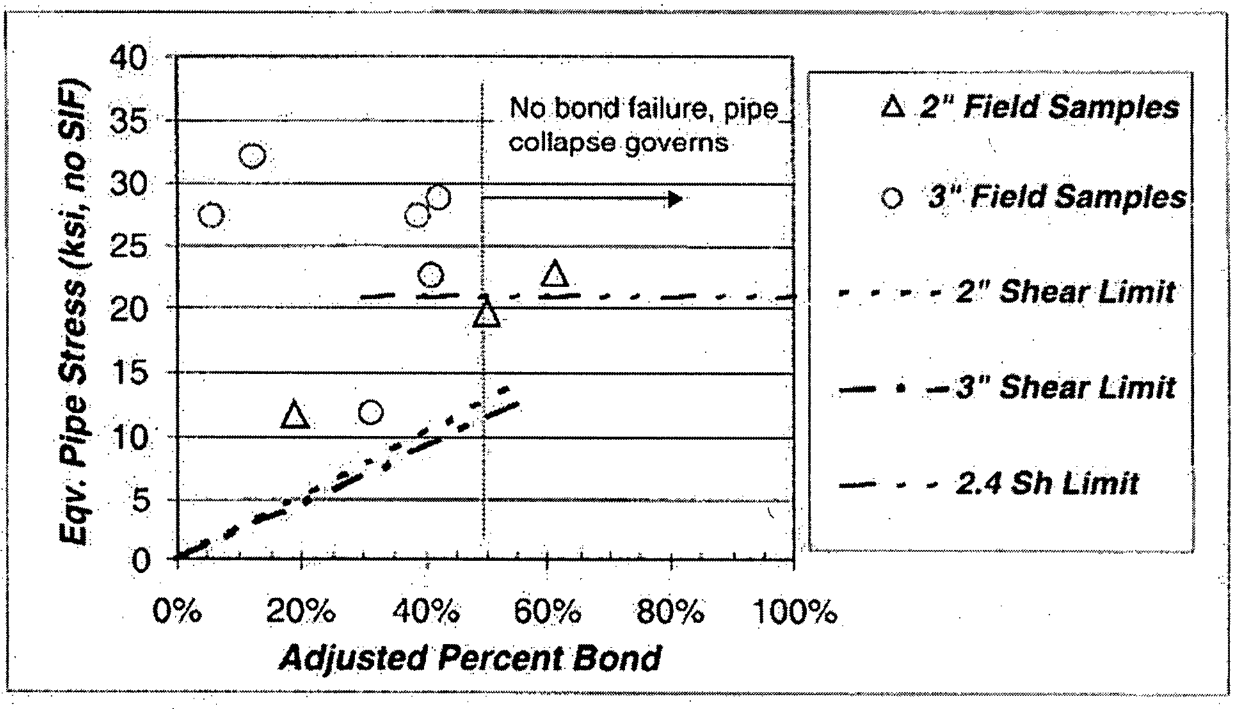


Figure 9 - Test Results for Joints Removed From Service

BRAZED JOINT CONFIGURATION AND MATERIALS

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

BRAZED JOINT CONFIGURATION AND MATERIALS

1.0 MATERIALS

Typical materials of construction of brazed piping are copper-nickel (SB-466) or nickel alloy (SB-165) annealed piping, and cast bronze fittings and valves (SB-61 or SB-62) dimensioned to MIL-F-1183. The brazing alloy is SFA 5.8 BAg-1, BAS-1a, or BAg-7. ASME, Section III Code minimum properties of the piping and fitting materials are:

Material	Item	S_h, ksi	Yield, ksi	Ultimate, ksi
SB466 CDA706	Pipe	8.7	13	38
SB-165	Pipe	17.5	28	70
SB-61	fitting	8.5	16	34
SB-62	fitting	7.5	14	30

2.0 CONFIGURATION

As shown in Figure 1 of Attachment A, a typical brazed joint fitting has a deep socket for inserting the pipe. Although it appears similar to a socket welded joint, the fabrication and structural behavior are quite different. Whereas the socket weld achieves its joint strength by a fillet weld, resulting in fusion of similar material between the pipe and the outer face of the fitting, the braze achieves its strength by surface bonding of the outside of the pipe to the inside of the fitting socket using a dissimilar metal braze filler of silver alloy. The resulting braze filler metal is very thin (approximately 1 to 5 mils). The load transfer between pipe and fitting is thus primarily by shear through the braze filler. It is noted that there is no inherent stress concentration factor like that normally applicable to socket welds because there is no significant pipe wall bending induced by the shear load transfer over a length that is several wall thicknesses long.

The following has been excerpted from a standard piping handbook.[4]

> *The length of lap in a joint, the shear strength of the brazing alloy, and the average percentage of the brazing surface area that normally bonds are the principal factors determining the strength of brazed joints. The shear strength may be calculated by multiplying the width by the length of lap by the percentages of bond area and by taking into consideration the shear strength of the alloy used.*

For the standard braze joint fittings used at MPS3, the joint overlap is about four to one. The smallest overlap occurs in a three inch joint, with an overlap length of 3.6 times pipe wall thickness.

[4] Crocker and King, *Piping Handbook*, 5th Edition, McGraw-Hill Book Company, page 7-212

3.0 BRAZED JOINT FUNCTIONAL CHARACTERISTICS

Since the piping loads causing longitudinal stress in the pipe are all transferred by shear stress through the brazed bond, the shear stress in the brazed bond is directly related to longitudinal pipe stress divided by a factor equal to the overlap ratio. Thus for a fully bonded brazed joint, the shear stress is about one fourth of the piping longitudinal stress. If the bond is only 50 percent of maximum, then the bond shear stress will be about half the piping longitudinal stress. Given that piping and brazing filler metals have similar strength, a brazed joint has more than enough residual strength to tolerate moderate bond imperfections. Consequently, the joint is not the weak link in the piping assembly.

Consistent with this inherent over-design of brazed joints, the Construction Codes, such as Section III of the ASME Code and ANSI B31.1, require only visual inspection of the resulting bond. ND-5360, Visual Acceptance Standards for Brazed Joints, states "Brazing metal shall give evidence of having flowed uniformly through a joint by the appearance of an uninterrupted, narrow, visible line of brazing alloy at the joint." Surface exams such as by liquid penetrant are not required. Volumetric exams are not specified or even defined for brazed joints.

If the lack of bond is severe, then the brazed joint becomes the weak link in the piping assembly. It fails by shear failure of the brazed bond. Brazing with a lower level of bond may however be acceptable if the piping design basis loads are low enough. A brazing material defect with weepage is not the result of a flaw in the pipe or fitting pressure boundary. The pressure-retaining boundary retains its structural integrity. Although the shear load transfer between the pipe and fitting is clearly a pressure boundary function, the brazing material functions more as a sealant between the connected components and less like a pressure boundary.

With regard to structural integrity, imperfections in the sealant function of the braze material are permissible, provided its load transfer function retains adequate margin. Thus, because there is no direct degradation of the pressure boundary, the available flaw evaluation methodologies such as in ASME Code Case N-513-2 or Generic Letter 90-05, are not directly applicable. In addition, the characterization of braze imperfections is very different from the planar flaws or loss of wall thickness that are addressed in ASME Code, Section III, IWA-3000.

EXAMPLE STRUCTURAL ASSESSMENT

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

Braze Bond Structural Assessment Joint 1A (example only)

Part 1 Basic Data (dashed boxes are inputs)

	Inputs:		Inputs:
Line No:	3SWP-002-999-3	*Pipe Dia*	2.375 in
Sys Function:	A supply to ACUS-1A	*Nom. Wall Thk*	0.156 in
Piping Iso:	CP-0123456	*Pipe Mat'l*	SB 466 CDA 706
Joint:	1A	*Fitting Mat'l*	SB 61or 62
Side of Joint:	Upstream	Ref. Bond Strength:	7,500 psi
Jt. Orientation:	Mark 1 is up	Bond Adjustment	10%

Measured Ave. Bond 55% (calculated. For bond measurements, see sheet 'UT Readings')

55 % >= 60 % ? No, Detailed assessment required

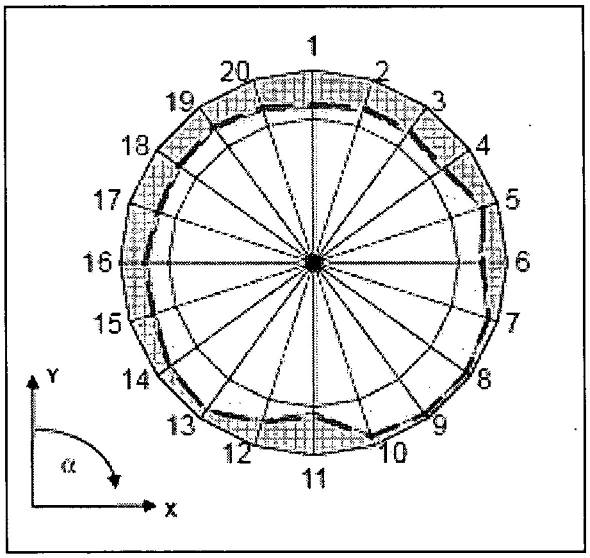
Part 2 Bond Data Summary (data from sheet 'Bond Calcs')

Offsets based on adjusted bond:

Dxx	0.098 in
Dyy	-0.205 in
Doffset	0.227 in (19% of pipe radius)
Alpha	12.0 degrees - rotation angle of principal axes

Calculated effective bond data are in principal axes system, and are based on adjusted bond.

	Actual	Adjusted
Bxx	58%	54%
Byy	49%	43%
Bbend	49%	43%
Bpress	55%	50%



Note: Plot is figurative only, actual braze bond is cylindrical, not through-wall.

Braze Bond Structural Assessment Joint 1A

Part 3 Calculated Bond Load Capability

D	2.375	in
tnom	0.156	in
Pipe Z	0.566	in^3
Linsert	0.656	in (from lookup table at right)
Smax(100%)	38,493	psi (from formula at right)

Lookup Tbl: L.insert per MilSpec		
D.nom	D.od	Linsert
3/4	1.05	11/32
1	1.315	7/16
1.5	1.9	5/8
2	2.375	21/32
2.5	2.875	25/32
3	3.5	53/64

Load Capability (Allowable Nominal Pipe Stress)
(Based on bond levels from Part 2)

	Actual	Adjusted	
Sxx	22,495	20,619	psi
Syy	18,807	16,463	psi
Sallow	18,807	**16,463**	**psi**

stress based on shear allow. and percent bond

$$S_{max}b_{adj} = b_{adj}\left(\frac{\pi D^2 \cdot L_{insert}}{4Z_{pipe}}\right)\tau_{max}$$

Part 4 Pipe Stress Data

(stress calc inputs)

Stress Calc	NP-X1901
Rev / CCN	Rev. 5 CCN 4
Line No:	3SWP-002-999-3
Sys Function:	A supply to ACUS-1A
Piping Iso:	CP-0123456
Joint:	1A

(data from Part 1)

Pipe Dia	2.375 in
Nom. Wall Thk	0.156 in
Pipe Mat'l	SB 466 CDA 706
Fitting Mat'l	SB 61or 62
A.pressure	1.865 in^2
Z.pipe	0.566 in^3

Inputs:

Stress Node	101
Alt. Stress Node	n/a
SIF Used	2.1
Primary SIF	1.575

$$S_{p\_offset} = D_{offset}\cdot\frac{P_{max}A_{press}}{Z_{pipe}}$$

$$S = \frac{S - S_{lp}}{psif} + S_{p\_offset} + S_{lp}\cdot\frac{B_{bend}}{B_{press}}$$

Inputs:

			Calculated Nominal Stresses	
Design Pressure	100 psig			
Max Op. Pressure	100 psig			
Slp	761 psi	Sp_offset	75	psi
Eq. 8 (P+DL)	2500 psi	Sust'd 8'	1830	psi
Eq. 9 (N/U)	3500 psi	N/U 9'	2465	psi
Eq. 9F (Design Basis0	6500 psi	Faulted 9F'	4370	psi
		Max Pipe Nominal Stress	**4370**	**psi**
		Apply Safety Factor of 1.5	**6555**	**psi**

Part 5 Structural Integrity Determination Joint 1A

Joint Load Capability	16,463	psi	(from Part 3)
1.5*Design Basis Load	6,555	psi	(from Part 4)

Check: **6,555 < 16,463 ===> Braze is adequate for design basis loads**
Monitor until repair/replacement

Braze Bond Measurements Joint 1A

						R	Rmin
	Bond Adjustment		10%			1	0.75
Reading	Angle	Meas. Bond	Adj Bond	PlotValue	Adj Plot	Max	Min
1	0	30%	22%	0.825	0.806	1	0.75
2	18	40%	33%	0.850	0.833	1	0.75
3	36	40%	33%	0.850	0.833	1	0.75
4	54	35%	28%	0.838	0.819	1	0.75
5	72	70%	67%	0.925	0.917	1	0.75
6	90	50%	44%	0.875	0.861	1	0.75
7	108	80%	78%	0.950	0.944	1	0.75
8	126	90%	89%	0.975	0.972	1	0.75
9	144	90%	89%	0.975	0.972	1	0.75
10	162	80%	78%	0.950	0.944	1	0.75
11	180	20%	11%	0.800	0.778	1	0.75
12	198	50%	44%	0.875	0.861	1	0.75
13	216	80%	78%	0.950	0.944	1	0.75
14	234	70%	67%	0.925	0.917	1	0.75
15	252	50%	44%	0.875	0.861	1	0.75
16	270	50%	44%	0.875	0.861	1	0.75
17	288	40%	33%	0.850	0.833	1	0.75
18	306	45%	39%	0.863	0.847	1	0.75
19	324	50%	44%	0.875	0.861	1	0.75
20	342	40%	33%	0.850	0.833	1	0.75

Nreadings	20	Ave	55%	50%
dTheta	18	Min	20%	11%
degrees		Max	90%	89%

Braze Bond Calculations — Joint 1A

Boffset	Nreadings
10%	20

D
2.375
Aoffset
Input
0 degrees
0.000 rad

Equivalent bond based on measured bond readings, without adjustment

Angle	Meas. Bond	cos(theta)	db*cos	db*cos^2	db*sin*cos	sin(theta)	db*sin	db*sin^2
0	30%	1.000	0.300	0.300	0.000	0.000	0.000	0.000
18	40%	0.951	0.380	0.362	0.118	0.309	0.124	0.038
36	40%	0.809	0.324	0.262	0.190	0.588	0.235	0.138
54	35%	0.588	0.206	0.121	0.166	0.809	0.283	0.229
72	70%	0.309	0.216	0.067	0.206	0.951	0.666	0.633
90	50%	0.000	0.000	0.000	0.000	1.000	0.500	0.500
108	80%	-0.309	-0.247	0.076	-0.235	0.951	0.761	0.724
126	90%	-0.588	-0.529	0.311	-0.428	0.809	0.728	0.589
144	90%	-0.809	-0.728	0.589	-0.428	0.588	0.529	0.311
162	80%	-0.951	-0.761	0.724	-0.235	0.309	0.247	0.076
180	20%	-1.000	-0.200	0.200	0.000	0.000	0.000	0.000
198	50%	-0.951	-0.476	0.452	0.147	-0.309	-0.155	0.048
216	80%	-0.809	-0.647	0.524	0.380	-0.588	-0.470	0.276
234	70%	-0.588	-0.411	0.242	0.333	-0.809	-0.566	0.458
252	50%	-0.309	-0.155	0.048	0.147	-0.951	-0.476	0.452
270	50%	0.000	0.000	0.000	0.000	-1.000	-0.500	0.500
288	40%	0.309	0.124	0.038	-0.118	-0.951	-0.380	0.362
306	45%	0.588	0.265	0.155	-0.214	-0.809	-0.364	0.295
324	50%	0.809	0.405	0.327	-0.238	-0.588	-0.294	0.173
342	40%	0.951	0.380	0.362	-0.118	-0.309	-0.124	0.038
		0.000	-0.078	5.160	-0.326	0.000	0.037	5.940
	Bpress	check=0	ry	Bpyy	Bpxy	check=0	rx	Bpxx
	55%		-0.141	0.258	-0.016	0.550	0.068	0.292

Roffset	Yoffset	Byy	Bxy	Byy+Bxx	Xoffset	Bxx
0.186	-0.168	0.247	-0.011	0.536	0.080	0.290
	BByy	49%	Bave	54%	BBxx	58%
	Byy_p	0.244			Bxx_p	0.292
		49%				58%

Byy-Bxx=0	Bxy=0	tan 2alpha	cos 2alpha	sin 2alpha	tan check	alpha
-0.043	-0.011	0.519	0.888	0.461	0.519	0.239 rad
FALSE	FALSE					13.7 deg

$$b_{adj} = \frac{b - b_{offset}}{1 - b_{offset}}$$

Equivalent bond based on adjusted bond readings

$$B'_{yy} = \frac{1}{N}\sum b_i \cos(\theta_i)^2$$

$$B'_{xx} = \frac{1}{N}\sum b_i \sin(\theta_i)^2$$

$$B'_{xy} = \frac{1}{N}\sum b_i \sin(\theta_i)\cos(\theta_i)$$

$$B_{yy} = B'_{yy} - r_{yy}^2 b_{av}$$

$$B_{xx} = B'_{xx} - r_{xx}^2 b_{av}$$

$$B_{xy} = B'_{xy} - r_{xx} r_{yy} b_{av}$$

$$\tan(2\alpha) = \frac{2B_{xy}}{|B_{yy} - B_{xx}|}$$

$$\cos(2\alpha) = \frac{|B_{yy} - B_{xx}|}{\sqrt{(B_{yy} - B_{xx})^2 + 4B_{xy}^2}}$$

$$\sin(2\alpha) = \frac{\mathrm{sgn}(\tan(2\alpha)) \cdot |2B_{xy}|}{\sqrt{(B_{yy} - B_{xx})^2 + 4B_{xy}^2}}$$

$$\alpha = \frac{1}{2}\operatorname{asin}(\sin(2\alpha))$$

$$B_{p,yy} = \frac{B_{yy} + B_x}{2} + \frac{B_{yy} - B_x}{2}\cos 2\alpha + B_{xy}\sin 2\alpha$$

$$B_{p,xx} = \frac{B_{yy} + B_x}{2} - \frac{B_{yy} - B_x}{2}\cos 2\alpha - B_{xy}\sin 2\alpha$$

$$B_{p,xy} = B_{xy}\cos 2\alpha - \frac{B_{yy} - B_x}{2}\sin 2\alpha$$

Angle	Adj. Bond	cos(theta)	db*cos	db*cos^2	db*sin*cos	sin(theta)	db*sin	db*sin^2
0	22%	1.000	0.222	0.222	0.000	0.000	0.000	0.000
18	33%	0.951	0.317	0.302	0.098	0.309	0.103	0.032
36	33%	0.809	0.270	0.218	0.159	0.588	0.196	0.115
54	28%	0.588	0.163	0.096	0.132	0.809	0.225	0.182
72	67%	0.309	0.206	0.064	0.196	0.951	0.634	0.603
90	44%	0.000	0.000	0.000	0.000	1.000	0.444	0.444
108	78%	-0.309	-0.240	0.074	-0.229	0.951	0.740	0.704
126	89%	-0.588	-0.522	0.307	-0.423	0.809	0.719	0.582
144	89%	-0.809	-0.719	0.582	-0.423	0.588	0.522	0.307
162	78%	-0.951	-0.740	0.704	-0.229	0.309	0.240	0.074
180	11%	-1.000	-0.111	0.111	0.000	0.000	0.000	0.000
198	44%	-0.951	-0.423	0.402	0.131	-0.309	-0.137	0.042
216	78%	-0.809	-0.629	0.509	0.370	-0.588	-0.457	0.269
234	67%	-0.588	-0.392	0.230	0.317	-0.809	-0.539	0.436
252	44%	-0.309	-0.137	0.042	0.131	-0.951	-0.423	0.402
270	44%	0.000	0.000	0.000	0.000	-1.000	-0.444	0.444
288	33%	0.309	0.103	0.032	-0.098	-0.951	-0.317	0.302
306	39%	0.588	0.229	0.134	-0.185	-0.809	-0.315	0.255
324	44%	0.809	0.360	0.291	-0.211	-0.588	-0.261	0.154
342	33%	0.951	0.317	0.302	-0.098	-0.309	-0.103	0.032
		0.000	-0.086	4.622	-0.362	0.000	0.041	5.378
	Bpress	check=0	ry	Bpyy	Bpxy	check=0	rx	Bpxx
	50%		-0.173	0.231	-0.018	0.500	0.083	0.269

Roffset	Yoffset	Byy	Bxy	Byy+Bxx	Xoffset	Bxx
0.227	-0.205	0.216	-0.011	0.482	0.098	0.265
	BByy	43%	Bave	48%	BBxx	53%
	Byy_p	0.214			Bxx_p	0.268
		43%				54%

Byy-Bxx=0	Bxy=0	tan 2alpha	cos 2alpha	sin 2alpha	tan check	alpha
-0.049	-0.011	0.445	0.914	0.406	0.445	0.209 rad
FALSE	FALSE					12.0 deg

Measured Bonds

Bond values calculated at A_offset angle			
Yoffset	Byy	Xoffset	Bxx
-0.168	49%	0.080	58%

Adjusted Bonds

Bond values calculated at A_offset angle			
Yoffset	Byy	Xoffset	Bxx
-0.205	43%	0.098	53%

MECHANICAL TESTS

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

MECHANICAL TESTS

1.0 BACKGROUND

The correlation developed by the testing conservatively determines a required bond level for a given intensity of joint loading. The results of these tests support the use of the comparison shown in Figure 2, Attachment A, for the structural integrity analysis. It is noted that the evaluation of testing results was with respect to a braze shear capability of 5.0 ksi, which in the final methodology has been increased to 7.5 ksi, provided that piping loads have 1.5 safety factor applied. For consistency with testing as performed, the 5.0 ksi shear capability discussed is retained in this Attachment D.

2.0 TEST SAMPLE DESIGNS

The effort to empirically confirm required bond levels for varying intensities of joint loadings consisted of three separate series of mechanical tests:

a) specially fabricated joints with a controlled average bond level,
b) specially fabricated joints that had disbondment on a contiguous arc-segment of the joint, and
c) field sample piping joints, salvaged from piping removed from the plant.

All joints were tested in three-point bending with the brazed fitting in the middle of the configuration.

2.1 Specially Fabricated Joints With a Controlled Average Bond Level

By a combination of machining and use of insert-groove type fittings, a series of test joints were fabricated with equivalent bond levels of 12, 30, 40 and 60 percent. The machining removed only about 30 mils of pipe thickness so that piping strength was not significantly affected. The samples were fabricated for two-inch and for three-inch joints. Three examples of each size and bond level were fabricated, for a total of 24 samples. (Of the 24 samples in this category, one of the 40 percent bond samples was subsequently found to have less than the fully intended bond and is excluded from the results.)

2.2 Specially Fabricated Joints That had Disbondment on a Contiguous Arc-Segment of the Joint:

These test items were intended to explore the effect of having a significantly non-uniform distribution of bond area around the circumference of the joint. Six samples were fabricated with disbondment segment angles of 36, 48, 72, 90, 108 and 126 degrees. The average bond levels for these, assuming perfect bond except in the disbonded, are ranged from 90 percent down to 65 percent, respectively.

2.3 Field Sample Piping Joints:

These joints were salvaged from piping that was removed from the plant after about 20 years of service, and screened by Ultrasonic Testing (UT). Piping joints with the lowest of measured bond were selected for testing.

The nine items selected for testing included the following:

Description	Quantity
Two inch couplings	3
Three inch couplings	2
Three inch tee (run sides)	1
Three inch flanges	3

The couplings and the tee included two brazed joints subjected to test loads. The test flanges were mated to full strength flanges not under test.

3.0 MECHANICAL TEST RESULTS

The results from testing on each of the series of tests are described in the balance of this section. The referenced figures are included in Attachment A. A test report has been incorporated into the Millstone Station plant records.

3.1 Specially Fabricated Joints With a Controlled Average Bond Level:

For the intentionally disbonded joints, all joints with 30 percent or better true bond, achieved full piping collapse strength with no failure of the bond. Refer to Figure 3. As testing of each joint continued above the piping collapse load, one of the 40 percent true bond joints had indications of bond failure. The 12 percent true bond joints all experienced bond failure before reaching piping collapse load, but withstood a minimum of 37 percent of the piping collapse load. Refer to Figure 4. All test items achieved their test collapse load at a load well above that which would be predicted for a 5 ksi braze shear strength.

3.2 Specially Fabricated Joints that had Disbondment on a Contiguous Arc-Segment of the Joint

From 36 through 72 degrees of segment disbondment, the test items all achieved full piping collapse load. The test items from 90 through 126 degrees disbondment exhibited progressively lower collapse load, as shown in Figure 4. At 126 degrees disbondment, the test item achieved about 60 percent of the piping collapse load. The load deflection curves for these joints did not exhibit any indications of bond failure, however at the extremes of deflection (well above the level that would be acceptable for application of this methodology) the higher angle joints were significantly distorted. For such large levels of deflection, it was apparent that the close mechanical fit-up of the pipe in socket configuration contributed to joint bending strength. All test items achieved their test collapse load at a load well above that which would be predicted for a 5 ksi braze shear strength.

3.3 Field Sample Piping Joints

The field sample test items exhibited considerable variation in collapse load for roughly similar UT bond readings. The variations were expected for the field samples. Figures 6 and 7 show the displacement load curve for the tested field samples. Bond failure limited the collapse load in the two-inch Joints 37 and 39, and the three-inch Joints 3 and 9. The load curve for Joint 9 has a slight discontinuity at 11.9 ksi that is conservatively considered to indicate initial bond failure, even though the load continues above this point. The collapse load for other samples was limited by the piping collapse load, which is equivalent to about 21 ksi. Even with the low UT bond readings, the field samples developed at least 50 percent of the piping collapse load. The higher than expected collapse load for some of the three-inch joints is believed to be partly due to the thickness of filler metal present as a fillet at the face of some of the joints. All test items achieved their test collapse load at a load well above that which would be predicted for a 5 ksi braze shear strength and the adjusted percent bond used in this methodology.

The adequacy of the 5 ksi shear stress assumed in the methodology in Equation 3 of Figure 2, Attachment A, for estimating joint strength is confirmed by the testing margins shown in the following table.

Table 1: Test Load vs. Bond Shear Capacity

Test Joint	Average UT %	Adjusted UT %	Test Collapse Load, ksi	Shear Capacity Load, ksi	Test / Shear Margin
36	65	61	22.8	15.8	1.44*
37	27	19	11.6	4.9	2.41
39	55	50	19.6	13.0	1.52
2	45	39	27.3	9.0	3.02*
3	47	41	22.6	9.6	2.38*
4A	15	5	27.3	1.3	23.59*
9	38	31	11.9	7.2	1.69
9J	48	42	28.6	9.8	2.95*
31A	21	12	32.0	2.8	11.61*

* Piping collapse load reached before bond failure or deflection run out.

The data in Table 1 is plotted in Figure 9, Attachment A. Of the joints that were limited by bond failure prior to reaching piping collapse load, the minimum margin factor was 1.52. This minimum margin appears in Joint 39, with a 50 percent adjusted average bond. Review of detailed bond readings around the circumference of Joint 39 gives an equivalent adjusted bond of 43 percent for the bending axis used during the test, corresponding to a margin factor of 1.74 for this test case.

ULTRASONIC TEST PROCEDURE

Provided For Reference Only
(subject to change)

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

Non Destructive Examination Procedure

Millstone Station

ULTRASONIC EXAMINATION PROCEDURE FOR EXAMINATION OF BRAZED JOINTS - MILLSTONE UNIT 3 SERVICE WATER PIPING

MP-UT-45

Rev. 000-01

Approval Date: 07/24/07

Effective Date: 07/31/07

Ultrasonic Examination Procedure for Examination Of Brazed Joints – Millstone Unit 3

TABLE OF CONTENTS

1. PURPOSE

1.1 Objective

This procedure describes equipment and procedures that shall be used in the ultrasonic inspection of brazed pipe joints.

1.2 Applicability

1.2.1 This procedure contains all the specific application requirements for the examination of Millstone Unit 3 service water system brazed joints to determine percentage of bonded areas.

1.3 Discussion

1.3.1 In ultrasonic examination of brazed pipe joints, ultrasonic waves are transmitted from a search unit into the brazed joint to determine the amount of braze bond present beneath the search unit.

1.3.2 Brazed joints shall be examined by the straight-beam (compressional wave) method as illustrated in Figure 1. Signals, if present along the base line, occur successively (reading from left to right) from the following sources; the insert groove (if present), the fitting inside diameter, the pipe inside diameter and possible multiple reflections.

1.3.3 To examine a brazed joint, the transducer is placed over the bonded area of the joint and moved around the circumference in increments and in a number of passes determined by the number of lands, land or engagement area width and the crystal size. The percent of bond and pattern are determined for each increment, land or pass and the total joint.

2. PREREQUISITES

2.1 General

2.1.1 The outer surface of the fitting socket shall be prepared sufficiently to obtain satisfactory sound transmission and shall not be rounded in the longitudinal direction and should be relatively parallel to the pipe surface.

2.1.2 For joint configurations that cannot be satisfactorily ultrasonically examined, this procedure is not applicable.

2.2 Personnel Requirements

2.2.1 Only Level II, or Level III personnel may independently perform, interpret, evaluate and report examination results.

2.2.2 Levels II and III shall be certified in accordance with Reference 6.1.

2.2.3 The UT examiners shall have sufficient knowledge and training to determine ultrasonically the bond in brazed joints.

2.2.4 UT examiners shall demonstrate ability to recognize such technical deficiencies as insufficient beam penetration (transmission), poor transducer contact and interfering contact surface roughness from patterns displayed on the ultrasonic screen.

2.2.5 UT examiners shall maintain proficiency for examination of brazed joints by performing an examination of a brazed joint at least every six months.

2.2.6 Examiners who do not meet the requirement of 2.2.5 above shall demonstrate their ability to examine brazed joints prior to performing examinations in the field. See Table 1 for initial examiner qualification and proficiency requirements.

2.3 **Measuring and Test Equipment**

2.3.1 All measuring and test equipment shall meet the requirements of WC-8.

2.4 **Examination Limitations**

2.4.1 Examiners shall identify potential examination coverage limitations prior to performing the examination.

3. DEFINITIONS

3.1 Face of Fitting - The annulus surrounding the socket end.

3.2 Insert Groove - The groove in the fitting socket prepared to contain the brazing alloy ring.

3.3 Land, Fitting - That portion of the fitting on the side of the insert groove nearest the middle of the fitting.

3.4 Land, Center - That portion of the fitting between the grooves in a multiple insert fitting.

3.5 Land, Pipe - That portion of fitting on the side of the insert groove toward the end of the fitting.

3.6 Examiner – A person that has sufficient knowledge in determining bond.

3.7 Level III Examiner – The person in charge of ensuring examiners are qualified and have sufficient knowledge in determining bond.

4. INSTRUCTIONS

4.1 **Examination Preparation**

4.1.1 After preparing the surface of the fitting, lay out the circumference as follows:

a) Marking shall be accomplished using a permanent marker on the fitting surface, in increments not exceeding one inch. If the joint is to be re-examined, vibro-etching may be advisable but is not mandatory

b) Markings shall be numbered clockwise as viewed facing the fitting from the pipe.

4.2 **Examination Method**

4.2.1 The straight beam longitudinal wave method shall be used.

4.2.2 The position of reflections along the base line of the viewing screen shall be indexed for signals from an insert groove, the inside diameter of the fitting, and the inside diameter of the pipe.

4.2.3 For fittings containing insert grooves, place the transducer so that the active area is over one land only. Mark the first back reflection of the insert groove, inside diameter of fitting (no bond) and the inside diameter of the pipe (bond) at the left edge of the signal, on the face of the viewing screen. If necessary, check the back reflections with the reference calibration standard to ensure positive signal identification.

4.2.4 The amplitude of any one signal shall not reach a saturation point on viewing screen presentation.

4.2.5 For fittings which contain no insert grooves, place the transducer so that the active area: covers 1/2 of the OD of the fitting in the engagement area.

4.2.6 Reflection markings and scope presentations will be as above except there will be no ring groove signal.

4.2.7 The *continuous* or static scan technique shall be used.

4.2.8 In the continuous scan, the transducer is moved in a continuous movement from one increment mark to the next increment mark. The bond and no-bond signals are mentally averaged while scanning the increment. The bond for the increment is estimated to the nearest five percent in accordance with 4.2.9 through 4.2.11.

4.2.9 In the static scan, the transducer is placed on the increment mark. The bond and no-bond signals are recorded for the increment. The bond for the increment is estimated to the nearest five percent in accordance with 4.2.9 through 4.2.11.

4.2.10 Readings for joints with inside pipe diameters less than 1-1/2 inches shall be taken at four equally spaced intervals in the increment, and for joints with inside pipe diameters greater than 1-1/2 inches, the readings shall be taken at three equally spaced intervals in the increment.

4.2.11 These increments shall be measured on the outside diameter of the fitting.

4.2.12 Bond indications shall be recognized as to the percentage of bond without actually referring to the formula:

$$\% \text{ bond} = \frac{100\,(\text{bond amplitude}}{(\text{bond amplitude plus no-bond amplitude})}$$

4.2.13 Increments for which no ultrasonic reading can be obtained shall be marked as follows:

a) "X" - Increments which are inaccessible due to fitting configuration.

b) "NA" - Increments which are inaccessible due to piping, configuration or location.

c) "NP" - Increments in which there is a lack of ultrasonic penetration.

d) Increments of the above type shall be assigned percent bond values as follows:

"NA" = 0% bond

"NP" and "X" = Increments up to a total length not exceeding 20 percent of the circumference of the land shall be assigned a percentage bond value equal to that of the lowest readable increment adjacent to the "X" or "NP" increments or 60 percent whichever is the least.

"X" or "NP" increments in excess of 20 percent of the circumference shall be assigned a bond value of 0 percent.

The examiner may, at his discretion, shift the incremental scale so that the minimum number of increments contain "X", "NP" or "NA" values.

NOTE: Within the 20 percent limitation, two or more adjoining "X" and/or "NP" increments are considered a group of increments if the average of the remaining increments is 60 percent or more. The outermost two of any group within the 20 percent maximum limitation shall be rated on the basis of the adjacent readable increment. The inner increments of the group shall be assigned a zero value for calculation purposes.

4.2.14 The bond for the land (or pass of a no insert fitting) is the average of the readings for all increments in the land.

4.2.15 The percentage bond for the joint is that percentage of the total design faying surface which is bonded.

4.3 **Required Documentation**

4.3.1 The UT calibration data shall be documented on Attachment 1.

4.3.2 A sketch for each component detailing the increment locations shall be documented on Attachment 2.

5. REVIEW AND SIGN-OFF

The intent of this section is to clarify who is responsible to sign off on the examination data sheet.

5.1 The Examiner shall print name, sign, and date the data sheet. The examiner shall then submit the completed data sheet to the appropriate reviewer.

5.2 Reviewer's sign-off box can be signed only by Dominion Level II or III personnel (or their designee's) certified in the ultrasonic method.

5.2.1 Review of the data sheet is intended to provide reasonable assurance of accuracy, thoroughness and procedure compliance.

5.2.2 The reviewer should compare the examiners data sheet against the AWO and other known parameters of the component(s) being examined.

5.2.3 Review of the examination data sheet shall take place as soon as possible, and prior to the close-out of the AWO. The examination data sheet shall then be forwarded to the appropriate AWO package and/or job supervisor.

6. REFERENCES

6.1 ANSI/ASNT CP-189, 1991 Edition

6.2 WC-8, "Control and Calibration of Measuring and Test Equipment"

6.3 Granted Relief Request IR-2-38, "Structural Integrity Assessment Methodology for Brazed Joints (TAC NO. MC8893) - Millstone Power Station, Unit No. 3

7. SUMMARY OF CHANGES

7.1 Revision 000-01

7.1.1 Deleted paragraph 1.2.1 which stated that procedure was for Engineering use only until NRC acceptance of relief request.

7.1.2 Added paragraphs 2.2.5 and 2.2.6 to address proficiency of examiners.

7.1.3 Added Table 1 which establishes frequency, number of samples required, and acceptance criteria for initial qualification, maintenance of proficiency, and requalification.

Table 1

Brazed Joint Examiner Qualification

Qualification Type	No. of Samples	Period of Qualification
Initial Qualification	6	3 Years
Proficiency	3	6 months
Requalification	6	3 Years

Acceptance Criteria:

Initial Qualification:

The percent bond of the six test specimens as reported by the examinee shall be compared to the true bond and accepted on the following basis; the arithmetic average of the six test specimens shall not deviate by more than 8% from the true bond and no single specimen shall deviate by more than 15% from the true bond.

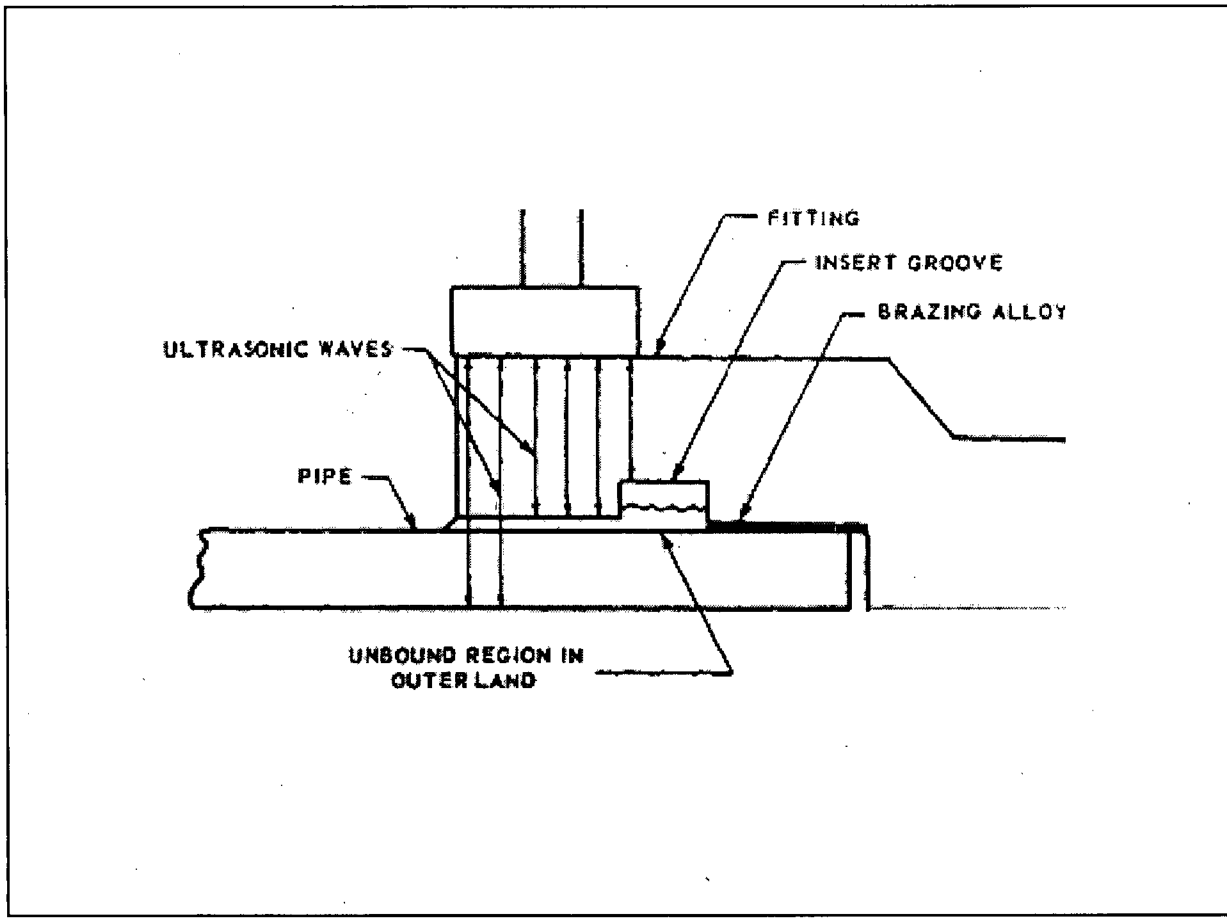
Proficiency Maintenance:

The percent bond of the three test specimens as reported by the examinee shall be compared to the true bond and accepted on the following basis; the arithmetic average of the three test specimens shall not deviate by more than 15% from the true bond.

Requalification:

Same as initial qualification.

Figure 1


FITTING
INSERT GROOVE
BRAZING ALLOY
ULTRASONIC WAVES
PIPE
UNBOUND REGION IN
OUTER LAND

ATTACHMENT 1
ULTRASONIC CALIBRATION DATA SHEET

Plant: ____________________ Unit: ______________

Purpose: ____________________________________

Cal Block Number ____________________________

DWG No. ____________________________________

Page ________ of ______

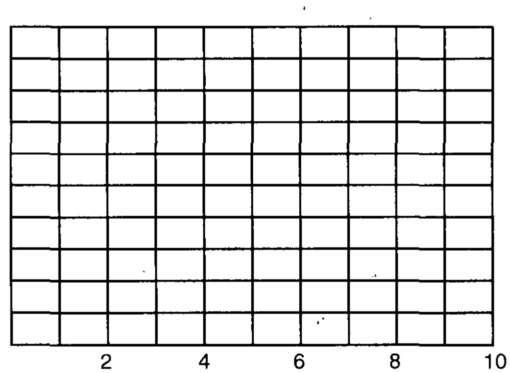
AWO Number: ________________________________

Cal Block Temp _____________________________

Thermometer S/N & Due Date __________________

Search Unit	
Manufacturer	
Style or Type	
Frequency	
Size & Shape	
Mode T or C	
Search Unit Angle	
Measured Angle	
Serial Number	
Cable Type, Length	
No. of Connectors	

Instrument & Settings	
Mfg. / Model	
Serial Number	
Range	
Material Velocity	
Delay	
Pulser	
Reject	
Frequency	
Damping	
Zero Value	
Pulse Rep Rate	
Gain Setting	



Attachments (Check)	
Sketch Sheet	
Supplements	

Calibrations	Time
Initial Calibration	
Final Calibration	
Final Calibration	

CRT Setup	Inches
Metal Path	
Depth	

Couplant Data	
Brand	
Batch Number	
SAP Batch Mgmt. No.	

Component ID	Component Type	Comments

Examiner (Print & Sign) ______________________________ Level __________ Date ____________

Examiner (Print & Sign) ______________________________ Level __________ Date ____________

Reviewer (Signature) _________________________________ Level __________ Date ____________

Attachment 2

Millstone Power Station	BRAZED JOINT SKETCH SHEET PAGE OF

Examined by (print/sign) ______________________ Level ______ Date ______

Millstone Power Station Reviewer (sign) ______________________ Level ______ Date ______

ENCLOSURE 2

RESPONSE TO THE REQUEST FOR ADDITIONAL INFORMATION ON USE OF A BRAZED JOINT STRUCTURAL INTEGRITY METHODOLOGY

(10 CFR 50.55a(a)(3)(i) REQUEST IR-3-04, TAC NO. ME1256)

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

RESPONSE TO THE REQUEST FOR ADDITIONAL INFORMATION ON USE OF A BRAZED JOINT STRUCTURAL INTEGRITY METHODOLOGY

As a part of the inservice inspection (ISI) program, Dominion Nuclear Connecticut, Inc. (DNC) submitted a letter dated April 28, 2009 requesting approval to use an alternative brazed joint assessment methodology for the resolution of nonconforming conditions on ASME Code Class 3, moderate energy system piping with brazed joints at Millstone Power Station Unit 3 (MPS3). This attachment provides a response to NRC questions received in a letter dated July 27, 2009.

NRC QUESTION 1:

Relief Request IR-3-04 contains many similarities in regards to the precedent relief request, IR-2-38 (ADAMS Accession No. ML051610101). It is unclear to the NRC staff why relevant information from the precedent relief request, contained in letters dated September 14, 2006 (ADAMS Accession No. ML062580234) and January 2, 2007 (ADAMS Accession No. ML070030092), was not incorporated into the current submittal. Please provide clarification as to why this information was not included and provide responses to the RAI's enclosed in the letter dated September 14, 2006, and the supplemental information from the January 2, 2007, letter, as applicable to Relief Request IR-3-04. If a question from the RAI is considered not applicable, please provide detailed justification as to why not.

DNC RESPONSE:

DNC agrees that Relief Request IR-3-04 should have included the relevant supplementary information and changes to methodology that were contained in the referenced letters dated September 14, 2006 and January 2, 2007. A revision to IR-03-04 with applicable changes to the final brazed joint methodology is included as Enclosure 1 of this submittal. In addition, updated responses to the referenced RAIs and supplementary responses have been prepared and are included in Enclosure 3.

NRC QUESTION 2:

In Section 5.3.4 of Relief Request IR-3-04, the licensee discusses the use of safety factors from ASME Code, Section XI, Appendix C paragraph C-3320(b) and C-3420(a), with these being the same safety factors permitted in Code Case N-513-1. Code Case N-513-1 has been superseded by Code Case N-513-2, as stated in Regulatory Guide 1.147, Revision 15. Please provide a discussion as to why the safety factors as listed in Code Case N-513-2 are not used.

DNC RESPONSE:

The safety factor of 1.5 that is utilized in the brazed joint assessment methodology is conservative relative to testing that was performed on brazed piping joints having actual and simulated flaws, as described in the submittal and its supplements. The discussion of safety factors from the ASME Code for piping components and flaws in the submittal was intended to show that, while the joint configuration is different than those directly addressed by Code rules (including Code Case N-513-2), the selected safety factor was comparable and consistent with Code guidance. Code Case N-513-2 does not directly contain safety factors but instead refers to Section XI Appendix C. The safety factor of 1.5 used for brazed joint assessment remains conservative to the level D safety factors of 1.3 for SF_m and 1.4 for SF_b listed in Section XI, 2004 Edition, Appendix C, paragraph C-2621 for circumferential flaws; and 1.3 for SF_m as listed in paragraph C-2622 for axial flaws. The reference to the prior version of the Code Case, N-513-1, was inadvertent.

NRC QUESTION 3:

Having employed an alternative to ASME Code requirements for the assessment of degraded brazed joints in the Class 3 service water system, via Relief Request IR-2-38, please provide a discussion on when this methodology was applied to degraded brazed joints during the last inservice inspection interval. Use an actual example from the plant and include the engineering evaluation used to assess the degraded joint; ultrasonic examination (UT) data gathered under MP-UT-45 Revision 000-01, Ultrasonic exam procedure in attachment E of the submittal, supporting the engineering evaluation; UT data from the monitoring of the degraded joint; UT data from augmented examinations; and work orders performing the code repair.

DNC RESPONSE:

The brazed joint methodology as finally approved was employed in three instances during the last inservice inspection interval. In two of the instances the leaking joints were repaired within 90 days of discovery and in the third the repair was performed at the next refueling outage. For the third instance, Enclosure 4 provides a summary of the original assessment, subsequent UT monitoring, and final repair.

Serial No.09-506
Docket No. 50-423

ENCLOSURE 3

RESPONSE TO THE REQUEST FOR ADDITIONAL INFORMATION ENCLOSED IN THE LETTERS DATED SEPTEMBER 14, 2006 AND JANUARY 2, 2007

(10 CFR 50.55a(a)(3)(i) REQUEST IR-3-04, TAC NO. MC8893)

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

RESPONSE TO THE REQUEST FOR ADDITIONAL INFORMATION ENCLOSED IN THE LETTERS DATED SEPTEMBER 14, 2006 AND JANUARY 2, 2007

BRAZED JOINT STRUCTURAL INTEGRITY METHODOLOGY

As a part of the inservice inspection (ISI) program, Dominion Nuclear Connecticut, Inc. (DNC) submitted a letter dated April 28, 2009 requesting approval to use an alternative brazed joint assessment methodology for the resolution of nonconforming conditions on ASME Code Class 3, moderate energy system piping with brazed joints at Millstone Power Station Unit 3 (MPS3). By letter dated July 27, 2009, the staff requested that the submittal address previous requests for additional information that had been responded to in DNC letters dated September 14, 2006 and January 2, 2007. This attachment provides updates of the original responses contained in the two letters for consistency with the final methodology and the current request. To summarize and address the prior RAI correspondence, the following table lists each RAI and the changes necessary to incorporate it into the present submittal. Where the disposition of the RAI in Table 1 is listed as "Incorporated in Revision," the information is included in the revised relief request. Where the disposition is listed as "Supplemental Information," the information is additional information beyond that provided in the revised relief request and is addressed in the responses to the RAIs.

It is recognized that some NRC questions posed in the year 2006 referred to earlier versions of ASME Code Editions and Code Cases than are currently approved for use. However, it is believed the intent of the questions remains valid, and the updated DNC responses are with respect to currently approved ASME documents as referenced.

Table 1 - Disposition of Prior RAIs

Question RAI	Topic	Response still Valid?	Disposition [1, 2]-Refer to Notes to Table at end of Table 1	Revisions to 4/28/09 Submittal
1	Timing of repair	Yes	**Incorporated in revision**	Affected Section 5.5
2	Feasibility of braze reinforcement	Yes	Supplemental information	None
3	Applicable Code year	No	Superseded by current submittal	None
4	Corrosion potential	Yes	Supplemental information	None
5	Timing of repair	Yes[3]	**Incorporated in revision**	Affected Section 5.5
6	Progression of degradation mechanism	Yes[3]	Supplemental information; but do not use to extend repair period	Already addressed by #1 and #5
7	Augmented exam extent	Yes[3]	**Incorporated in revision**	Affected Section 5.6
8	Provide NAVSEA document	Yes	Supplemental information	None
9	Average bond determination	Yes	Supplemental information	None
10	Testing samples and examiner qualification	Yes	Supplemental information	None
11	Examiner qualification	Yes	Supplemental information	None
12	Performance demonstration	Yes	Supplemental information	None
13	Bond data adjustment	Yes	Supplemental information	None
14	Non-uniform bond	Yes	Supplemental information	None
15	System function evaluation	Yes	Supplemental information	None
16	Acceptance criteria development	Yes [4]	Supplemental information; **Need to change reference to "tmax=5000 psi" in RAI response**	None
17	Stress analysis calculations	Yes	Supplemental information	None
18	Stress intensification factors	Yes	Supplemental information	None
19	Attach. A figure 2	Yes	Supplemental information	None
20	Testing methodology	Yes [4]	Supplemental information; **Need to change reference to 5 ksi braze shear strength in RAI response**	None

Question RAI	Topic	Response still Valid?	Disposition [1, 2]-Refer to Notes to Table at end of Table 1	Revisions to 4/28/09 Submittal
21	Attachment A figures 8 and 9	Yes	Supplemental information	None
22	Attachment C	Yes	**Need to revise Attachment C to show current factors of 7.5 ksi maximum shear and FS=1.5 on stress**	Replaced original example with revised
23	Time of repair	Yes	**Incorporated in revision**	Affected Section 5.5
1/2/2007 Supple-ment item 1	Periodic reassessment by UT	Yes	**Incorporated in revision**	Affected Section 5.6
1/2/2007 Supple-ment item 2	Shear stress experimental data	Yes	Supplemental information	None
1/2/2007 Supple-ment item 3	Braze shear strength and factor of safety	Yes	**Incorporated in revision**	Affected Section 5.3.4; also Attachment C (to be replaced as per RAI #22 above)

Notes to Table
[1] Where responses directly affect submittal text, "Incorporated in Revision" is noted
[2] Where responses provide supplemental information, "Supplemental Information" is noted
[3] Change references of "N-513-1" to "N-513-2"
[4] Editorial changes as noted

NRC QUESTION 1:

Discuss the hardship in performing an American Society of Mechanical Engineers Boiler and Pressure Vessel (ASME Code) repair or replacement of a leaking brazed joint during normal operation or during a scheduled outage when an ASME Code-required leakage test was performed.

DNC RESPONSE:

DNC does not intend to use NRC staff approval of the proposed alternative structural integrity methodology as a basis for continued use of a temporary non-Code repair for a condition that is identified during a planned scheduled outage, or to support restart from such scheduled outages. In such cases, the NRC review and approval of a temporary non-Code repair will still be needed.

The DNC procedure in use for non-Code repairs of ASME Class 3 piping is consistent with limitations that are described in Generic Letter 90-05, and the information to Licensees regarding resolution of degraded and nonconforming conditions in RIS-2005-20. Specifically, the DNC procedure requires a Code repair at the earliest of the following:

- Next scheduled shutdown of sufficient duration to complete repairs, or a scheduled shutdown greater than 30 days
- Next refueling outage
- Time at which flaw / leak size is predicted to exceed the flaw / leak size accepted by evaluation
- Leaks discovered during plant shutdown

DNC is requesting the use of this alternative methodology for conditions that reveal brazed joint leakage in ASME Class 3, moderate energy piping that remains structurally sound. With assurance of structural integrity, and the effects of leakage appropriately assessed and mitigated, these conditions have no safety consequence. NRC approved methodologies are not currently available for establishing structural integrity in brazed joints. With no approved methodology, the operability of affected systems and components can become impacted and applicable limiting conditions for operation in technical specifications must be met. Unnecessary emergent repairs will result in associated safety equipment unavailability, forced outages, and transients to the unit that would otherwise be avoidable with an approved methodology for establishing structural integrity in this moderate energy piping.

NRC QUESTION 2:

Discuss the feasibility to stop the leakage by applying a fillet brazing at the end surface of the leaking brazed joint or installing a mechanical device to seal or collect the leak during normal operation or during a scheduled outage when an ASME Code-required leakage test was performed. In this case, the structural integrity of the leaking brazed joint is assumed not to be a concern.

DNC RESPONSE:

Assuming structural integrity is confirmed, but leakage from the joint is unacceptable with respect to system performance, the leak may be stopped by application of adhesive sealant or soft rubber patch to the brazed joint. These measures are for leak control and provide no enhancement to structural integrity. Similarly, it is not anticipated that DNC would attempt to stop a brazed joint leak by application of a fillet. A good braze repair on a leaking joint would be extremely difficult to obtain and may adversely affect the integrity of the entire joint.

More often, DNC would expect to collect and divert any leakage from brazed joints in the same manner it does for other leaks. In accordance with standard practice for leaks, nearby components sensitive to saltwater such as stainless steel piping or electrical junction boxes are identified to ensure they are protected from the leakage. The leakage collection setup typically includes an inverted witch's hat and tubing to a floor drain or container. It is noted that the leakage rate from a brazed joint is best characterized as weepage, and measured as drops per minute or often several minutes per drop. Such a leak can at times become indistinguishable from normal condensation. There is an advantage to leakage collection in that the leak remains observable and, therefore, is a direct indicator of the condition of the joint. Periodic operator rounds can observe any significant increase in leakage and an appropriate re-assessment of structural integrity can be performed, if required.

NRC QUESTION 3:

Provide the bases for using the ASME Code 1998 Edition of Section XI with no Addenda for the Section XI Repair/Replacement Program activities. The NRC staff notes that in your previous relief request dated May 19, 2005, you performed a temporary non-ASME Code repair to a leaking brazed joint in service water drain line during plant operation at Millstone Unit 3. In that relief request, you referenced ASME Code 1989 Edition with no Addenda of Section XI, IWA-4000 as the ASME Code repair requirements which is different from the ASME Code edition you referenced in the current relief request (1998 Edition with no Addenda).

DNC RESPONSE:

The original response to this question is superseded by the current relief request.

NRC QUESTION 4:

Provide the water chemistry of the service water in the referenced piping systems and discuss its potential corrosion degradation on its adjacent components due to the leaking of the brazed joints. If the service water is seawater, the dripping of seawater on stainless steel components will cause the initiation of stress-corrosion cracking on its surface. Also, discuss the corrective action program that you will implement to inspect and clean up the dripping on the adjacent components.

DNC RESPONSE:

The proposed methodology is limited to the evaluation of structural integrity of brazed joints and is not meant as a methodology to address the extent of a condition and its associated safety significance with respect to other system interactions from the weepage, or leakage, of a brazed joint. However, this proposed methodology will be used in conjunction with the DNC corrective action program, which independently imposes additional requirements of the operability determination process that remain consistent with considerations described in NRC Generic Letter 90-05 for evaluating such moderate energy Class 3 piping conditions. The DNC corrective action program requirements are also consistent with the information contained in RIS-2005-20 with respect to resolution of degraded and nonconforming conditions. Therefore, the use of this proposed methodology as the basis for structural integrity of a degraded brazed joint remains conditional, as it will also require evaluation of the safety significance of system interactions that may be related to the condition. Considerations for flooding, jet spray, loss of flow, other interactions, the failure consequences and the impact to safe shutdown capabilities, are to be considered in evaluation of safety significance of system interactions that may be associated with the condition of a degraded brazed joint. Consequently, the corrosive conditions that may be present from exposure to seawater in the MPS3 service water system would be evaluated and mitigated as appropriate, as with any associated structures, systems and components that must be conservatively evaluated and mitigated in conjunction with DNC's corrective action program and the use of this proposed methodology for evaluating structural integrity of a degraded brazed joint.

As a reference to the requested information, the water chemistry of the service water at MPS3 is described in many of the service water system component specifications. This is a list of properties excerpted from such a component specification.

pH	8.5	
Color	5	
Alkalinity (as $CaCO_3$)		
Phenolphthalein	12	ppm
Methyl Orange	102	ppm
Free CO (calculated)	1.0	ppm
Free Available Chlorine (FAC)	0.12 – 0.17	ppm

Total Hardness (as $CaCO_3$)	5,500	ppm
Nitrate (NO_3)	0.47	ppm
Sulfate (SO_4)	2300	ppm
Chloride (Cl)	16,300	ppm
Phosphate (PO_4)	0.21	ppm
Total Solids		
Volatile	5,996	ppm
Fixed	28,404	ppm
Total	34,400	ppm
Dissolved Solids		
Volatile	4,522	ppm
Fixed	27,940	ppm
Total	32,492	ppm
Suspended Solids	1,908	ppm
Anionic Detergent	1.09	ppm
Silica (SiO_2)	2.8	ppm
Calcium (Ca)	440	ppm
Magnesium (Mg)	1,070	ppm
Iron (Fe)	0.13	ppm
Manganese (Mn)	0.03	ppm
Alumina (as Al_2O_3)	9.5	ppm
Chromium (Cr-Total)	0.02	ppm
Nickle (Ni) Less than -	0.01	ppm
Copper (Cu)	0.08	ppm
Potassium (K)	6.8	ppm
Sodium (Na)	11,000	ppm
Radioactivity	Negligible	

NRC QUESTION 5:

To support your relief request, you referenced ASME Code Case N-513-1 which permits continued operation of low energy systems with minor leakage when justified by an evaluation of system performance. The NRC staff notes that the referenced ASME Code Case allows the continued operation of the degraded Class 3 piping only for a limited time, not exceeding the time to the next scheduled outage. However, your proposed relief request extends the time limit for the proposed alternative to exceed the next refueling outage interval with justification (Section 5.5 on page 11), which is not consistent with ASME Code Case N-513-1. Confirm in your response that the application of the proposed alternative is limited to the next scheduled outage with sufficient time for performing an ASME Code repair or replacement, but not beyond the next refueling outage. The NRC staff's review of your June 9, 2005, relief request on the proposed use of a brazed joint assessment methodology is based on this condition being met. A separate relief request should be submitted if this condition cannot be met.

DNC RESPONSE:

The intended use of the proposed methodology was for a limited period of time, allowing for a timely repair or replacement activity to be planned for discrete degraded brazed joint conditions needing evaluation, commensurate with safety. DNC agrees with the NRC staff on the schedule limitations applied to the use of this proposal. Specifically, the use of this structural integrity evaluation method will be conditional, in that its application for any degraded brazed joint condition will not exceed the time to the next scheduled outage of sufficient duration for performing an ASME Code repair or replacement, but not beyond the next refueling outage. If a timely repair cannot be made, DNC will apply for a separate relief pursuant to provisions of 10 CFR 50.55a(a) to extend the duration of applicability beyond this intended limited period.

NRC QUESTION 6:

On page 4 of Enclosure 1, you stated that the lack of full braze bonding originates from construction or fabrication, and is not progressive over time. On page 10, you reported from a search and review of external operating experience that corrosion degradation was attributed to braze failures in closed loop and electrical cooling systems. You also stated that there was no operating experience indicating progressive failure for open loop sea water systems. To support your conclusion that no progressive failure mechanism exists in the open loop systems, you performed failure analysis on two brazed joint specimens removed from Millstone seawater service with nearly 20 years of service and no corrosion product was found. However, these specimens were taken from brazed joints that were not leaking. To adequately support your conclusion, the root cause for the leakage needs to be determined since the joint was not leaking when it was first put in service. Furthermore, failure analysis should be performed on samples taken from leaking brazed joints to determine the degradation mechanism that caused leaking. The potential degradation mechanism could be fatigue-related cracking, stress-corrosion cracking, or another mechanism and may not be limited to corrosion. These mechanisms may combine with the fabricated defects and cause leaking when it breaks the outside surface. Lacking sufficient evidence, a time-dependent evaluation, assuming the presence of a degradation mechanism progressive with time, should be performed.

DNC RESPONSE:

DNC agrees with the NRC staff on evaluating the type of degradation mechanism(s) that could be applicable to the affected service water piping. DNC's corrective action program requires that such evaluations be completed before using the proposed methodology to evaluate the fabricated defects' effects on structural integrity of brazed joints. The DNC corrective action process will evaluate the extent of condition and document a basis for conclusions regarding the type of degradation associated with each separate application of this methodology at MPS3. If progressive degradation mechanism(s) are found to be contributing to the source of leakage in the affected service water piping joint being evaluated, the proposed methodology will not be relied upon to establish structural integrity without a separate request to the NRC for review and approval of the temporary non-Code repair, pursuant to provisions of 10 CFR 50.55a(a). It is noted that NRC approved techniques for evaluation like Code Case N-513-2, with provisions for evaluating time-dependent and progressive forms of degradation, are not applicable to the form of leakage and materials in brazed joints used in the MPS3 service water system. DNC is, however, able to conservatively establish the applicability of appropriate evaluation techniques because the leakage from brazed joints has been extensively evaluated.

The cause of leakage from service water brazed joints has been investigated several times. Each investigation shows leakage to be attributed to a defect in the braze during original fabrication. All braze joints have some areas with lack of bond. Before a brazed joint is made, the pipe and fitting are thoroughly coated with flux material. When the joint is heated and the braze filler is applied to the face, the flux melts and the brazed material flows by capillary action. The capillary action is effective as long as the gap is the proper size and both sides of the joint are heated to the required brazing temperature in a continuous motion around the joint. Some small round spots of lack of bond formed by either flux inclusions or voids exist in essentially all brazed joints but they do not adversely affect the performance of the joint. If, however, one or both sides of the joint are not properly heated, as can happen when one side of a joint is significantly heavier, or if heating is interrupted, larger areas of lack of bond may connect together to form a leak path. These areas without braze filler metal are often filled with residual flux that solidifies to form a glass-like plug in the void. This glass-like plug is very hard and chemically inert and it can block the leak path for an indefinite time although it is very brittle and mechanical or thermal shock can shatter the glass-like plug opening the leak path at any time.

Brazed joints that are leaking when removed from service typically have the same internal appearance as those that were not leaking. The leakage flow rate is so small that there are no velocity effects, such as erosion. There is only limited surface corrosion.

Other degradation mechanisms such as fatigue cracking or stress corrosion cracking are typically not credible in this application. Regarding fatigue, the leaking brazed joints have been found at various locations that are not highly stressed. Also, the service water system inherently experiences only small temperature swings and the cyclic duty is low. Regarding stress corrosion cracking (SCC), copper base alloys are susceptible to SCC in ammonia solutions but not in the seawater environment of this piping [(1)]. Also, the brazing process inherently anneals the base materials in the area of the joint and results in low residual stress after the brazing process. There has been no

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(1) http://www.library.unsw.edu.au/~thesis/adt-NUN/public/adt-NUN20040129.095303/index.html. See page 5a, Table 1.1.

observed stress corrosion cracking of the copper base materials at MPS3. For these reasons, and because the stated mechanism is credible and consistent with the observed behavior, it is not appropriate to assume an unobserved mechanism for the weeping of the joints.

Although it has been concluded that no time-related metal degradation is involved in the weeping of brazed joints at MPS3, an essential part of the proposal's basis is that if there is such a mechanism at work, its evolution is very slow and not a factor in affecting structural integrity for an operating cycle. Generally, leaking brazed joints take many years to appear as the properties of the blockage/sealing materials from flux and trace elements in unbonded areas of the joint progress. Leaking brazed joints also do not increase their leak rate over a time that extends into the months of an operating cycle. The periodic monitoring (Section 5.4 of the submittal) is required by plant procedure for any service water leak and this monitoring will detect any significant increase in leakage and alert the operators of a need to reassess the structural integrity of the joint.

Not withstanding this response, repairs to leaking brazed joints will be performed on a schedule consistent with the response to Question 5 above.

NRC QUESTION 7:

Based on your discussion in Section 5.6, "Augmented Examination" (page 12 of Enclosure 1), the guidance provided is not consistent with that provided in ASME Code Case N-513-1. In ASME Code Case N-513-1, a sample size of at least five of the most susceptible and accessible locations, or if fewer than five are available, then all susceptible and accessible locations shall be examined. To exempt the previously examined joints from re-examination could be non-conservative, since the joints may have been examined a long time ago or [with] a technique used that may not have been able to identify the degraded condition. Furthermore, if additional degradation was found in the expanded sample, the referenced ASME Code Case requires this process to be repeated until no significant degradation is detected or until 100% of susceptible and accessible locations have been examined. Please justify this difference or revise the guidance in Section 5.6 and in the Millstone procedures or Corrective Action Program regarding the requirement to determine the extent of condition in similar brazed joints. The guidance should be consistent with that provided in ASME Code Case N-513-1.

DNC RESPONSE:

Augmented examination shall be consistent with ASME Code Case N-513-2.

NRC QUESTION 8:

Provide a copy of NAVSEA 0900-LP-001-700, "Fabrication and Inspection of Brazed Piping Systems," dated January 1, 1973. The NRC staff understands that your ultrasonic testing (UT) procedure MP-UT-45, "Ultrasonic Examination Procedure for Examination of Brazed Joints - Millstone Unit 3 Service Water Piping," Rev. 000-00 (Attachment E to Enclosure 1) was developed based on the NAVSEA procedure. Identify the differences between the two procedures (NAVSEA vs. MP-UT-45) and discuss the reasons for the differences.

DNC RESPONSE:

DNC will not be able to provide the NAVSEA Standard per your request due to certain publishing restrictions regarding its use. The NAVSEA Standard contains the UT criteria for the technique that has been used by the U.S. Navy for many years. Although DNC referenced this Standard to develop its request, the use of the technique described in the DNC procedure MP-UT-45, and by this proposal, has been independently validated and qualified for use by DNC at MPS3.

NRC QUESTION 9:

Using an example, describe how the average bond level of a brazed joint was determined by UT examination. Also, describe how the average threshold bond level of 60% was determined to be acceptable without further evaluation for brazed piping.

DNC RESPONSE:

As an example of determining an average braze bond level, refer to the original submittal Enclosure 1, Attachment C, page 3, titled "Braze Bond Measurements." There are 20 UT readings taken at even intervals around the circumference of the fitting. The boxed-in section headed "Meas. Bond" lists the actual percent bond based on the ratio of signals back reflected from the inner surface of the fitting and the inner surface of the pipe. Below the column of the 20 measured readings is a calculated average of the readings; the average is 55% in this example.

The 60% threshold for acceptance of a braze bond was chosen based on test results showing that for an intentional partial bond of 60% the brazed joint develops the full bending strength load of the piping, even when the bending is extended well beyond required design levels. In fact, the testing showed even at 30% partial bond the joint developed nearly the full piping strength. The Enclosure 1, Attachment A, Page 4, Figure 3 showing a load-deflection curve for 30% and 60% bond level illustrates these observations. Figure 8 on page 8 of the same attachment also illustrates this conclusion. The 60% figure is also consistent with the acceptance criterion in the NAVSEA standard referenced in our original submittal.

NRC QUESTION 10:

Describe in detail the trial demonstrations of the UT procedure you mentioned on page 5 of Enclosure 1. Describe the samples used for the demonstrations and identify the range of data scattering and standard deviation pertaining to readings reported by qualified examiners. Also, describe the qualification of the examiners participating in the demonstrations including a discussion as to how they were qualified and what were the qualification requirements.

DNC RESPONSE:

Trial Demonstration, Qualification:

Using techniques developed from NAVSEA 0900-LP-001-7000; five UT operators (Some currently qualified level II or III and some with previous Navy experience) conducted a blind, round robin test on six brazed joints which had been previously installed but were removed as part of plant modifications. The qualification of examiners participating in the demonstration was as follows:

Three of the UT examiners were Ultrasonic Level II or III technicians trained and qualified in accordance with ANSI/ASNT CP-189, 1991 Edition (three of these examiners are PDI Supplement 2 & 3 qualified). Two additional non-certified examiners familiar with UT examination of brazed joints per NAVSEA 0900-LP-001-7000 were utilized in the UT evaluation. One of the non-certified individuals is an ex-NAVSEA 7000 examiner (equivalent to a Level III under ANSI/ASNT CP-189).

The requirements for performing UT evaluation on the trial demonstration brazed samples was familiarization with the NAVSEA 0900-LP-001-7000 requirements as well as the expected UT signals from components with or without insert grooves, fitting back wall, and lack of bond signals.

Trial Demonstration, Sampling Description:

A total of 6 samples were used in the UT evaluation. These six joints were selected as representative of the ASME section III service water brazed joints that have experienced weeping type leaks in service at MPS3. The selected joints included two and three inch tees, couplings and elbows.

Description	Quantity	Joint Identification Number
Two inch tee	2	24J and 24K
Two inch coupling	2	25II and 25JJ
Three inch elbow	2	OS 5A and OS 5B

The UT results of each individual, along with the average of all five operators and the maximum deviation and standard deviation from that average are presented in Table 1 on the next page.

After all UT testing, each brazed joint was mechanically cross-sectioned three times and then polished and examined to measure the actual percentage of bond at each section. These values and the average are also presented in Table 1 for comparison.

Trial Demonstration, Data Identification: (see Table 1)

Average UT results ranged from a low of 54% bond to a high of 87% with a maximum single deviation of 9% and standard deviations ranging from 2 to 5%. This shows a good correlation and precision between the five operator's UT results as compared to the NAVSEA document that requires standard test specimens to be examined by three qualified inspectors and to average their results to set the true bond for that standard. To qualify, operators must examine six test joints with no single joint deviating more than 15% from the true bond value and the arithmetic average of the six deviations shall not exceed 8%.

Mechanical sections performed to determine the actual physical % bond range from a low of 66% to a high of 90%. These values correlate well with the UT % bond and average 10% higher than the UT % bond, showing that the UT measurements are inherently conservative.

Table 1: UT Evaluation of % Bond vs. % Bond Determined by Cross Sectioning

Joint ID	Individual % Bond by UT Examination					Avg UT Bond %	Max Dev	Std Dev	Individual % Bond by Section			Average % Bond by Sectioning	Differential Sectioning% - UT%
24J	74	77	74	78	78	76	+2 −2	2.05	84	81	93	86	10
24K	48	53	59	51	57	54	+5 −6	4.45	81	70	53	68	14
25II	77	88	87	91	87	86	+5 −9	5.29	95	92	74	87	1
25JJ	70	76	78	70	79	75	+4 −5	4.34	87	88	94	90	15
OS 5A	55	61	57	52	55	56	+5 −4	3.32	75	60	64	66	10
OS 5B	61	60	64	55	63	61	+3 −6	3.51	65	88	72	75	14

1. Each brazed joint was UT examined by five Technicians. The results of technician examinations are listed under "Individual % Bond by UT Examination."
2. The average of the individual UT exams for each brazed joint is listed under "Avg UT Bond %" followed by the maximum deviation from the average and the Standard Deviation (by the n-1 formula).
3. After completion of the UT examinations, each brazed joint was saw cut to expose three equally spaced circumferential cross sections and then polished to reveal the braze metal and all defects or voids in the braze ring area. These were measured to determine the "actual" percentage bond at each cross section. These values are listed under "Individual % Bond by Section."
4. The average of the individual sectioning examinations for each brazed joint is listed under "Average % Bond by Sectioning."
5. The difference between the UT and Sectioning % Bond, is listed under "Differential (Sectioning % - UT %). In all cases the "actual" measured (sectioning) % bond exceeded the percentage bond determined by UT examination with the average difference being just over 10%.

NRC QUESTION 11:

Describe the qualification programs that you already have in-house to qualify your Level II or III technicians, including procedures and equipment to perform the UT examination of the brazed joints. Also, describe your in-house training program for your UT examiners to obtain adequate knowledge and skill to determine the bond in the brazed joints.

DNC RESPONSE:

The DNC written practice for qualification and certification of NDE personnel addresses the education, training and experience requirements contained in CP-189 and 10 CFR 50 for UT personnel.

Qualification and certification used in the Millstone Power Station procedure, MP-UT-45, is as described in NAVSEA 0900-LP-001-7000.

Equipment selection was based upon which search units would provide the resolution for discriminating the bond, insert groove and lack of bond signals. The specific equipment used was a Krautkramer USN-52L and a 5.0Mhz dual search unit.

Specific training for NAVSEA 0900-LP-001-7000 examination was limited to the method of calibration, and contains requirements for examiners and inspector qualification. Direction was provided to the examiners to discriminate the lack of bond indications from insert groove, fitting back wall and pipe back wall indications.

The DNC written practice includes instruction and practical requirements for brazed joint examiners. The following personnel requirements will be prerequisites for use of the Millstone Power Station procedure MP-UT-45:

1. Only Level II, or Level III personnel may independently perform, interpret, evaluate and report examination results.

2. Levels II and III shall be certified in accordance with [ANSI/ASNT CP-189, 1991 Edition.]

3. The UT examiners shall have sufficient knowledge and training to determine ultrasonically the bond in brazed joints.

4. UT examiners shall demonstrate ability to recognize such technical deficiencies as insufficient beam penetration (transmission), poor transducer contact and interfering contact surface roughness from patterns displayed on the ultrasonic screen.

5. UT examiners shall maintain proficiency for examination of brazed joints by performing an examination of a brazed joint at least every six months.

6. Examiners who do not meet the requirement of [item 5 above] shall demonstrate their ability to examine brazed joints prior to performing examinations in the field. See Table 2 below for initial examiner qualification and proficiency requirements.

Table 2: Brazed Joint Examiner Qualification

Qualification Type	No. of Samples	Period of Qualification
Initial Qualification	6	3 Years
Proficiency	3	6 Months
Requalification	6	3 Years

	Acceptance Criteria:
Initial Qualification:	The percent bond of the six test specimens as reported by the examinee shall be compared to the true bond and accepted on the following basis; the arithmetic average of the six test specimens shall not deviate by more than 8% from the true bond and no single specimen shall deviate by more than 15% from the true bond.
Proficiency Maintenance:	The percent bond of the three test specimens as reported by the examinee shall be compared to the true bond and accepted on the following basis; the arithmetic average of the three test specimens shall not deviate by more than 15% from the true bond.
Requalification:	Same as initial qualification.

NRC QUESTION 12:

To ensure the performance of a qualified UT examination of brazed joints, was a performance demonstration program used? Discuss how this program was implemented to qualify the ultrasonic examination procedures, equipment and the personnel to perform the examination of brazed joints including data collection and evaluation. Discuss how this program followed the approach delineated in Appendix VIII to ASME Code Section XI. Describe whether the sample sets prepared for the performance demonstration consisted of fabricated samples or field samples (if available, with joint configuration, pipe/fitting size and wall thickness) similar to that of the brazed joints to be examined, and contained representative flaws.

DNC RESPONSE:

A performance demonstration was not used as brazed joints do not fall under the jurisdiction of Appendix VIII.

The round robin was conducted entirely on field-removed samples and the examiners obtained the data in a blind fashion with no access to other examiners' data. The samples were not masked, however, not masking samples in no way aids the examiner in determining the amount of bonding present. Access to the internal diameter (ID) does not aid the examiner in determining the amount of bond present because the lack of bond exists between the component outside diameter (OD) and the backwall of the inserted pipe or fitting which is not visible.

All samples contained as-found (from field removal) conditions had varying degrees of bonding, which ranged from 0% bond to 100% bond.

NRC QUESTION 13:

Describe in detail how the adjustment of bond readings (b_{adj}) to account for UT uncertainties was determined, including the database to support the UT data adjustment discussed in page 7 of Enclosure 1.

DNC RESPONSE:

The adjustment to measured bond readings for use in evaluation was based on the recognition that there would be some uncertainty in bond readings. After some initial exams and comparisons among different examiners, a figure of 10% bond uncertainty at low bond readings was selected. The database of initial exams is described in the response to Question 10. Low bond joints typically have a patchy bond area and are thus subject to more uncertainty. At high bond readings, i.e., when almost all the signal is reflected from the pipe wall and almost none is reflected from the fitting, the uncertainty was expected to be smaller, and is not significant anyway since the joint achieves full strength near 50% true bond conditions. Although the bond adjustment figure was determined using an approximation, the use of the selected adjustment is validated by the fit to the data when the adjustment is included.

NRC QUESTION 14:

In Section 5.3.2 (page 7 of Enclosure 1), you stated that for bond readings that are significantly non-uniform around the circumference of the braze, an effective (lower) bond is computed based on the equivalent moment of the adjusted bond areas. For clarification, provide an example to demonstrate this calculation and discuss the reasons and conservatism of this approach.

DNC RESPONSE:

The example given in the submittal, Enclosure 1, Attachment C, page 1 has a moderately non-uniform bond distribution. A simpler example of non-uniform bond distribution is given in Attachment 1 of this response. In the example, most of the bond is missing (cross-hatched) while on the lower portion of the joint, the bond level is 80%. The average adjusted bond is 47%. In this example, the adjusted bond bending strength about the weak axis is equivalent to a 41% uniform bond, lower than the 47% average bond level. Therefore, the accounting of bond distribution at low levels is important to consider. The method used in the evaluation is based on straightforward geometry. The bending strength is taken as a sum of the bending strength of each small arc segment, each of which is taken to be proportional to its percent bond and distance from the bending axis. The geometry calculation is displayed on page 12 of the example in Attachment 1.

The stress evaluation assumes that the piping bending loads are all in the weak axis. This is conservative because the bond shear due to torsion is not adversely affected by the bond distribution and because the actual bending loads would not always be aligned with the weak axis.

NRC QUESTION 15:

Assuming the worst-case scenario that a complete failure of a three-inch pipe/fitting braze joint occurred, what would be the upper-bound leakage rate at 100 psig? Discuss its potential impact on the functional requirements of the system and the reduction of the system margins of safety.

DNC RESPONSE:

An upper-bound of 699 gal/min is estimated for the described conditions, although such a worst-case scenario is not a credible event with the proposed alternative. This estimate is derived using the flow formula in Crane's handbook, and assumes structural integrity has fully failed, which requires a complete failure of the bond followed by severance of the joint in three inch piping, and results in no system flow resistance and a discharge coefficient of 1.0.

$$q = C_d \cdot A \cdot \sqrt{2 \cdot g \cdot h_L}$$

$$C_d := 1.0$$

$$A := 1.865\,in^2$$

$$h_L := \frac{100\,psi}{64 \cdot \frac{lbf}{ft^3}} \qquad h_L = 225\,ft$$

$$q := C_d \cdot A \cdot \sqrt{2 \cdot g \cdot h_L} \qquad q = 699.453\,\frac{gal}{min}$$

Downstream cooling to the affected components would be lost, since the piping is assumed to have no structural integrity and is separated at the joint. However, catastrophic failure of the piping is not a credible outcome for this alternative methodology, where the non-conformance encountered amounts to weepage or some fraction of a drop per minute, and there is evidence of substantial braze bonding in the joint by UT measurement.

If structural integrity of the joint is retained, joint severance does not occur. An upper-bound maximum flow can be conservatively estimated at 6 gpm as stated in the original submittal, Enclosure 1, page 6, Section 5.3.1 "System Effects." As stated, this value is very low compared to pump capacity, so the net flow to affected components would remain nearly unchanged. In addition, the safety significance of system interactions are evaluated for each leaking brazed joint. Leakage is mitigated as appropriate to prevent adverse impacts upon structures, systems and components that are associated with, or in the proximity of, the affected brazed joint. The evaluation will not permit flow margins to be reduced below the design basis level, so there is no reduction in system margins of safety.

NRC QUESTION 16:

Discuss how the average UT bond readings of 60% or more, as the acceptance criteria, was determined. Discuss the conservatism of this acceptance criteria in terms of the mechanical properties of the brazing materials and the uncertainties of the UT bond readings.

DNC RESPONSE:

The determination of 60% for use as acceptance criteria is discussed in response to Question 9. The conservatism of the acceptance criteria is demonstrated as follows.

If the actual bond were 50%, then by Formula (3) in Attachment A, Figure 2 of the original attachment, the allowable loading of ($S_{max}(b_{adj})$) becomes the following:

$$S_{max}(b_{adj}) = \frac{\pi}{4} \cdot \frac{D^2 \cdot L_{ins} \cdot \tau_{max}}{Z_{pipe}} \cdot b_{adj}$$

$b_{adj} := 50\%$

$D := 2.375\,in$

$L_{ins} := .656\,in$

$\tau_{max} := 7500\,psi$

$Z_{pipe} := 0.566\,in^3$

$$S_{max}(b_{adj}) := \frac{\pi}{4} \cdot \frac{D^2 \cdot L_{ins} \cdot \tau_{max}}{Z_{pipe}} \cdot b_{adj}$$

$S_{max}(b_{adj}) = 19255psi$

This result is the maximum nominal longitudinal pipe stress for an actual bond of 50%, exclusive of any stress intensity factor (SIF). A SIF of (0.75)(2.1) = 1.575 is required in piping stress analysis for primary loads. Thus, the above maximum nominal stress is equivalent to an intensified stress value of 30,327 psi, or 20,217 psi when divided by a factor of safety of 1.5 for comparison with ASME Code stress calculations. Piping stress would have to reach its Faulted Code allowable of 2.4 Sh, where Sh is the piping allowable stress at operating temperature, to exceed the 7.5 ksi shear stress assumption for the braze material.

Actual braze material in a good bond is estimated to have a shear strength of about 15 ksi, based on brazing procedure qualification tests. Brazing wire such as "SFA-5.8 BAg-1" does not have an ASME specified minimum yield or ultimate stress.

In the joint strength evaluation model proposed, the joint strength is directly proportional to braze shear strength and the adjusted percent bond. At low bond readings, the factor of conservatism introduced by the bond reading adjustment increases. For example, a 30% bond reading would be adjusted to 22%, a reduction by a factor of 1.36. The combined conservatism of the braze bond adjustment and assumed bond shear stress capacity in actual practice is best illustrated by the submittal Enclosure 1, Attachment D, page 3, Table 1. The table shows a margin factor of at least 1.52 when the specified evaluation parameters are used, and that value is conservatively low, as described in the request.

NRC QUESTION 17:

Identify the Construction Code qualification stress analysis reports that were reviewed to determine the design-basis loadings at the subject braze joint (page 7 of Enclosure 1, 5.3.3). Confirm that these are NRC-accepted piping stress analysis reports.

DNC RESPONSE:

The Construction Code for the MPS3 service water piping is ASME III, 1971 Edition with Summer 1973 Addenda. For Code analysis, the piping is divided into separable portions and stress analyzed as described in licensing basis. Refer to the Updated Final Safety Analysis Report (UFSAR), in Section 3.9, Mechanical Systems and Components, and in Table 3.9B-11, Stress Analysis Requirements. The analyses are documented in stress calculations, one for each portion of the piping system. In application of the proposed alternative, the stress calculation specific to the brazed joint being evaluated would be used as the source of piping loads and stress. The stress calculation on record is not being modified. The methodologies and stress limits that are employed in the analyses remain consistent with what are documented in the UFSAR.

NRC QUESTION 18:

It appears that no stress intensification factors were applied in the stress analysis of the subject brazed joints (page 8 of Enclosure 1, 5.3) as discussed in 2.0 of Attachment B to Enclosure 1. Is this approach consistent with the applicable Construction Code requirements for stress analysis of the brazed joints? If not, please elaborate.

DNC RESPONSE:

The theoretical and testing bases for the proposed alternative were derived from applied forces and moments. The testing applied a load in a three point bending configuration resulting in an easily calculated moment at the brazed joints. As a convenience for evaluation purposes these are converted to equivalent nominal pipe stress, however the strength correlation to braze bond is based upon empirical analysis of the loads testing. Local stress concentration effects at the joint, if any exist, were inherent in the tests on actual brazed joint fittings. The stress intensification factors (SIF) as required for Code stress analysis of the brazed joint configuration does not enter into the strength correlation.

When existing Code stress analysis of piping is used as input to the evaluation, DNC can either access the detailed piping loads that are available as computerized output, or use the summarized pipe stress output that includes the effects of the detailed piping loads. The Code stress results include the effect of an SIF that is required when comparing stress results to Code allowable stress limits. To get nominal stress from the Code results the SIF must be factored out. This allows the actual joint loading, in terms of nominal stress, to be compared directly to joint strength, also in terms of nominal stress.

NRC QUESTION 19 (i):

For equation (3) in Figure 2 of Attachment A to Enclosure 1:

Describe briefly how these equations were developed and identify the references.

DNC RESPONSE:

Equation 3 was developed from first principles Strength of Materials, in which stress or load at a point is proportional to its distance from the bending axis. The strength (bending moment capacity) of a brazed joint is, therefore, the integration of the strength of each bond area times its distance from the neutral axis.

In torsion, all the incremental areas are the same distance from the axis of rotation, so the strength of the joint in torsion is twice the strength in bending. Therefore, it is conservative to combine the torsion and bending together, and to compare the result with the bending strength. A formal derivation of the formula is included in Attachment 1.

NRC QUESTION 19 (ii):

For equation (3) in Figure 2 of Attachment A to Enclosure 1:

> For the applicable braze materials, provide the ASME Code-allowable mechanical properties including the allowable shear stress, the certified mechanical test data of the braze alloy used in the fabrication of the referenced components and the minimum mechanical properties based on the material specifications referenced in purchasing.

DNC RESPONSE:

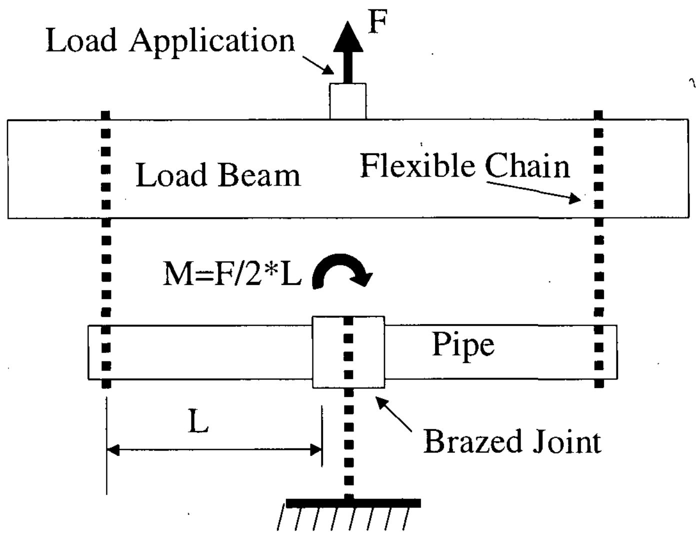
The ASME Code does not define allowable mechanical properties for braze material. For ASME III, Class 2 and 3, the Code does not require Certified Material Test Reports. The fabricated example brazed joints were fabricated from materials taken from station stock and are, therefore, representative of actual joints in service. Since the failure of a brazed joint occurs at the interface and not through the braze metal, mechanical properties of the braze metal do not directly determine the strength of the joint.

NRC QUESTION 20 (i):

The NRC staff notes that all brazed joints in the program were tested by three-point bending with the brazed fitting in the middle of the configuration. Provide the technical bases for the selection of this testing method to evaluate the strength of the subject braze joints. Also, discuss the limitations and uncertainties of using this testing method to evaluate the bond strength of the braze joints given that the test sample is a composite of fitting, piping and braze materials and a bending load is applied to the sample. In AWS C3.2, "Standard Method for Evaluating the Strength of Brazed Joints," a tensile testing method is recommended. Describe in detail, including sketches as applicable, how the three-point bending test was performed and provide a sample calculation to show how the test data was collected and evaluated. You stated in page 1 of Attachment B to Enclosure 1 that the load transfer between pipe and fitting is primarily by shear through the braze filler. Provide a discussion of why the three-point bending test is an acceptable method to evaluate the bond strength of the brazed joints.

DNC RESPONSE:

The three point bending test was utilized because the most significant design loads experienced by the joints are bending due to deadweight and seismic loads. Also, testing in torsion or direct pullout would have required a complicated test fixture, and these loadings are not the most severe when there is any non-uniformity of the bond. Figure 1 is a diagram of this testing configuration.



Three Point Bending Test Apparatus
FIGURE 1

A test machine of very large load capability would be required for direct pullout testing. Uncertainty on the loads and moments applied to the joint are also reduced with the three-point bending testing fixture that was used. The testing load cell is calibrated and the accuracy of the moment arm is known to within a fraction of an inch. Therefore, accuracy of test loading is reasonably adequate.

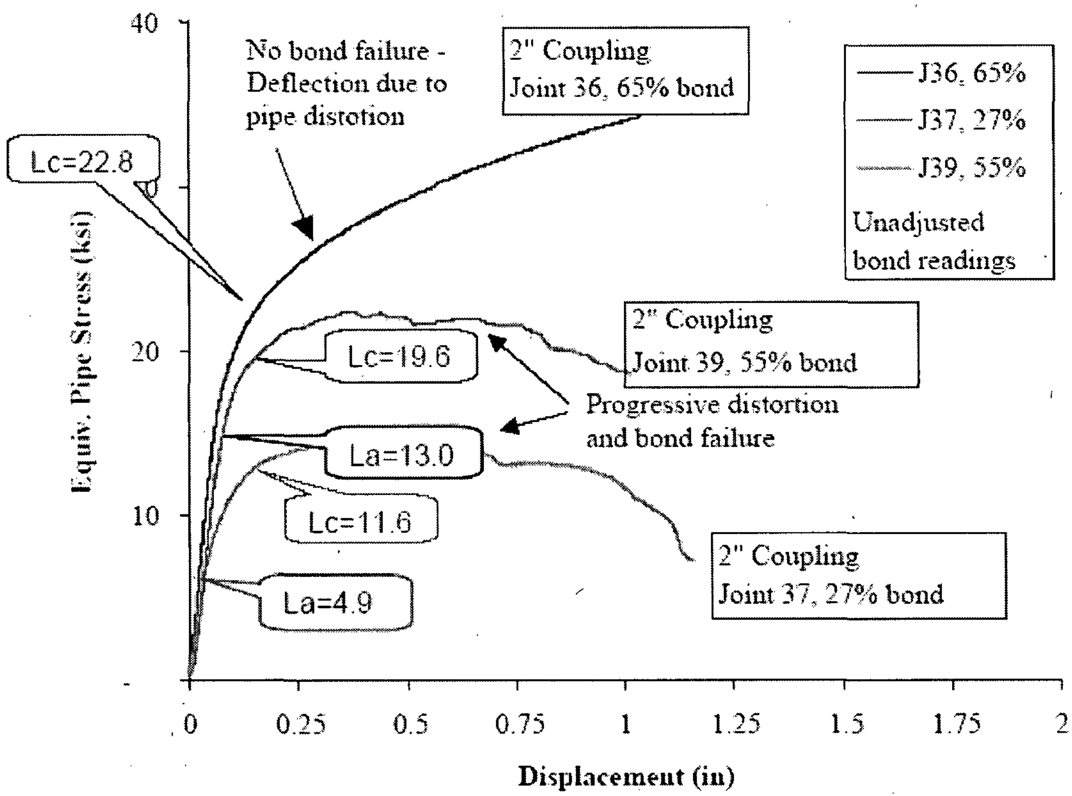
The testing configuration that was used, which includes the pipe, fitting and braze, is an optimal model for simply and predictably determining the structural integrity of the joint. The fact that the piping deformation and deflection sometimes governs the limit load means that the piping cannot exert enough load to exceed joint capacity.

NRC QUESTION 20 (ii):

You stated in Section 4.1 [Attachment D of Enclosure 1] that all test items (refer to Figure 4 in Attachment A) achieved their test collapse load at a load well above that which would be predicted for a 5-ksi braze shear strength. Provide details regarding how the test collapse load is calculated from an assumed 5-ksi braze shear strength. Show how the test collapse load, piping collapse load and the bond failure load was determined. In the three-point bending test, explain how the failure of the bond, as to both local bond failure and total bond failure, was determined.

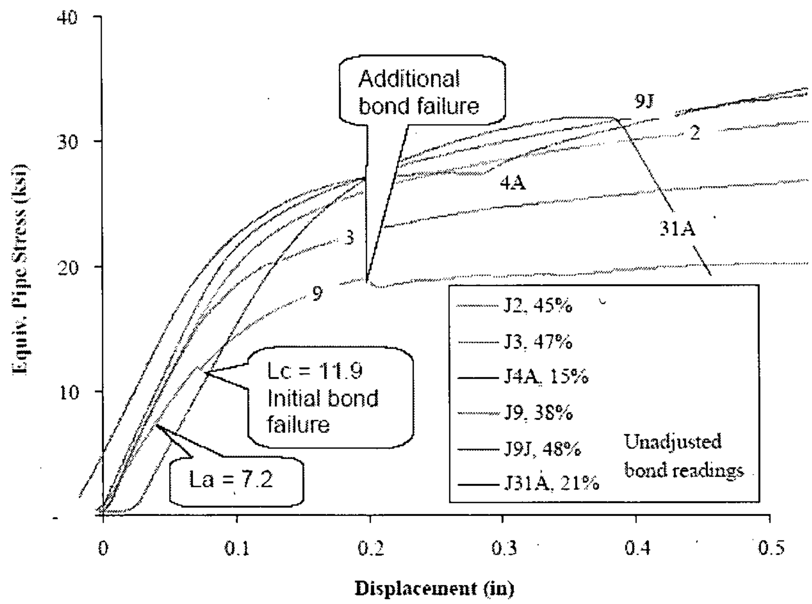
DNC RESPONSE:

The test collapse load is derived from the load-deflection curve. The collapse load is defined in ASME III, Appendix II, Section II-1430. Refer to Figures 2 and 3 below, which are annotated versions of Figures 6 and 7 of the original request.



TWO INCH FIELD SAMPLES
FIGURE 2

Initial bond failure is detectable by a discontinuity or knee in the load-deflection curve. This is indicated by Lc in the figures. The discontinuity or knee is the ASME-defined test collapse load. La on the figures indicates the allowable joint load based on the submitted methodology. The difference between the La and Lc illustrates the margin in the overall methodology.



THREE INCH FIELD SAMPLES
FIGURE 3

The Lc and La load values are the "Test Collapse Load" and "Shear Capacity Load" (based on 5 ksi shear) that were listed in Attachment D, Table 1 of the original request. The collapse load force was converted to a moment at the joint. The moment was converted to an equivalent nominal pipe stress by dividing it by the piping section modulus. The test collapse load does not depend on assumed joint shear strength. Referring to Table 1 in Section 4.3 of Attachment D, test joint 36 had a measured test collapse load of 2,025 lb. With a moment arm of 12.64 inch, the computed moment at that load was 12,799 in-lb, and the nominal pipe stress for that moment was 22.8 ksi based on a piping sectional volume Z of 0.561 in^3.

The minimum joint strength predicted from a 5 ksi braze shear strength is calculated using Formula (3) from Figure 2 in the request. Continuing the above example, with L.insert = 0.656 inches, D = 2.375 inches, and Z.pipe = 0.561 in^3, the lower bound of joint strength for 100% bond is 25.9 ksi. For 61% adjusted bond in the joint 36 example, the joint strength is reduced to 15.8 ksi as listed in Table 1 for that joint.

The above discussion of test results based on a maximum shear of 5000 psi remains valid for an assumed shear of 7500 psi when the factor of safety of 1.5 on actual piping pressure and loads is utilized for assessments, as required by the final methodology.

In the testing there was no differentiation between local and total bond failure. Under progressive loading the initial bond failure is expected to be local, and additional loading results in additional bond failure. Since all tests were continued up to a deflection limit in order to determine an ultimate load capability, subsequent bond failure beyond the initial failure occurred. However, the brazed joint is considered to have failed at the initial indication of bond failure, and the subsequent additional bond disruption is of no consequence to the determination of credited joint strength.

After full deflection the piping had ovalized and some joints were distorted. There were no complete severances of the joints. A post-test UT was not performed, which would have measured bond levels after the joint was destructively loaded well beyond its collapse load. The bond readings following testing are not used for a correlation with the collapse load, which is the failure of the joint. Consequently, the post-test UT is not required.

After testing, the two joints 37 and 4A were separated and visually examined by the independent testing laboratory. In un-bonded areas, superficial corrosion of the pipe and fitting materials was noted. There was no observed corrosion of the braze filler metal. A portion of joint 37 was sectioned and "significant lack of braze bonding and detachment" was noted. This result was consistent with the measured pre-test bond level of 27%.

NRC QUESTION 20 (iii):

Provide a detailed description of how the data in Table 1 were derived. Also, describe how the bond failure, test collapse load and shear capacity loads were determined from the mechanical testing. Discuss whether the specimens were destructively examined or re-UT examined to determine the level of bond failure resulting from the testing.

DNC RESPONSE:

The response to Question 20 (ii) addresses this question.

NRC QUESTION 20 (iv):

The NRC staff notes that there is significant data scattering in the test results of field samples of brazed joints as shown in Figure 7 of Attachment A to Enclosure 1. Provide reasons for the observed data scattering and discuss its impact on the reliability of bond level determined by UT examination.

DNC RESPONSE:

Figure 7 shows load deflection curves for the several samples, and it exhibits expected variations that are based on percent bond. Figure 9, related to Figure 7, shows data scatter at adjusted bond levels below 50%; however, all data points are above the acceptance criteria. The figure shows some three inch samples with data well above acceptance threshold. The three inch samples have a relatively large meniscus fillet at the face of the joint. The scatter for three inch samples that is shown in the figure appears to reflect how this fillet characteristic is not credited for strength in the evaluation methodology. Also, the percent adjustment at low bond readings is an almost 10% reduction on measurements that is an added conservative adjustment to the true bond. The aggregate of such conservatisms result in a relatively large data scatter while still validating the intended margin factor of 1.5.

NRC QUESTION 21 (i):

Figures 8 and 9 in Attachment A to Enclosure 1 - Describe how the shear (Sh) limit was determined and what the 2.4 Sh limit means.

DNC RESPONSE:

The "Sh" value is the ASME III Code allowable stress of the piping for operating temperatures. The 2.4 Sh value is the maximum stress for faulted conditions (Level D) permitted by ASME III. This value is shown because, by Code, the maximum piping stress, including stress intensification effects, must be less than 2.4 Sh. Therefore, the 2.4 Sh stress level represents the maximum loading of interest in piping systems.

NRC QUESTION 21 (ii):

Figures 8 and 9 in Attachment A to Enclosure 1 – Describe how the equivalent pipe stress was determined from the test load.

DNC RESPONSE:

See the response to Question 20 (ii).

NRC QUESTION 21 (iii):

Figures 8 and 9 in Attachment A to Enclosure 1 – Describe how no bond failure was determined and whether destructive examination to support the determination was performed. How was the local bond failure differentiated from the gross bond failure? Was it based on the shape of the test curves or the appearance of the test samples?

DNC RESPONSE:

See the response to Question 20 (ii).

NRC QUESTION 22:

For Attachment C to Enclosure 1 (Example Structural Assessment), a more detailed description of the assessment methodology should be provided. It would be helpful to provide sketches to show the dimensions. For Part 2, it is not clear how the effective bond was calculated and its relationship to the bond level determined by UT. Further explanation is needed for the plot, and the definition and calculation of Dxx, Dyy, Doffset, Alpha, Bxx, Byy Bbend and Bpress. Provide a sketch to show the locations of the 20 UT readings at joint 1A and how the average reading at each location was obtained. For Part 3, additional explanation is needed for the definition and calculation of Sxx, Syy, Sallow and the use of the Lookup Table. For Part 4, describe in detail the method, the input data and the equations used in the calculation of the max nominal stress of 4370 psi. Discuss whether this stress calculation shown was based on data taken from NRC-approved piping stress analysis reports.

DNC RESPONSE:

The response to Question 17 addresses the question on stress calculation approval. With respect to the NRC staff request for a more detailed description of the assessment methodology, a new example of the evaluation using this methodology is included in Attachment 1.

NRC QUESTION 23:

The NRC staff notes that your proposed use of the alternative brazed joint assessment methodology in lieu of an ASME Code repair or replacement, when leakage is found in a brazed joint resulting from the performance of a system leakage test performed in a scheduled outage, is not consistent with the purpose of the ASME Code-required system leakage testing. The ASME Code-required system leakage test should be scheduled in such a manner that there is sufficient time to perform an ASME Code repair or replacement of the affected component. Allowing a plant to start up with known leakage will not provide an acceptable level of quality including defense in depth in the operation of the plant. The proposed alternative should not be implemented on a generic basis during a scheduled outage. Therefore, given this, it is not clear to the staff what the acceptable level of quality, including defense in depth in the operation of the plant, that this proposed change represents. Please clarify the NRC staff's understanding of this.

DNC RESPONSE:

The request will not apply to leakage identified during a scheduled ASME Code-required system leakage test and it will only be applicable to leakage associated with brazed joints during system operation outside of a refueling outage.

SUPPLEMENT TO A REQUEST FOR BRAZED JOINT STRUCTURAL INTEGRITY ASSESSMENT METHODOLOGY, REQUEST IR-3-04

BACKGROUND

By letter dated April 28, 2009, Dominion Nuclear Connecticut, Inc. (DNC) submitted a request for re-approval to use an alternative brazed joint structural integrity methodology for the resolution of nonconforming conditions on ASME Code Class 3, moderate energy system piping with brazed joints at Millstone Power Station Unit 3 (MPS3), as a part of the inservice inspection (ISI) program at MPS3. By letter dated July 27, 2009 the staff requested that the submittal address previous requests for additional information that had been responded to in DNC letters dated September 14, 2006 and January 2, 2007. The balance of this attachment contains the most recent supplement to the request and adds clarifications.

This attachment supplements the Request IR-3-04 with the following three discussion items:

- Periodic ultrasonic test examinations (UT) are used to re-confirm the percentage of bonding
- Additional minimum brazed joint shear stress experimental values are provided
- Proposed use of brazed joint shear strength and safety factor is revised

DISCUSSION ITEMS THAT SUPPLEMENT REQUEST IR-3-04

1. Periodic UT Confirmation of a Percentage of Bonding:

The DNC procedure that is used to evaluate the structural integrity of existing brazed joints in ASME Class 3 piping is consistent with the intent of Generic Letter 90-05. Accordingly, the methodology that is proposed in the DNC Request IR-3-04 will also require a periodic UT of the affected brazed joint at least once every three months. The periodic UT will be used to re-confirm the percentage of bonding is input into the evaluation of brazed joint structural integrity.

2. Minimum Brazed Joint Shear Stress Experimental Values

The test data in Table 1 supports the proposed methodology in Request IR-3-04 for evaluating the structural integrity of brazed joints. Table 1 was derived from existing ASME Brazing Procedure Qualification Records of qualification tests performed in accordance with the ASME Boiler and Pressure Vessel Code, Section IX. Each test includes a set of either reduced or full section tensile tests. In order to pass these tests the brazed joint must be at least as strong as the specified minimum tensile strength of the weaker of the two base metals joined. Figure 1 shows a simple schematic of a tensile test specimen. The tensile test specimen loads the braze bond in shear. The shear stress data in Table 1 was calculated by dividing the ultimate load by the theoretical shear area of each braze joint instead of the cross-sectional area of the pipe. Where failure occurred in the base metal (as was the case in all but two of the reported tests) the ultimate shear strength of the brazed joint was not measured but must be greater than the reported values.

TABLE 1: MINIMUM BRAZE JOINT SHEAR STRESS

Specimen	Pipe O.D.(1)	Lap Length	Shear Area	Load (lbs)	Shear Stress	Type and Location of failure
BPQR 112: three-inch P-110 Pipe to P-107 Fitting with Pre-placed BAg-1a Insert Ring Reduced Section tensile test data						
V-T1	0.750 (1)	0.570	0.428	5,600	13,100	Ductile - Fitting
V-T2	0.752 (1)	0.570	0.429	4,800	11,200	Ductile - Fitting
H-T1	0.753 (1)	0.570	0.429	4,300	10,000	Ductile - Fitting
H-T2	0.753 (1)	0.570	0.429	4,800	11,200	Ductile - Fitting
BPQR 113: 3/4-inch P-107 Pipe to P-110 Fitting with Pre-placed Bag-7 Insert Ring Full Section tensile test data						
V-1	1.050	0.305	1.006	14,100	14,000	Ductile - Pipe
V-2	1.050	0.305	1.006	14,800	14,700	Ductile - Pipe
H-1	1.050	0.305	1.006	14,900	14,800	Ductile - Pipe
H-2	1.050	0.305	1.006	15,100	15,000	Ductile - Pipe
BPQR 113: 3/4-inch P-107 Pipe to P-101 Fitting Face Fed Bag-7 filler metal Full Section tensile test data						
V-1	1.040	0.250	0.817	12,900	**15,800**	Ductile - Braze
V-2	1.040	0.250	0.817	14,700	18,000	Ductile - Pipe
H-1	1.040	0.250	0.817	14,500	17,700	Ductile - Pipe
H-2	1.040	0.250	0.817	12,900	**15,800**	Ductile - Braze
NOTE: (1). A pipe O.D. is used unless the value given is annotated with this note. This note denotes the value shown is a dimension of width.						

In all but two of the reported tensile tests, the specimens failed in the base material and therefore do not provide an ultimate shear strength for the brazed joint. With a failure in the base material, the reported values demonstrate that the brazed joint was capable of carrying at least the reported shear stress without failure. Therefore, ultimate shear stress for brazed joints in specimens that failed in base material was actually higher than the reported values.

In the two joints where failure occurred in the braze, the ultimate shear strength of the braze was 15,800 psi. Values of the other 10 specimens range from 10,000 to 18,000 psi. These values do not take into account any loss of shear area due to voids, inclusions or other flaws, which typically exceed 10 percent and may include up to 25 percent of the braze area and are still acceptable to ASME IX criteria.

Considering the data from failures in either pipe of fitting base materials, and the ideal assumptions of shear area that are used to derive shear stress of Table 1, the data reasonably supports a conclusion that the ultimate shear strength of these brazed joints is much greater than where failure occurred in pipe of fitting base materials.

The indicated ultimate shear strength from the actual brazed joint failures is shown to be greater than 15,000 psi. As a conservative measure, a '2 times' margin has been used. This will result in a usable allowable shear stress value of 7,500 psi as input to the evaluation of the structural integrity of the braze joints using the methodology described in DNC request IR-3-04.

3. Brazed Joint Shear Strength and Safety Factor Use in Evaluation

DNC will revise the brazed joint evaluation procedure previously described in Request IR-3-04 in the following manner:

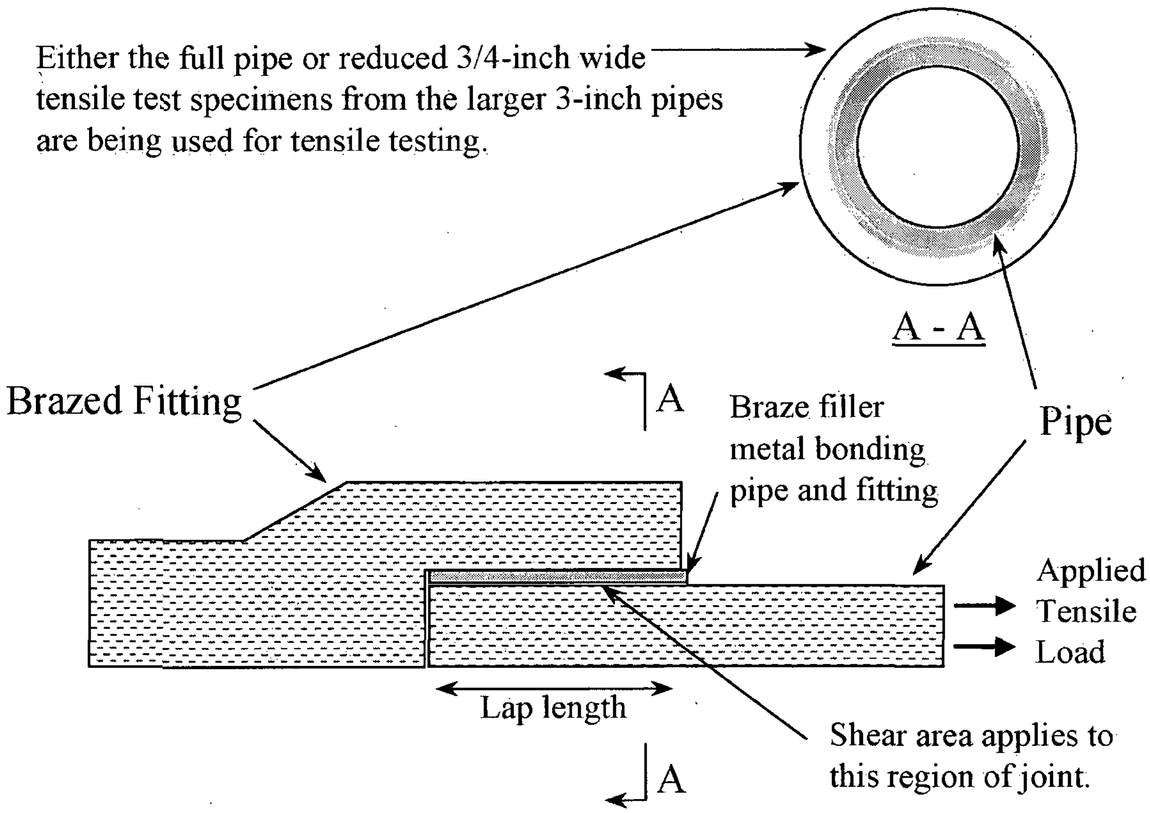
(a) The braze joint shear strength assumed for evaluation purposes will be changed to 7,500 psi, as justified above. Thus, in Enclosure 1, Attachment A, Figure 2 of the original submittal, the parameter τ_{max} in Equation 3 is revised to 7,500 psi.

(b) The piping analysis loads and equivalent stresses used to evaluate the braze joint will be multiplied by a safety factor of 1.5, which is conservative to factors required by ASME III Code Case N-513-2. Thus, in Enclosure 1, Attachment A, Figure 2 of the original submittal, Equation (1) is revised to read

$$1.5\ Seq < Smax(badj)$$

(c) Corresponding changes will be made to the "Braze Bond Structural Assessment", shown by example in the original submittal, to implement (a) and (b) above.

FIGURE 1: TENSILE TEST SPECIMEN SCHEMATIC



NOTE: This schematic shows how the tensile test specimens that are described in Table 1 load the braze bond in shear.

ATTACHMENT 1

DETAILED EXPLANATION OF BRAZED JOINT EVALUATION

(10 CFR 50.55a(a)(3)(i) REQUEST IR-3-04, TAC NO. MC8893)

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

DETAILED EXPLANATION OF BRAZED JOINT EVALUATION

(10 CFR 50.55a(a)(3)(i) REQUEST IR-3-04, TAC NO. MC8893)

This attachment provides a detailed explanation of an example brazed joint evaluation. The example evaluation is on pages 9 through 12 of this attachment. Other than a simplified dataset and minor formatting, the example uses the same evaluation as provided with the original submittal.

In the example evaluation on pages 10 through 13, the dashed boxes indicate input fields; all other fields are calculated or referenced from others. The following items are associated with the call outs on the example evaluation.

1. "Part 1" of the evaluation on page 9 lists basic data that identifies the brazed joint, the basic system function of the piping, and the relevant design drawings and stress analysis. The only specific numerical input used in the evaluation is the pipe diameter and wall thickness, 2.375 and 0.156 inches in this example. The numerical values of the lower bound bond shear strength (7,500 psi) and percent bond adjustment parameter (10%) are a constant for all evaluations.

2. The average of the unadjusted bond measurements is listed on page 9 and is 52% in this example. This value is linked to its calculation on page 11. As per the alternative, if this value is above 60% then the bond is acceptable without further evaluation. In this example, the average of 52% is less than 60%, so a detailed evaluation is necessary.

3. Dxx and Dyy are the offsets of the weighted center of bond strength from the nominal centerline on the joint. Bond strength is best evaluated in a coordinate system aligned with its center of strength. Its local strength is simply the shear load capability of a good bond times the local percent bond. When the bond is non-uniform, the purely axial loads of pressure thrust develop a bending moment with respect to the center of strength axis, with the Dxx and Dyy being the components of the effective moment arm, the resultant of which is denoted as Doffset. The Dxx and Dyy are calculated on page 12. In this example, the bond is symmetric about the vertical axis, so Dxx is 0.000 in, while for the horizontal axis there is more bond below the centerline, resulting in the negative value -0.193 inches for Dyy.

4. Alpha is another parameter representing the non-uniformity of the bond. It is the angular offset of the principle axes of the bond relative to the coordinate system used for bond measurements. It is also calculated on page 12. In this example the bond is symmetric about the measurement axes so the Alpha value is zero.

5. The braze bond data is presented in two columns. The first contains values based on measured, or "Actual" readings; the second contains values based on adjusted bond readings. The data based on "Actual" readings are presented for information only and are not used in the evaluation. The more conservative "Adjusted" values are used for evaluation. The listed parameters include Bxx and Byy. These are the effective bond for bending loads about the principle axes, calculated on page 12. The resultant of these, Bbend, is used for evaluation of bending loads. The Bpress value is the effective bond for axial loading such as pressure.

6. This figure on page 9 is a figurative representation of the bond distribution. The angular location of the bond measurements is shown. As a geometric necessity in a 2D plot, the cylindrical area of the bond surface is represented as an annular area. The x and y axes show the coordinate system used for measurement and the indicated angle is the sense of the Alpha parameter described in item 4 above. The grey portion of the annular area of the plot represents the effective degree of full strength bond and the cross-hatch portion represents the degree of disbondment. A 100% bond would be all grey. For an alternative representation of the same data, a linear graph of the same bond distribution is shown on page 11.

7. On page 10, Part 3 of the evaluation is devoted to determining the load capacity of the brazed joint. These geometric inputs include piping dimensions (linked from page 9), the piping section modulus (calculated from D and t), and the socket depth of the braze fitting, Linsert. This latter value is linked to the spreadsheet lookup table on the right for the socket depth. The dimensional standard for the fittings (MIL-F-1183, called "MilSpec") is what is listed in the piping specification used for procurement and construction.

8. The strength of the bonded joint is represented by the equivalent piping bending stress; i.e., the bending stress in the pipe for the same bending moment that the braze joint can withstand. The joint strength is presented as an allowable stress so as to permit simple comparisons with pipe stress levels available in pipe stress calculations. The derivation of the Formula (3) of Figure 2 in Attachment A of the original submittal is as follows:

$$M_b = \int \tau \cdot b \cdot y \, da$$

b_{adj} =effective uniform percent bond

$$\tau = \frac{y}{R} \cdot \tau_{max}$$

$$y = R \cdot \sin(\theta)$$

$$da = \cdot R \cdot L_{insert} \cdot d\theta$$

$$M_b = 4 \cdot \int_0^{\frac{\pi}{2}} \tau_{max} \cdot b_{adj} \cdot L_{insert} \cdot \left(\frac{D}{2} \cdot \sin(\theta) \right)^2 d\theta$$

$$M_b = \tau_{max} \left[\pi \cdot \left(\frac{D}{2} \right)^2 \cdot L_{insert} \right] \cdot b_{adj}$$

Since $S_{max} = \frac{M_b}{Z_{pipe}}$ then

$$S_{max} = \frac{\pi}{4} \cdot \frac{D^2 \cdot L_{insert} \cdot \tau_{max}}{Z_{pipe}} \cdot b_{adj}$$

The "S_{max}(100%)" value in the example represents the strength of a fully bonded joint. It is based on the formula in the box on the right side of page 10, in the example evaluation, which is basically the same formula as derived above. Thus, in the example the Smax(100%) value is calculated as:

$$S_{max}(b_{adj}) = b_{adj} \cdot \left(\frac{\pi}{4} \cdot \frac{D^2 \cdot L_{ins}}{Z_{pipe}} \right) \cdot \tau_{max}$$

$$1.0 \left(\frac{\pi \cdot 2.375^2 \cdot .65625}{4 \cdot .56645} \right) \cdot 7500\,psi = 38493psi$$

9. For values of b_{adj} less than 100%, the braze joint strength is simply $b_{adj} \bullet S_{max}$. These values of Sxx, Syy, etc are based on this relation, using b_{adj} = Bxx, Byy, etc. from page 9 (see item 5). Thus Syy = 38,493• 41% = 15,631 psi. The Sallow is the minimum of Sxx and Syy and represents the worst case joint strength. Thus, Sallow = 15,631 psi.

10. Once the joint load capability is known the actual loads in the piping are required for comparison. The Pipe Stress Data part of the evaluation summarizes stress results from the piping analysis and converts it to be in the same terms as the joint load capability so as to permit a direct comparison. This top part identifies the applicable pipe stress analysis. It is the same analysis that documents the ASME Code and licensing basis qualification of the piping and is therefore a valid basis for determining design basis loading on the brazed joint.

11. The piping characteristics here are copied from earlier portions, except for "A.pressure", which is the effective area for pressure thrust load calculations. It is based on the outside piping diameter (2.375 inches) rather than the inside diameter of the pipe because the brazed joint socket leaves the end of the pipe exposed to system pressure.

12. This section identifies the piping analysis node corresponding to the brazed joint. It also lists the ASME Code stress intensification factor (SIF) that was used for stress calculations. This is needed because for calculating ASME Code pipe stress results, an SIF multiplier was applied to moment loading, so if nominal stresses are used to represent moment loading the effect of the SIF must be divided out. Thus,

$$S_{Code} = SIF \cdot \frac{M_{pipe}}{Z_{pipe}}$$

$$S_{nominal} = \frac{S_{Code}}{SIF}$$

The SIF is listed at its nominal value (2.1 for all brazed joints) and also the ASME Code value used for primary loading, "Primary SIF" = 0.75 • 2.1 = 1.575.

13. These formulas are used to convert the Code pipe stress results to nominal results. The first formula calculates the stress, "S_{p_offset}", representing the additional nominal stress resulting from the product of the pressure thrust (pressure times area) and the lateral offset of the braze bond center of effort, Doffset, as discussed in item 3 above. In the formula, P_{max} is the maximum pressure and $A_{.press}$ is the area for pressure thrust (the same as "A.pressure" described above).

The second formula in the box calculates the nominal piping stress, S', equivalent to the braze joint loading. The only new term in the formula is S_{lp}, which is the ASME longitudinal pressure stress that is included with the moment stress term in ASME Code stress results. The ASME Code formula for S_{lp} is:

$$S_{lp} = \frac{P \cdot D}{2 \cdot t_{nom}}$$

The derivation of the formula for S' is as follows.

With 100% bond, the maximum shear on the braze filler metal due to pipe bending and pressure loading is

$$\tau_{bond} = \tau_{bend} + \tau_{press}$$

With less than 100% bond, the maximum shear on the remaining braze filler metal is

$$\tau_{bond} = \frac{\tau_{bend}}{B_{bend}} + \frac{\tau_{press}}{B_{press}}$$

Since the acceptance criterion is

$$\tau_{bond} < \tau_{max}$$

and defining

$$\tau_{allow} = B_{bend} \cdot \tau_{max}$$

the acceptance criterion can alternatively be written as

$$B_{bend} \cdot \tau_{bond} = \tau_{bend} + \tau_{press} \cdot \frac{B_{bend}}{B_{press}} < \tau_{allow}$$

Since the bond shear stress is directly proportional to pipe stress, the above criterion becomes

$$S_{bend} + S_{lp} \cdot \frac{B_{bend}}{B_{bpress}} < S_{allow}$$

Since

$$S_{Code} = S_{lp} + psif \cdot S_{bend}$$

then

$$S_{bend} = \frac{S_{Code} - S_{lp}}{psif}$$

Adding in the offset pressure bending term, the criterion becomes

$$\frac{S_{Code} - S_{lp}}{psif} + S_{p\_offset} + S_{lp} \cdot \frac{B_{bend}}{B_{press}} < S_{allow}$$

The left side is the required stress for comparison to the allowable

$$S' = \frac{S_{Code} - S_{lp}}{psif} + S_{p\_offset} + S_{lp} \cdot \frac{B_{bend}}{B_{press}}$$

14. This block lists the ASME Code pipe stress input on the left and the conversion of the pipe stresses to nominal stresses on the right. The S_{lp} value on the left is calculated based on the design pressure and piping dimensions using the formula stated above.

$$S_{lp} := \frac{100\,psi \cdot 2.375\,in}{2 \cdot .156\,in} \qquad S_{lp} = 761\,psi$$

The 64 value of Sp_offset due to the non-uniform bond is based on the formula in the box above:

$$0.193 \cdot \frac{100 \cdot 1.865}{0.566} \cdot psi = 64\,psi$$

The conversion of the ASME Code stresses into nominal stresses using the formula derived above is illustrated by the conversion of the 2500 psi value for Eq. 8:

$$\frac{2500 - 761}{1.575} + 64 + 761 \cdot \frac{40.6\%}{46.7\%} = 1830\ psi$$

The same formula applied to the Eq. 9 value (3500 psi) and Eq. 9F value (4500 psi) results in the listed nominal stress values of 2465 psi and 3100 psi respectively. Since the 3100 psi value bounds the others it is used for comparison to the allowable.

14A. As agreed in the response to Supplement Item 3, the nominal stress is multiplied by a factor of safety of 1.5.

15. Part 5 simply compares the results of Parts 3 and 4 to determine whether the brazed joint has adequate structural integrity to withstand all design basis loadings. In this case 4,650 psi joint loading is less than the 15,631 psi joint loading capability, so the joint is structurally adequate for design basis loads pending its repair. (If the comparison were not successful, the joint would be declared inoperable and appropriate action would be taken.)

16. The "Braze Bond Measurements" sheet records and summarizes the braze bond UT readings. The UT readings are those recorded by procedure MP-UT-45 as provided with the original submittal. This sheet performs the bond level adjustments and also develops tables of values for plotting the percent bond around the circumference of the joint.

17. The "Meas. Bond" column is an input field for listing the measured percent bond at each of the joint locations around the circumference. In this example, the readings are all 40% except for ones at locations 7-9 and 13-15. The "Adj. Bond" column is the result of adjusting each of the bond readings according to the formula stated in the submittal. For example, the 40% bond is adjusted to:

    (40-10)/(100-10) = 33%

    The columns of measured and adjusted bond values are used on page 12 of the evaluation.

18. The Average, Minimum and Maximum bond readings are summarized here. The average for the measured bonds listed here is the source of the "Measured Ave. Bond" value reported on page 9.

19. The linear graph plot shown here is an alternative representation of the bond readings to the polar plot shown on page 9.

20. The "Braze Bond Calculations" on page 12 is used to determine the effective bond characteristics such as its principle coordinate system and the effective bond for bending about the principle axes.

21. The top half of the evaluation shown on page 12 calculates results for the as-measured bond readings from page 11. The results are shown for information only, because the results are not used in the formal evaluation.

22. The lower half of page 12 calculates results for the adjusted bond readings from the evaluation shown on page 11. The adjusted bond values are more conservative (lower), and the effective bond values calculated are used in the formal evaluation of bond strength.

23. The geometric formulas presented here are used in the evaluation shown on page 12. The outline of the bond calculations is presented in item 24.

24. The evaluation shown on page 12 first calculates the first, second and cross-product moments of the bond distribution (variables ry, rx, Bpyy, Bpxx and Bpxy respectively). From these the offsets of the center of bond effort (Yoffset, Xoffset) are computed, and then the bond moment terms are translated to the offset coordinate system (Byy, Bxx, Bxy) using formulas from the second formula box. From these three latter terms the angle of the principle axes, Alpha, is determined in a standard manner in the third formula box. With this series of formulas Alpha is forced to be in the range -45 to +45 degrees. With Alpha now available, the bond moment terms in the original coordinate system can be rotated into the principle coordinate system, resulting in Byy_p and Bxx_p. The equivalent bond levels for bending are reported as twice these values, noting a 100% bond would have a bond moment for bending of 0.5.

25. The bond characterization values Dxx, Dyy, Bxx, Byy and Alpha listed in the evaluation shown on page 9 are linked to these calculated values at the bottom of the spreadsheet. Again, the results based on measured bonds are for information only and the results based on adjusted bonds are used for evaluation.

The following pages, pages 10 through 13 of this attachment, show an example evaluation described in items 1 through 25 above.

Braze Bond Structural Assessment Joint NRC 1 (example only)

Part 1 Basic Data (dashed boxes are inputs)

1

	inputs:		inputs:
Line No:	3SWP-002-999-3	*Pipe Dia*	2.375 in
Sys Function:	A supply to ACUS-1A	*Nom. Wall Thk*	0.156 in
Piping Iso:	CP-0123456	*Pipe Mat'l*	SB 466 CDA 706
Joint:	NRC 1	*Fitting Mat'l*	SB 61or 62
Side of Joint:	Upstream	Ref. Bond Strength:	7,500 psi
Jt. Orientation:	Mark 1 is up	Bond Adjustment	10%

2 *Measured Ave. Bond* 52% (calculated. For bond measurements, see sheet 'UT Readings')

52 % >= 60 % ? No, Detailed assessment required

Part 2 Bond Data Summary (data from sheet 'Bond Calcs')

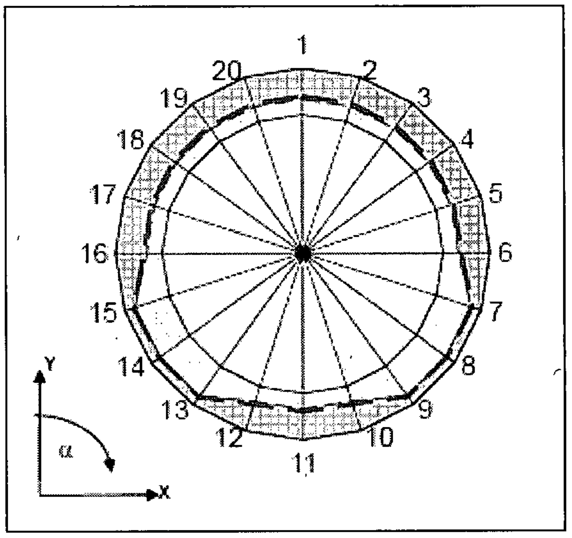
Offsets based on adjusted bond:

3 Dxx	0.000	in
Dyy	-0.193	in
Doffset	0.193	in (16% of pipe radius)
4 Alpha	0.0	degrees - rotation angle of principal axes

Calculated effective bond data are in principal axes system, and are based on adjusted bond.

5	Actual	Adjusted
Bxx	55%	50%
Byy	47%	41%
Bbend	47%	41%
Bpress	52%	47%

6



Note: Plot is figurative only, actual braze bond is cylindrical, not through-wall.

Braze Bond Structural Assessment   Joint   NRC 1

7 — **Part 3   Calculated Bond Load Capability**

D	2.375	in
tnom	0.156	in
Pipe Z	0.566	in^3
Linsert	0.656	in (from lookup table at right)
Smax(100%)	38,493	psi (from formula at right)

8 —

Lookup Tbl: L.insert per MilSpec

D.nom	D.od	Linsert
3/4	1.05	11/32
1	1.315	7/16
1.5	1.9	5/8
2	2.375	21/32
2.5	2.875	25/32
3	3.5	53/64

Load Capability (Allowable Nominal Pipe Stress)
(Based on bond levels from Part 2)

9 —

	Actual	Adjusted	
Sxx	21,262	19,348	psi
Syy	18,082	15,631	psi
Sallow	18,082	**15,631**	**psi**

stress based on shear allow. and percent bond

$$S_{max} b_{adj} = b_{adj} \left(\frac{\pi D^2 \cdot L_{insert}}{4 Z_{pipe}} \right) \cdot \tau_{max}$$

Part 4   Pipe Stress Data

10 —

(stress calc inputs)

Stress Calc	NP-X1901
Rev / CCN	Rev. 5 CCN 4
Line No:	3SWP-002-999-3
Sys Function:	A supply to ACUS-1A
Piping Iso:	CP-0123456
Joint:	NRC 1

11 —

(data from Part 1)

Pipe Dia	2.375	in
Nom. Wall Thk	0.156	in
Pipe Mat'l	SB 466 CDA 706	
Fitting Mat'l	SB 61or 62	
A.pressure	1.865	in^2
Z.pipe	0.566	in^3

12 —

inputs:

Stress Node	101
Alt. Stress Node	n/a
SIF Used	2.1
Primary SIF	1.575

13 —

$$S_{p\_offset} = D_{offset} \cdot \frac{P_{max} \cdot A_{press}}{Z_{pipe}}$$

$$S = \frac{S - S_{lp}}{psif} + S_{p\_offset} + S_{lp} \cdot \frac{B_{bend}}{B_{press}}$$

14 —

inputs:

Design Pressure	100	psig
Max Op. Pressure	100	psig
Slp	761	psi
Eq. 8 (P+DL)	2500	psi
Eq. 9 (N/U)	3500	psi
Eq. 9F (Design Basis0	4500	psi

Calculated Nominal Stresses

Sp_offset	64	psi
Sust'd 8'	1830	psi
N/U 9'	2465	psi
Faulted 9F'	3100	psi
Max Pipe Nominal Stress	**3100**	**psi**
Apply Safety Factor of 1.5	**4650**	**psi**

14A —

Part 5   Structural Integrity Determination   Joint   NRC 1

15 —

Joint Load Capability	15,631	psi	(from Part 3)
1.5*Design Basis Load	4,650	psi	(from Part 4)

Check: 4,650 < 15,631 ===> Braze is adequate for design basis loads
Monitor until repair/replacement

16

Braze Bond Measurements

17

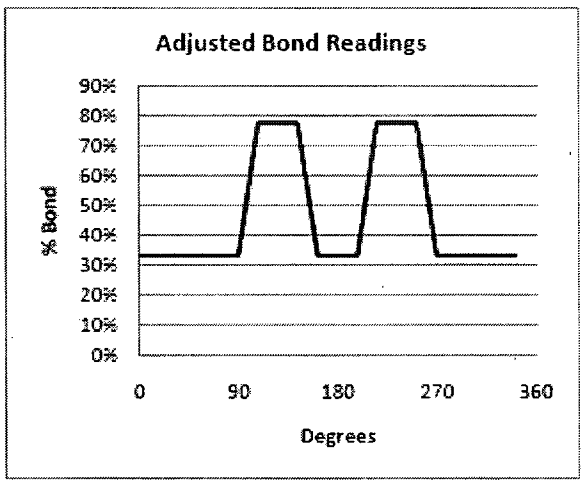
Joint NRC 1

Reading	Angle	Meas. Bond	Adj Bond	PlotValue	Adj Plot	R Max	Rmin Min
	Bond Adjustment		10%			1	0.75
1	0	40%	33%	0.850	0.833	1	0.75
2	18	40%	33%	0.850	0.833	1	0.75
3	36	40%	33%	0.850	0.833	1	0.75
4	54	40%	33%	0.850	0.833	1	0.75
5	72	40%	33%	0.850	0.833	1	0.75
6	90	40%	33%	0.850	0.833	1	0.75
7	108	80%	78%	0.950	0.944	1	0.75
8	126	80%	78%	0.950	0.944	1	0.75
9	144	80%	78%	0.950	0.944	1	0.75
10	162	40%	33%	0.850	0.833	1	0.75
11	180	40%	33%	0.850	0.833	1	0.75
12	198	40%	33%	0.850	0.833	1	0.75
13	216	80%	78%	0.950	0.944	1	0.75
14	234	80%	78%	0.950	0.944	1	0.75
15	252	80%	78%	0.950	0.944	1	0.75
16	270	40%	33%	0.850	0.833	1	0.75
17	288	40%	33%	0.850	0.833	1	0.75
18	306	40%	33%	0.850	0.833	1	0.75
19	324	40%	33%	0.850	0.833	1	0.75
20	342	40%	33%	0.850	0.833	1	0.75

Nreadings	20	Ave	52%	47%
dTheta	18	Min	40%	33%
degrees		Max	80%	78%

18

19



20 — **Braze Bond Calculations** **Joint NRC 1**

Boffset	Nreadings
10%	20

D: 2.375

Aoffset input: 0 degrees; 0.000 rad

Equivalent bond based on measured bond readings, without adjustment

Angle	Meas. Bond	cos(theta)	db*cos	db*cos^2	db*sin*cos	sin(theta)	db*sin	db*sin^2
0	40%	1.000	0.400	0.400	0.000	0.000	0.000	0.000
18	40%	0.951	0.380	0.362	0.118	0.309	0.124	0.038
36	40%	0.809	0.324	0.262	0.190	0.588	0.235	0.138
54	40%	0.588	0.235	0.138	0.190	0.809	0.324	0.262
72	40%	0.309	0.124	0.038	0.118	0.951	0.380	0.362
90	40%	0.000	0.000	0.000	0.000	1.000	0.400	0.400
108	80%	-0.309	-0.247	0.076	-0.235	0.951	0.761	0.724
126	80%	-0.588	-0.470	0.276	-0.380	0.809	0.647	0.524
144	80%	-0.809	-0.647	0.524	-0.380	0.588	0.470	0.276
162	40%	-0.951	-0.380	0.362	-0.118	0.309	0.124	0.038
180	40%	-1.000	-0.400	0.400	0.000	0.000	0.000	0.000
198	40%	-0.951	-0.380	0.362	0.118	-0.309	-0.124	0.038
216	80%	-0.809	-0.647	0.524	0.380	-0.588	-0.470	0.276
234	80%	-0.588	-0.470	0.276	0.380	-0.809	-0.647	0.524
252	80%	-0.309	-0.247	0.076	0.235	-0.951	-0.761	0.724
270	40%	0.000	0.000	0.000	0.000	-1.000	-0.400	0.400
288	40%	0.309	0.124	0.038	-0.118	-0.951	-0.380	0.362
306	40%	0.588	0.235	0.138	-0.190	-0.809	-0.324	0.262
324	40%	0.809	0.324	0.262	-0.190	-0.588	-0.235	0.138
342	40%	0.951	0.380	0.362	-0.118	-0.309	-0.124	0.038
		0.000	-0.068	4.876	0.000	0.000	0.000	5.524
	Bpress	check=0	ry	Bpyy	Bpxy	check=0	rx	Bpxx
	52%		-0.131	0.244	0.000	0.520	0.000	0.276

21

Roffset	Yoffset	Byy	Bxy	Byy+Bxx	Xoffset	Bxx
0.156	-0.156	0.235	0.000	0.511	0.000	0.276
BByy		47%	Bave	51%	BBxx	55%
Byy p		0.235			Bxx p	0.276
		47%				55%

Byy-Bxx=0	Bxy=0	tan 2alpha	cos 2alpha	sin 2alpha	tan check	alpha	
-0.041	0.000	0.000	1.000	0.000	0.000	0.000	rad
FALSE	TRUE					0.0	deg

23

$$B'_{yy} = \frac{1}{N}\sum b_j \cos(\theta_j)^2$$

$$B'_{xx} = \frac{1}{N}\sum b_j \sin(\theta_j)^2$$

$$B'_{xy} = \frac{1}{N}\sum b_j \sin(\theta_j)\cdot\cos(\theta_j)$$

$$B_{yy} = B'_{yy} - r_{yy}^2 \cdot b_{av}$$

$$B_{xx} = B'_{xx} - r_{xx}^2 \cdot b_{av}$$

$$B_{xy} = B'_{xy} - r_{xx} r_{yy} \cdot b_{av}$$

$$\tan(2\alpha) = \frac{2B_{xy}}{(B_{yy}-B_{xx})}$$

$$\cos(2\alpha) = \frac{|B_{yy}-B_{xx}|}{\sqrt{(B_{yy}-B_{xx})^2+4B_{xy}^2}}$$

$$\sin(2\alpha) = \frac{sgn(\tan 2\alpha)\cdot|2B_{xy}|}{\sqrt{(B_{yy}-B_{xx})^2+4B_{xy}^2}}$$

$$\alpha = \frac{1}{2}\,asin(\sin 2\alpha)$$

$$B_{p\_yy} = \frac{B_{yy}+B_x}{2} + \frac{B_{yy}-B_x}{2}\cos 2\alpha + B_{xy}\sin 2\alpha$$

$$B_{p\_xx} = \frac{B_{yy}+B_x}{2} - \frac{B_{yy}-B_x}{2}\cos 2\alpha - B_{xy}\sin 2\alpha$$

$$B_{p\_xy} = B_{xy}\cos 2\alpha - \frac{B_{yy}-B_x}{2}\sin 2\alpha$$

$$b_{adj} = \frac{b - b_{offset}}{1 - b_{offset}}$$

Equivalent bond based on adjusted bond readings

Angle	Adj. Bond	cos(theta)	db*cos	db*cos^2	db*sin*cos	sin(theta)	db*sin	db*sin^2
0	33%	1.000	0.333	0.333	0.000	0.000	0.000	0.000
18	33%	0.951	0.317	0.302	0.098	0.309	0.103	0.032
36	33%	0.809	0.270	0.218	0.159	0.588	0.196	0.115
54	33%	0.588	0.196	0.115	0.159	0.809	0.270	0.218
72	33%	0.309	0.103	0.032	0.098	0.951	0.317	0.302
90	33%	0.000	0.000	0.000	0.000	1.000	0.333	0.333
108	78%	-0.309	-0.240	0.074	-0.229	0.951	0.740	0.704
126	78%	-0.588	-0.457	0.269	-0.370	0.809	0.629	0.509
144	78%	-0.809	-0.629	0.509	-0.370	0.588	0.457	0.269
162	33%	-0.951	-0.317	0.302	-0.098	0.309	0.103	0.032
180	33%	-1.000	-0.333	0.333	0.000	0.000	0.000	0.000
198	33%	-0.951	-0.317	0.302	0.098	-0.309	-0.103	0.032
216	78%	-0.809	-0.629	0.509	0.370	-0.588	-0.457	0.269
234	78%	-0.588	-0.457	0.269	0.370	-0.809	-0.629	0.509
252	78%	-0.309	-0.240	0.074	0.229	-0.951	-0.740	0.704
270	33%	0.000	0.000	0.000	0.000	-1.000	-0.333	0.333
288	33%	0.309	0.103	0.032	-0.098	-0.951	-0.317	0.302
306	33%	0.588	0.196	0.115	-0.159	-0.809	-0.270	0.218
324	33%	0.809	0.270	0.218	-0.159	-0.588	-0.196	0.115
342	33%	0.951	0.317	0.302	-0.098	-0.309	-0.103	0.032
		0.000	-0.076	4.307	0.000	0.000	0.000	5.026
	Bpress	check=0	ry	Bpyy	Bpxy	check=0	rx	Bpxx
	47%		-0.162	0.215	0.000	0.467	0.000	0.251

22

24

Roffset	Yoffset	Byy	Bxy	Byy+Bxx	Xoffset	Bxx
0.193	-0.193	0.203	0.000	0.454	0.000	0.251
BByy		41%	Bave	45%	BBxx	50%
Byy_p		0.203			Bxx_p	0.251
		41%				50%

Byy-Bxx=0	Bxy=0	tan 2alpha	cos 2alpha	sin 2alpha	tan check	alpha	
-0.048	0.000	0.000	1.000	0.000	0.000	0.000	rad
FALSE	TRUE					0.0	deg

25

Measured Bonds

Bond values calculated at A_offset angle			
Yoffset	Byy	Xoffset	Bxx
-0.156	47%	0.000	55%

Adjusted Bonds

Bond values calculated at A_offset angle			
Yoffset	Byy	Xoffset	Bxx
-0.193	41%	0.000	50%

ENCLOSURE 4

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION ON USE OF A BRAZED JOINT STRUCTURAL INTEGRITY METHODOLOGY

(10 CFR 50.55a(a)(3)(i) REQUEST IR-3-04, TAC NO. ME1256)

Example of Application of Methodology

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

Example of Application of Methodology

As requested in NRC letter dated July 27, 2009, question 3, an example of the application of the previously approved brazed joint assessment methodology during the third ISI interval is provided. The example is of a brazed joint that was discovered to be leaking on March 4, 2008. The following activities then ensued.

Date	Activity	Document	Remarks
3/11/2008	UT Examination	AWO M30802596	Attached to Technical Evaluation
3/13/2008	Engineering Assessment	Technical Evaluation M2-EV-=08-0006	Included with this enclosure, Attachment 1 (19 pages)
5/29/ 2008	UT Re-examination	AWO M30804182	Inspection sheet included with this enclosure, Attachment 2 (2 pages)
8/26/2008	UT Re-examination	AWO M30804183	Inspection sheet included with this enclosure, Attachment 3 (2 pages)
10/8/2008	Begin MPS3 refueling outage	NA	
11/2/2008	Brazed Joint Repair	AWO M30802598, per DM3-00-0192-08	Brazed joints replaced with butt welds and socket welds

The table shows that the 90 day reinspection frequency requirement of the methodology was satisfied.

Note: The first examination and technical evaluation addressed nearby brazed joints that were not leaking and therefore met construction code requirements. These additional examinations were done for information only. Subsequent examinations addressed the leaking joint only.

(26 pages of attachments follow)

ATTACHMENT 1

Example of Application of Methodology

(10 CFR 50.55a(a)(3)(i) REQUEST IR-3-04, TAC NO. MC8893)

**DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3**

QA ☒ Non-QA ☐

DB or LB document change required? yes ☐ no ☒

TECHNICAL EVALUATION

for

Evaluation of Unit 3 Service Water Brazed Joint Flaw, Line 3SWP-075-V222

Millstone Unit 3

M3-EV-08-0006

Rev. 00

3/13/2008

~~18~~ 19 pages MJR 3/13/08

Preparer – Glenn Gardner — Date: 3/13/08

Independent Reviewer – Thomas Steahr — Date: 3/13/08

Engineering Approver – Martin Van Haltern — Date: 3/13/08

1.0 PURPOSE

The purpose of this evaluation is to determine the structural integrity of a leaking brazed joint in service water instrumentation piping to flow indicator FT-43B, upstream of root valve 3SWP*V222. This ¾" piping branches off line 3SWP-030-095-3. The brazed joint was identified as having evidence of leakage in CR-08-02368. A subsequent UT exam characterized the extent of brazed joint bond (Reference 3.3). This document provides a structural evaluation to support continued operation pending repair and summarizes requirements to monitor its condition.

2.0 BACKGROUND

A method for evaluating the structural integrity of degraded brazed joint was developed in Reference 3.4 and accepted by the NRC in Reference 3.5. The Reference 3.4 Technical Evaluation provides a spreadsheet based evaluation tool to assess the structural acceptability of degraded (including leaking) brazed joints. This Technical Evaluation, in conjunction with the UT procedure (Reference 3.6), provides the basis and specific instructions for examination, structural evaluation and reinspection requirements for degraded brazed joints in Millstone Unit 3 service water piping. Procedure MP-24-ENG-FAP947 (Reference 3.8) summarizes all requirements for responding to service water leaks.

The spreadsheet documented in the Reference 3.4 Technical Evaluation implements the approved methodology for evaluating brazed joint integrity. Its data inputs include calculated piping stress levels and the UT bond readings for the joint. The sheet is self documenting and provides a conclusion on whether the joint is acceptable for design basis loading. Specific directions for use of the spreadsheet are contained in Reference 3.4 and are not repeated here.

3.0 REFERENCES

3.1 CR-08-02092, Unplanned TRM for Minor Seepage From A SWP Strainer Backwash Line 3-SWP-003-021-3 Brazed Joint, dated 3/04/2008.

3.2 . Drawing No. 25212-21001 sheet 21, Rev. 9

3.3 Ultrasonic Examination Straight Beam Measurements, AWO Number M3-08-02596, dated 03/11/2008 (Attachment 1).

3.4 Technical Evaluation M3-EV-05-0002 "Examination and Structural Assessment of Brazed Joints" Revision 01 dated 7/17/07.

3.5 "Safety Evaluation by the Office of Nuclear Reactor Regulation, relief Request IR-2-38", US NRC, Transmitted by the letter dated February 28, 2007, Dominion licensing file 07-0153.

3.6 Procedure MP-UT-45 Rev 00-01 "Ultrasonic Examination Procedure for Examination of Brazed Joints – Millstone Unit 3 Service Water Piping".

3.7 Calculation No. NP-SWP-95-V222, Rev. 2 Change 0, "Root Valve Piping: Support Requirement Verification".

3.8 Procedure MP-24-ENG-FAP947, Rev. 001-01, "Non-Code Repairs in Safety Class 3 Piping", dated 9/24/2007

4.0 DISCUSSION

The UT was obtained on three brazed joints, FW-37, FW-38 and FW-8. Only FW-38 was leaking and that degraded condition is the one specifically evaluated here. FW-37 was not leaking and had greater braze bond than FW-38. FW-8 was at a flange that had interfering studs so only a partial set of readings was obtained on it; however it had readings comparable to FW-38. As discussed in Reference 3.4 the ASME Code does not have a requirement for minimum braze bond. Thus there is no degraded or non-conforming condition for either FW-37 and FW-8 and they are not considered to be a structural integrity concern requiring detailed evaluation. For information only the braze bond readings and evaluation summary for FW-37 are attached.

The formal evaluation of the leaking braze joint FW-38 is documented on the following spreadsheet pages. The braze bond UT readings are transcribed directly into the 'UT Readings' sheet. To account for 12 data points, the data input range for the average bond was modified to only consider the 12 data points, and zero percent bond readings were input for the other eight data point inputs that were not needed. A similar change was made on the 'Bond Calcs' sheet for the "BPress" on lines 29 and 65. Finally, on the summary sheet, the plot range was changed in order to show only the relevant 12 data points. Note that the methodology does specify a minimum number of UT data points and 12 points on the approximately 1.5" OD of the elbow fitting give a data point spacing of about 0.4 inches which is comparable with the UT probe size.

Braze Bond Structural Assessment Joint SWP95-FW-38

Ref: TE M3-EV-05-0002 Rev. 1 this sheet revised 07/17/2007

Part 1 Basic Data (dashed boxes are inputs)

	inputs:		inputs:
Line No:	SWP-075-V222	*Pipe Dia*	1.05 in
Sys Function:	FT-43B upstrm instr tubing	*Nom. Wall Thk*	0.154 in
Piping Iso:	CI-SWP-95 Sh 2	*Pipe Mat'l*	SB 466 CDA 706
Joint:	SWP95-FW-38	*Fitting Mat'l*	SB 61or 62
Side of Joint:	Dnstrm	Ref. Bond Strength:	7,500 psi
Jt. Orientation:	na	Bond Adjustment	10%

Measured Ave. Bond 42% (calculated. For bond measurements, see sheet 'UT Readings')

42 % >= 60 % ? No, Detailed assessment required

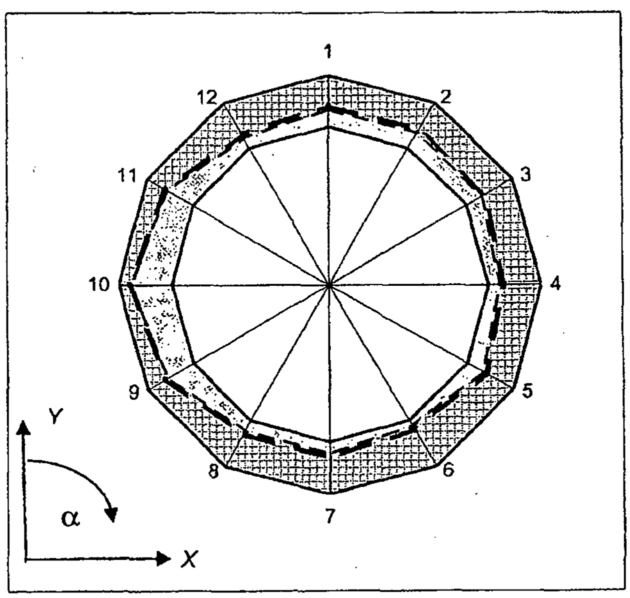
Part 2 Bond Data Summary (data from sheet 'Bond Calcs')

Offsets based on adjusted bond:

Dxx	-0.117	in
Dyy	0.038	in
Doffset	0.123	in (23% of pipe radius)
Alpha	-12.5	degrees - rotation angle of principal axes

Calculated effective bond data are in principal axes system, and are based on adjusted bond.

	Actual	Adjusted
Bxx	46%	40%
Byy	34%	27%
Bbend	34%	27%
Bpress	42%	35%



Note: Plot is figurative only, actual braze bond is cylindrical, not through-wall.

Braze Bond Structural Assessment Joint SWP95-FW-38

Part 3 Calculated Bond Load Capability

D	1.05	in
tnom	0.154	in
Pipe Z	0.085	in^3
Linsert	0.344	in (from lookup table at right)
Smax(100%)	26,169	psi (from formula at right)

Lookup Tbl: L.insert per MilSpec		
D.nom	D.od	Linsert
3/4	1.05	11/32
1	1.315	7/16
1.5	1.9	5/8
2	2.375	21/32
2.5	2.875	25/32
3	3.5	53/64

Load Capability (Allowable Nominal Pipe Stress)
(Based on bond levels from Part 2)

	Actual	Adjusted	
Sxx	12,134	10,391	psi
Syy	8,984	7,015	psi
Sallow	8,984	**7,015**	**psi**

stress based on shear allow. and percent bond

$$S_{max}(b_{adj}) = b_{adj} \cdot \left(\frac{\pi D^2 \cdot L_{insert}}{4 \cdot Z_{pipe}}\right) \cdot \tau_{max}$$

Part 4 Pipe Stress Data

(stress calc inputs)

Stress Calc: NP-SWP-95-V222
Rev / CCN: Rev. 2, CCN 0
Line No: SWP-075-V222
Sys Function: FT-43B upstrm instr tubing
Piping Iso: CI-SWP-95 Sh 2
Joint: SWP95-FW-38

(data from Part 1)

Pipe Dia	1.05	in
Nom. Wall Thk'	0.154	in
Pipe Mat'l	SB 466 CDA 706	
Fitting Mat'l	SB 61or 62	
A.pressure	0.825	in^2
Z.pipe	0.085	in^3

inputs:

Stress Node n/a
Alt. Stress Node n/a
SIF Used 2.1
Primary SIF 1.575

$$S_{p\_offset} = D_{offset} \cdot \frac{P_{max} A_{press}}{Z_{pipe}}$$

$$S = \frac{S - S_{lp}}{psif} + S_{p\_offset} + S_{lp} \cdot \frac{B_{bend}}{B_{press}}$$

inputs:

Design Pressure	100	psig
Max Op. Pressure	100	psig
Slp	170	psi
Eq. 8 (P+DL)	2448	psi
Eq. 9 (N/U)	5238	psi
Eq. 9F (Design Basis0	6402	psi

Calculated Nominal Stresses

Sp_offset	119	psi
Sust'd 8'	1695	psi
N/U 9'	3466	psi
Faulted 9F'	4205	psi
Max Pipe Nominal Stress	**4205**	psi
Apply Safety Factor of 1.5	**6308**	psi

Part 5 Structural Integrity Determination Joint SWP95-FW-38

Joint Load Capability	7,015	psi	(from Part 3)
1,5*Design Basis Load	6,308	psi	(from Part 4)

Check: **6,308 < 7,015 ===>** **Braze is adequate for design basis loads**
Monitor until repair/replacement

Braze Bond Measurements Joint SWP95-FW-38

							R	Rmin
	Bond Adjustment		10%				1	0.75
Reading	Angle	Meas. Bond	Adj Bond	PlotValue	Adj Plot		Max	Min
1	0	40%	*33%*	0.850	0.833		1	0.75
2	30	40%	*33%*	0.850	0.833		1	0.75
3	60	40%	*33%*	0.850	0.833		1	0.75
4	90	30%	*22%*	0.825	0.806		1	0.75
5	120	40%	*33%*	0.850	0.833		1	0.75
6	150	20%	*11%*	0.800	0.778		1	0.75
7	180	30%	*22%*	0.825	0.806		1	0.75
8	210	30%	*22%*	0.825	0.806		1	0.75
9	240	60%	*56%*	0.900	0.889		1	0.75
10	270	80%	*78%*	0.950	0.944		1	0.75
11	300	60%	*56%*	0.900	0.889		1	0.75
12	330	30%	*22%*	0.825	0.806		1	0.75
13	360	0%	*0%*	0.750	0.750		1	0.75
14	390	0%	*0%*	0.750	0.750		1	0.75
15	420	0%	*0%*	0.750	0.750		1	0.75
16	450	0%	*0%*	0.750	0.750		1	0.75
17	480	0%	*0%*	0.750	0.750		1	0.75
18	510	0%	*0%*	0.750	0.750		1	0.75
19	540	0%	*0%*	0.750	0.750		1	0.75
20	570	0%	*0%*	0.750	0.750		1	0.75

Nreadings	**12**	**Ave**	**42%**	**35%**	G9:G21
dTheta	30	**Min**	**20%**	**11%**	
degrees		**Max**	**80%**	**78%**	

Braze Bond Calculations

Joint SWP95-FW-38

Boffset	Nreadings
10%	12

D 1.05

Aoffset Input
0 degrees
0.000 rad

Equivalent bond based on measured bond readings, without adjustment

Angle	Meas. Bond	cos(theta)	db*cos	db*cos^2	db*sin*cos	sin(theta)	db*sin	db*sin^2
0	40%	1.000	0.400	0.400	0.000	0.000	0.000	0.000
30	40%	0.866	0.346	0.300	0.173	0.500	0.200	0.100
60	40%	0.500	0.200	0.100	0.173	0.866	0.346	0.300
90	30%	0.000	0.000	0.000	0.000	1.000	0.300	0.300
120	40%	-0.500	-0.200	0.100	-0.173	0.866	0.346	0.300
150	20%	-0.866	-0.173	0.150	-0.087	0.500	0.100	0.050
180	30%	-1.000	-0.300	0.300	0.000	0.000	0.000	0.000
210	30%	-0.866	-0.260	0.225	0.130	-0.500	-0.150	0.075
240	60%	-0.500	-0.300	0.150	0.260	-0.866	-0.520	0.450
270	80%	0.000	0.000	0.000	0.000	-1.000	-0.800	0.800
300	60%	0.500	0.300	0.150	-0.260	-0.866	-0.520	0.450
330	30%	0.866	0.260	0.225	-0.130	-0.500	-0.150	0.075
360	0%	1.000	0.000	0.000	0.000	0.000	0.000	0.000
390	0%	0.866	0.000	0.000	0.000	0.500	0.000	0.000
420	0%	0.500	0.000	0.000	0.000	0.866	0.000	0.000
450	0%	0.000	0.000	0.000	0.000	1.000	0.000	0.000
480	0%	-0.500	0.000	0.000	0.000	0.866	0.000	0.000
510	0%	-0.866	0.000	0.000	0.000	0.500	0.000	0.000
540	0%	-1.000	0.000	0.000	0.000	0.000	0.000	0.000
570	0%	-0.866	0.000	0.000	0.000	-0.500	0.000	0.000
		0.000	0.023	2.100	0.087	0.000	-0.071	2.900
	Bpress	check=0	ry	Bpyy	Bpxy	check=0	rx	Bpxx
	42%		0.055	0.175	0.007	0.417	-0.169	0.242
		Roffset	Yoffset	Byy	Bxy	Byy+Bxx	Xoffset	Bxx
		0.093	0.029	0.174	0.011	0.403	-0.089	0.230
			BByy	35% Bave		40% BBxx		46%
			Byy_p	0.172			Bxx_p	0.232
				34%				46%
Byy-Bxx=0	Bxy=0	tan 2alpha	cos 2alpha	sin 2alpha tan check		alpha		
-0.056	0.011	-0.396	0.930	-0.368	-0.396	-0.188 rad		
FALSE	FALSE					-10.8 deg		

$$b_{adj} = \frac{b - b_{offset}}{1 - b_{offset}}$$

Equivalent bond based on adjusted bond readings

$$B'_{yy} = \frac{1}{N}\cdot\sum b_i \cos(\theta_i)^2$$

$$B'_{xx} = \frac{1}{N}\cdot\sum b_i \sin(\theta_i)^2$$

$$B'_{xy} = \frac{1}{N}\cdot\sum b_i \sin(\theta_i)\cdot\cos(\theta_i)$$

$$B_{yy} = B'_{yy} - r_{yy}^2\cdot b_{av}$$

$$B_{xx} = B'_{xx} - r_{xx}^2\cdot b_{av}$$

$$B_{xy} = B'_{xy} - r_{xx} r_{yy}\cdot b_{av}$$

$$\tan(2\cdot\alpha) = \frac{2\cdot B_{xy}}{(B_{yy} - B_{xx})}$$

$$\cos(2\cdot\alpha) = \frac{|B_{yy} - B_{xx}|}{\sqrt{(B_{yy} - B_{xx})^2 + 4\cdot B_{xy}^2}}$$

$$\sin(2\cdot\alpha) = \frac{\mathrm{sgn}(\tan(2\cdot\alpha))\cdot|2\cdot B_{xy}|}{\sqrt{(B_{yy} - B_{xx})^2 + 4\cdot B_{xy}^2}}$$

$$\alpha = \frac{1}{2}\cdot \mathrm{asin}(\sin(2\cdot\alpha))$$

$$B_{p\_yy} = \frac{B_{yy} + B_x}{2} + \frac{B_{yy} - B_x}{2}\cdot\cos(2\cdot\alpha) + B_{xy}\cdot\sin(2\cdot\alpha)$$

$$B_{p\_xx} = \frac{B_{yy} + B_x}{2} - \frac{B_{yy} - B_x}{2}\cdot\cos(2\cdot\alpha) - B_{xy}\cdot\sin(2\cdot\alpha)$$

$$B_{p\_xy} = B_{xy}\cdot\cos(2\cdot\alpha) - \frac{B_{yy} - B_x}{2}\cdot\sin(2\cdot\alpha)$$

Angle	Adj. Bond	cos(theta)	db*cos	db*cos^2	db*sin*cos	sin(theta)	db*sin	db*sin^2
0	33%	1.000	0.333	0.333	0.000	0.000	0.000	0.000
30	33%	0.866	0.289	0.250	0.144	0.500	0.167	0.083
60	33%	0.500	0.167	0.083	0.144	0.866	0.289	0.250
90	22%	0.000	0.000	0.000	0.000	1.000	0.222	0.222
120	33%	-0.500	-0.167	0.083	-0.144	0.866	0.289	0.250
150	11%	-0.866	-0.096	0.083	-0.048	0.500	0.056	0.028
180	22%	-1.000	-0.222	0.222	0.000	0.000	0.000	0.000
210	22%	-0.866	-0.192	0.167	0.096	-0.500	-0.111	0.056
240	56%	-0.500	-0.278	0.139	0.241	-0.866	-0.481	0.417
270	78%	0.000	0.000	0.000	0.000	-1.000	-0.778	0.778
300	56%	0.500	0.278	0.139	-0.241	-0.866	-0.481	0.417
330	22%	0.866	0.192	0.167	-0.096	-0.500	-0.111	0.056
360	0%	1.000	0.000	0.000	0.000	0.000	0.000	0.000
390	0%	0.866	0.000	0.000	0.000	0.500	0.000	0.000
420	0%	0.500	0.000	0.000	0.000	0.866	0.000	0.000
450	0%	0.000	0.000	0.000	0.000	1.000	0.000	0.000
480	0%	-0.500	0.000	0.000	0.000	0.866	0.000	0.000
510	0%	-0.866	0.000	0.000	0.000	0.500	0.000	0.000
540	0%	-1.000	0.000	0.000	0.000	0.000	0.000	0.000
570	0%	-0.866	0.000	0.000	0.000	-0.500	0.000	0.000
		0.000	0.025	1.667	0.096	0.000	-0.078	2.556
	Bpress	check=0	ry	Bpyy	Bpxy	check=0	rx	Bpxx
	35%		0.072	0.139	0.008	0.352	-0.223	0.213
		Roffset	Yoffset	Byy	Bxy	Byy+Bxx	Xoffset	Bxx
		0.123	0.038	0.137	0.014	0.333	-0.117	0.196
			BByy	27% Bave		33% BBxx		39%
			Byy_p	0.134			Bxx_p	0.199
				27%				40%
Byy-Bxx=0	Bxy=0	tan 2alpha	cos 2alpha	sin 2alpha tan check		alpha		
-0.058	0.014	-0.467	0.906	-0.423	-0.467	-0.219 rad		
FALSE	FALSE					-12.5 deg		

Measured Bonds

Bond values calculated at A_offset angle

Yoffset	Byy	Xoffset	Bxx
0.029	35%	-0.089	46%

Adjusted Bonds

Bond values calculated at A_offset angle

Yoffset	Byy	Xoffset	Bxx
0.038	27%	-0.117	39%

5.0 SAFETY SIGNIFCANCE

This technical evaluation is prepared in support of an operability determination and is not a change to the design or operation of the plant as described in the licensing basis. Therefore a 50.59 screen is not required. Because the evaluation shows the piping meets approved evaluation criteria there is no impact on safety of plant operations.

6.0 CONCLUSIONS

The degraded socket welded fitting described in CR Reference 3.1 has been evaluated according to the NRC approved methodology documented in Reference 3.4 and determined to be structurally acceptable for continued service until such time a Code Repair can be performed. According to NRC agreement documented in Reference 3.4 and 3.5, the limitations for use require repair of FW-38 at the earliest of the following:

- next schedule outage of sufficient duration to complete repairs, or a scheduled shutdown greater than 30 days
- next refueling outage
- time at which the flaw/leak size is predicted to exceed the flaw/leak size accepted by evaluation

In addition, compliance with the accepted methodology requires periodic reassessments of FW-38 and augmented examination of five other similar joints, as detailed in Reference 3.8, Sections 2.6 and 2.4 respectively.

7.0 ATTACHMENTS

Item	Description	No. Pages
1	Braze Bond UT Readings	5
2	Structural Assessment of FW-37 (info)	4
3	Independent Review Comments	1
	Total pages of attachments	10

ATTACHMENT 1
ULTRASONIC CALIBRATION DATA SHEET

Plant: Millstone Unit: 3

Purpose: Eng. Info.

Cal Block Number 94-7794

DWG No. 25212-21001 SH 21

Page 1 of 4

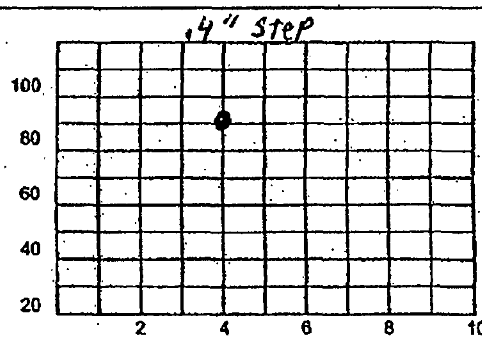
AWO Number: M3-08-02596

Cal Block Temp N/A

Thermometer S/N & Due Date N/A

Search Unit	
Manufacturer	KBA
Style or Type	Gamma
Frequency	5 MHz
Size & Shape	.25"
Mode T or C	C
Search Unit Angle	0°
Measured Angle	N/A
Serial Number	J06463
Cable Type, Length	Dual/6'
No. of Connectors	0

Instrument & Settings	
Mfg. / Model	KB
Serial Number	00CLXR
Range	1.0"
Material Velocity	.1960 NS
Delay	-.242
Pulser	Dual
Reject	0%
Frequency	2.8
Damping	1000 OHM
Zero Value	4.179
Pulse Rep Rate	High
Gain Setting	N/A



Attachments (Check)	
Sketch Sheet	N/A
Supplements	✓

Calibrations	Time
Initial Calibration	1700
Final Calibration	N/A
Final Calibration	2000

CRT Setup	Inches
Metal Path	N/A
Depth	1.0"

Couplant Data	
Brand	Soundsafe
Batch Number	06120A
SAP Batch Mgmt. No.	0000075238

Component ID	Component Type	Comments
FW 8, FW 37 and FW 38	Braze Joints	Joints upstream of 3SWP*V222

Examiner (Print & Sign) Michael Brehler / Michael Brehler Level II Date 3/11/08

Examiner (Print & Sign) N/A Level N/A Date N/A

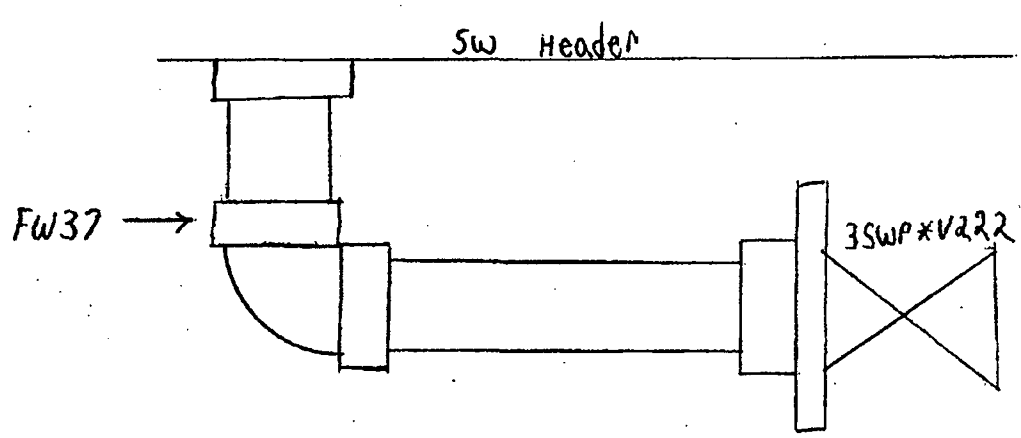
Reviewer (Signature) ______ Level ______ Date ______

Level of Use
Reference

STOP THINK ACT REVIEW

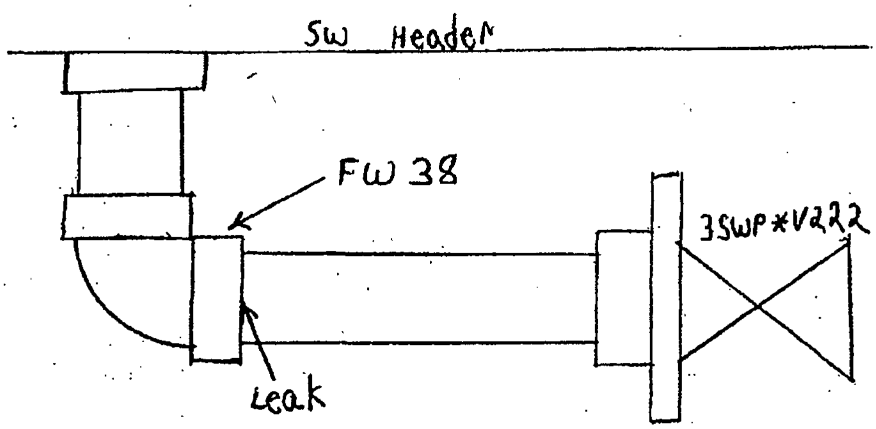
FW-37

Point No.	1st Signal (no bond)	2nd Signal (bond)
1	60	40
2	60	40
3	20	80
4	40	60
5	50	50
6	20	80
7	40	60
8	60	40
9	40	60
10	20	80
11	20	80
12	60	40
13	N	
14		
15		A
16		
Total		
Average		



FW-38

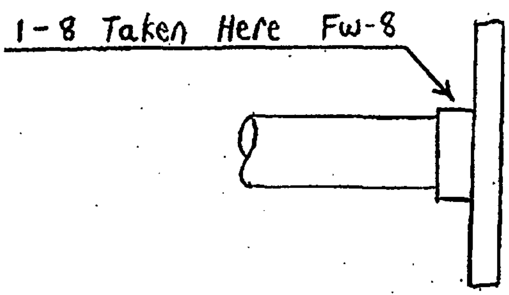
Point No.	1st Signal (no bond)	2nd Signal (bond)
1	60	40
2	60	40
3	60	40
4	70	30
5	60	40
6	80	20
7	70	30
8	70	30
9	40	60
10	20	80
11	40	60
12	70	30
13	N	
14		
15		
16		A
Total		
Average		

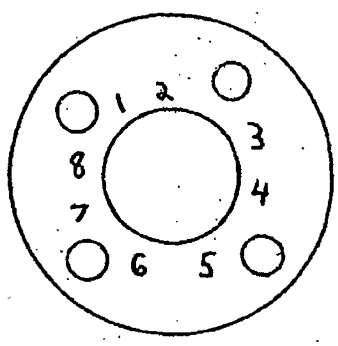


FW-8

Point No.	1st Signal (no bond)	2nd Signal (bond)
1	60	40
2	50	50
3	60	40
4	60	40
5	NP	NP 40
6	NP	NP 60
7	40	60
8	40	60
9	N	A
10		
11		
12		
13		
14		
15		
16		
Total		
Average		

Limited amount of Data due to Flange Bolting





Attachment 1 Exam Data Sheet

Millstone Power Station

ULTRASONIC EXAMINATION STRAIGHT BEAM MEASUREMENTS

Plant Millstone Unit 3	Page 1 of 1
System & Zone No. 3326	Exam Data Sheet No. N/A
Component ID 3/4" Piping US of 3SWP*V222	AWO Number M3-08-02596
Component Description 3/4" Pipe	Drawing No. 25212-21001 SH 21
Examination Purpose Eng. Info.	Line No. N/A

Instrument & Settings	
Manufacturer	KB
Model No.	USN 52L
Serial No.	00CLXR
Range	1.0"
Velocity	.196 μs
Delay	-.242 μs
Zero Value	4.179 μs
Cal Tolerance	±.005"

Calibration Block(s)		
Type	Serial No.	Material
Step Blk	94-7794	CUNI
N/A	N/A	N/A

Component Data	
Component T_{nom}	.154"
Component Dia.	3/4"
Attachments.	

Calibration Checks		Block Thickness		Instrument Reading	
Type	Time	Min.	Max.	Min.	Max.
Initial	2000	.100"	.400"	.100"	.400"
Intermediate	N/A	N/A		N/A	
Intermediate					
Final	2030	.100"	.400"	.100"	.400"

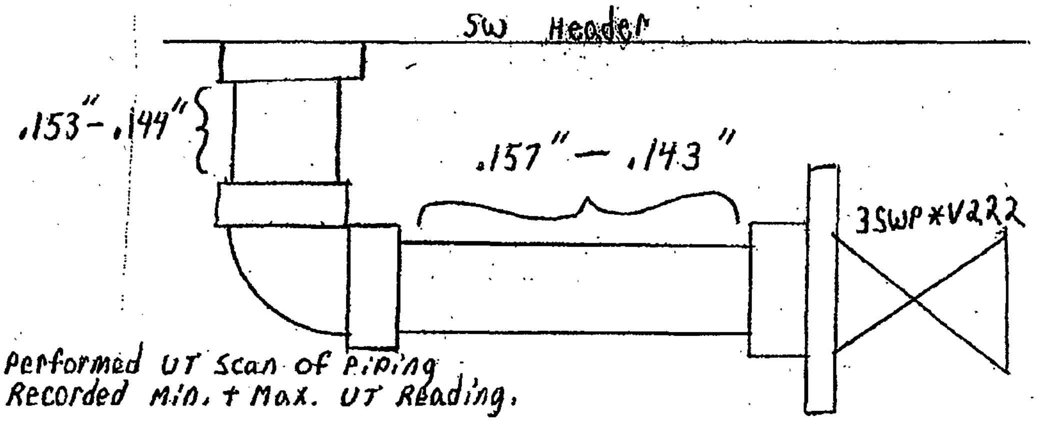
Search Unit Data	
Manufacturer	KBA
Type No.	Gamma
Serial No.	J06463
Frequency	5 MHZ
Size	.25"

Couplant Data	
Brand	Soundsafe
Batch No.	06120A
SAP Batch Mgmt. No.	0000075238

Coatings Factor Data	
Surface Painted	NO
ACT* mils =	N/A
ACT X 3 mils =	

* Average Coating Thickness

Sketch/Comments Area - Attach Photo(s) of Relevant Conditions Separately



Performed UT Scan of Piping
Recorded Min. + Max. UT Reading.

Examiner (print & sign) Michael Brehler / [signature] Level II Date 3/11/08

Reviewer (sign) ______ Level ______ Date ______

ANI/ANII If Required (Sign) N/A Date N/A

Level of Use **Reference**

STOP THINK ACT REVIEW

Braze Bond Structural Assessment Joint SWP95-FW37

Ref: TE M3-EV-05-0002 Rev. 1 this sheet revised 07/17/2007

Part 1 Basic Data (dashed boxes are inputs)

inputs:

Line No:	SWP-075-V222
Sys Function:	FT-43B upstrm instr tubing
Piping Iso:	CI-SWP-95 Sh 2
Joint:	SWP95-FW37
Side of Joint:	Upstrm
Jt. Orientation:	later

inputs:

Pipe Dia	1.05 in
Nom. Wall Thk	0.154 in
Pipe Mat'l	SB 466 CDA 706
Fitting Mat'l	SB 61or 62
Ref. Bond Strength:	7,500 psi
Bond Adjustment	10%

Measured Ave. Bond 59% (calculated. For bond measurements, see sheet 'UT Readings')

59 % >= 60 % ? No, Detailed assessment required

Part 2 Bond Data Summary (data from sheet 'Bond Calcs')

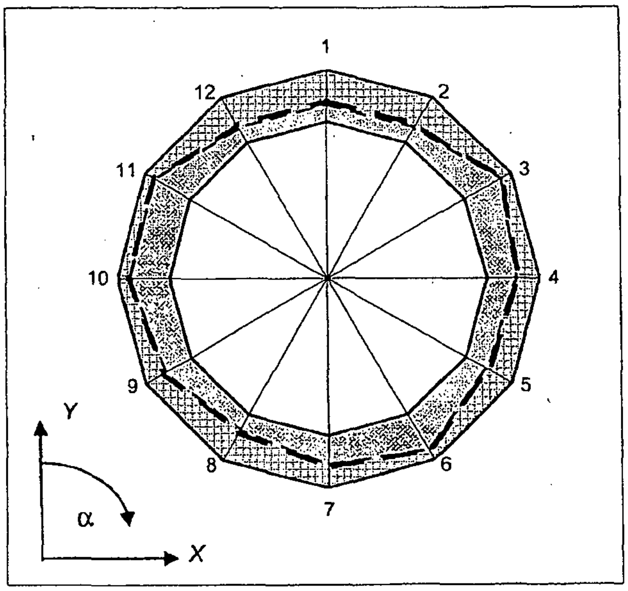
Offsets based on adjusted bond:

Dxx	**-0.008**	in
Dyy	**-0.026**	in
Doffset	**0.027**	in (5% of pipe radius)
Alpha	**9.7**	degrees - rotation angle of principal axes

Calculated effective bond data are in principal axes system, and are based on adjusted bond.

	Actual	Adjusted
Bxx	**66%**	**62%**
Byy	**52%**	**47%**
Bbend	**52%**	**47%**
Bpress	**59%**	**55%**

Note: Plot is figurative only, actual braze bond is cylindrical, not through-wall.



Braze Bond Structural Assessment Joint SWP95-FW37

Part 3 Calculated Bond Load Capability

D	1.05	in
tnom	0.154	in
Pipe Z	0.085	in^3
Linsert	0.344	in (from lookup table at right)
Smax(100%)	26,169	psi (from formula at right)

Lookup Tbl: L.insert per MilSpec

D.nom	D.od	Linsert
3/4	1.05	11/32
1	1.315	7/16
1.5	1.9	5/8
2	2.375	21/32
2.5	2.875	25/32
3	3.5	53/64

Load Capability (Allowable Nominal Pipe Stress)
(Based on bond levels from Part 2)

	Actual	Adjusted	
Sxx	17,213	16,218	psi
Syy	13,695	12,295	psi
Sallow	13,695	**12,295**	**psi**

stress based on shear allow. and percent bond

$$S_{max}(b_{adj}) = b_{adj} \cdot \left(\frac{\pi D^2 \cdot L_{insert}}{4 \cdot Z_{pipe}} \right) \cdot \tau_{max}$$

Part 4 Pipe Stress Data

(stress calc inputs)

Stress Calc	NP-SWP-95-V222
Rev / CCN	Rev. 2, CCN 0
Line No:	SWP-075-V222
Sys Function:	FT-43B upstrm instr tubing
Piping Iso:	CI-SWP-95 Sh 2
Joint:	SWP95-FW37

(data from Part 1)

Pipe Dia	1.05	in
Nom. Wall Thk	0.154	in
Pipe Mat'l	SB 466 CDA 706	
Fitting Mat'l	SB 61or 62	
A.pressure	0.825	in^2
Z.pipe	0.085	in^3

inputs:

Stress Node	n/a
Alt. Stress Node	n/a
SIF Used	2.1
Primary SIF	1.575

$$S_{p\_offset} = D_{offset} \cdot \frac{P_{max} A_{press}}{Z_{pipe}}$$

$$S = \frac{S - S_{lp}}{psif} + S_{p\_offset} + S_{lp} \cdot \frac{B_{bend}}{B_{press}}$$

inputs:

Design Pressure	100	psig
Max Op. Pressure	100	psig
Slp	170	psi
Eq. 8 (P+DL)	2448	psi
Eq. 9 (N/U)	5238	psi
Eq. 9F (Design Basis0	6402	psi

Calculated Nominal Stresses

Sp_offset	27	psi
Sust'd 8'	1619	psi
N/U 9'	3391	psi
Faulted 9F'	4130	psi
Max Pipe Nominal Stress	**4130**	psi
Apply Safety Factor of 1.5	**6195**	psi

Part 5 Structural Integrity Determination Joint SWP95-FW37

Joint Load Capability	12,295	psi	(from Part 3)
1,5*Design Basis Load	6,195	psi	(from Part 4)

Check: 6,195 < 12,295 ===> Braze is adequate for design basis loads
Monitor until repair/replacement

Braze Bond Measurements   Joint SWP95-FW37

							R	Rmin
	Bond Adjustment		10%				1	0.75
Reading	Angle	Meas. Bond	Adj Bond	PlotValue	Adj Plot		Max	Min
1	0	**40%**	***33%***	0.850	0.833		1	0.75
2	30	**40%**	***33%***	0.850	0.833		1	0.75
3	60	**80%**	***78%***	0.950	0.944		1	0.75
4	90	**60%**	***56%***	0.900	0.889		1	0.75
5	120	**50%**	***44%***	0.875	0.861		1	0.75
6	150	**80%**	***78%***	0.950	0.944		1	0.75
7	180	**60%**	***56%***	0.900	0.889		1	0.75
8	210	**40%**	***33%***	0.850	0.833		1	0.75
9	240	**60%**	***56%***	0.900	0.889		1	0.75
10	270	**80%**	***78%***	0.950	0.944		1	0.75
11	300	**80%**	***78%***	0.950	0.944		1	0.75
12	330	**40%**	***33%***	0.850	0.833		1	0.75
13	360	**0%**	***0%***	0.750	0.750		1	0.75
14	390	**0%**	***0%***	0.750	0.750		1	0.75
15	420	**0%**	***0%***	0.750	0.750		1	0.75
16	450	**0%**	***0%***	0.750	0.750		1	0.75
17	480	**0%**	***0%***	0.750	0.750		1	0.75
18	510	**0%**	***0%***	0.750	0.750		1	0.75
19	540	**0%**	***0%***	0.750	0.750		1	0.75
20	570	**0%**	***0%***	0.750	0.750		1	0.75

Nreadings	**12**	**Ave**	**59%**	**55%**	G9:G21
dTheta	30	**Min**	**40%**	**33%**	
degrees		**Max**	**80%**	**78%**	

Braze Bond Calculations

Joint SWP95-FW37

Boffset	Nreadings
10%	12

D 1.05

Aoffset input
0 degrees
0.000 rad

Equivalent bond based on measured bond readings, without adjustment

Angle	Meas. Bond	cos(theta)	db*cos	db*cos^2	db*sin*cos	sin(theta)	db*sin	db*sin^2
0	40%	1.000	0.400	0.400	0.000	0.000	0.000	0.000
30	40%	0.866	0.346	0.300	0.173	0.500	0.200	0.100
60	80%	0.500	0.400	0.200	0.346	0.866	0.693	0.600
90	60%	0.000	0.000	0.000	0.000	1.000	0.600	0.600
120	50%	-0.500	-0.250	0.125	-0.217	0.866	0.433	0.375
150	80%	-0.866	-0.693	0.600	-0.346	0.500	0.400	0.200
180	60%	-1.000	-0.600	0.600	0.000	0.000	0.000	0.000
210	40%	-0.866	-0.346	0.300	0.173	-0.500	-0.200	0.100
240	60%	-0.500	-0.300	0.150	0.260	-0.866	-0.520	0.450
270	80%	0.000	0.000	0.000	0.000	-1.000	-0.800	0.800
300	80%	0.500	0.400	0.200	-0.346	-0.866	-0.693	0.600
330	40%	0.866	0.346	0.300	-0.173	-0.500	-0.200	0.100
360	0%	1.000	0.000	0.000	0.000	0.000	0.000	0.000
390	0%	0.866	0.000	0.000	0.000	0.500	0.000	0.000
420	0%	0.500	0.000	0.000	0.000	0.866	0.000	0.000
450	0%	0.000	0.000	0.000	0.000	1.000	0.000	0.000
480	0%	-0.500	0.000	0.000	0.000	0.866	0.000	0.000
510	0%	-0.866	0.000	0.000	0.000	0.500	0.000	0.000
540	0%	-1.000	0.000	0.000	0.000	0.000	0.000	0.000
570	0%	-0.866	0.000	0.000	0.000	-0.500	0.000	0.000
		0.000	-0.025	3.175	-0.130	0.000	-0.007	3.925
	Bpress	check=0	ry	Bpyy	Bpxy	check=0	rx	Bpxx
	59%		-0.042	0.265	-0.011	0.592	-0.012	0.327
		Roffset	Yoffset	Byy	Bxy	Byy+Bxx	Xoffset	Bxx
		0.023	-0.022	0.264	-0.011	0.591	-0.006	0.327
			BByy	53% Bave		59% BBxx		65%
			Byy_p	0.262			Bxx_p	0.329
				52%				66%
Byy-Bxx=0	Bxy=0	tan 2alpha	cos 2alpha	sin 2alpha	tan check	alpha		
-0.063	-0.011	0.351	0.944	0.331	0.351	0.169 rad		
FALSE	FALSE					9.7 deg		

$$b_{adj} = \frac{b - b_{offset}}{1 - b_{offset}}$$

$$B'_{yy} = \frac{1}{N}\cdot\sum b_i \cdot \cos(\theta_i)^2$$

$$B'_{xx} = \frac{1}{N}\cdot\sum b_i \cdot \sin(\theta_i)^2$$

$$B'_{xy} = \frac{1}{N}\cdot\sum b_i \cdot \sin(\theta_i)\cdot\cos(\theta_i)$$

$$B_{yy} = B'_{yy} - r_{yy}^2 \cdot b_{av}$$

$$B_{xx} = B'_{xx} - r_{xx}^2 \cdot b_{av}$$

$$B_{xy} = B'_{xy} - \text{[illegible]}$$

$$\tan(2\cdot\alpha) = \frac{2\cdot B_{xy}}{(B_{yy} - B_{xx})}$$

$$\cos(2\cdot\alpha) = \frac{|B_{yy} - B_{xx}|}{\sqrt{(B_{yy} - B_{xx})^2 + 4\cdot B_{xy}^2}}$$

$$\sin(2\cdot\alpha) = \frac{\mathrm{sgn}(\tan(2\cdot\alpha))\cdot|2\cdot B_{xy}|}{\sqrt{(B_{yy} - B_{xx})^2 + 4\cdot B_{xy}^2}}$$

$$\alpha = \frac{1}{2}\cdot \mathrm{asin}(\sin(2\cdot\alpha))$$

$$B_{p\_yy} = \frac{B_{yy} + B_x}{2} + \frac{B_{yy} - B_x}{2}\cdot\cos(2\cdot\alpha) + B_{xy}\cdot\sin(2\cdot\alpha)$$

$$B_{p\_xx} = \frac{B_{yy} + B_x}{2} - \frac{B_{yy} - B_x}{2}\cdot\cos(2\cdot\alpha) - B_{xy}\cdot\sin(2\cdot\alpha)$$

$$B_{p\_xy} = B_{xy}\cdot\cos(2\cdot\alpha) - \frac{B_{yy} - B_x}{2}\cdot\sin(2\cdot\alpha)$$

Equivalent bond based on adjusted bond readings

Angle	Adj. Bond	cos(theta)	db*cos	db*cos^2	db*sin*cos	sin(theta)	db*sin	db*sin^2
0	33%	1.000	0.333	0.333	0.000	0.000	0.000	0.000
30	33%	0.866	0.289	0.250	0.144	0.500	0.167	0.083
60	78%	0.500	0.389	0.194	0.337	0.866	0.674	0.583
90	56%	0.000	0.000	0.000	0.000	1.000	0.556	0.556
120	44%	-0.500	-0.222	0.111	-0.192	0.866	0.385	0.333
150	78%	-0.866	-0.674	0.583	-0.337	0.500	0.389	0.194
180	56%	-1.000	-0.556	0.556	0.000	0.000	0.000	0.000
210	33%	-0.866	-0.289	0.250	0.144	-0.500	-0.167	0.083
240	56%	-0.500	-0.278	0.139	0.241	-0.866	-0.481	0.417
270	78%	0.000	0.000	0.000	0.000	-1.000	-0.778	0.778
300	78%	0.500	0.389	0.194	-0.337	-0.866	-0.674	0.583
330	33%	0.866	0.289	0.250	-0.144	-0.500	-0.167	0.083
360	0%	1.000	0.000	0.000	0.000	0.000	0.000	0.000
390	0%	0.866	0.000	0.000	0.000	0.500	0.000	0.000
420	0%	0.500	0.000	0.000	0.000	0.866	0.000	0.000
450	0%	0.000	0.000	0.000	0.000	1.000	0.000	0.000
480	0%	-0.500	0.000	0.000	0.000	0.866	0.000	0.000
510	0%	-0.866	0.000	0.000	0.000	0.500	0.000	0.000
540	0%	-1.000	0.000	0.000	0.000	0.000	0.000	0.000
570	0%	-0.866	0.000	0.000	0.000	-0.500	0.000	0.000
		0.000	-0.027	2.861	-0.144	0.000	-0.008	3.694
	Bpress	check=0	ry	Bpyy	Bpxy	check=0	rx	Bpxx
	55%		-0.050	0.238	-0.012	0.546	-0.015	0.308
		Roffset	Yoffset	Byy	Bxy	Byy+Bxx	Xoffset	Bxx
		0.027	-0.026	0.237	-0.012	0.545	-0.008	0.308
			BByy	47% Bave		54% BBxx		62%
			Byy_p	0.235			Bxx_p	0.310
				47%				62%
Byy-Bxx=0	Bxy=0	tan 2alpha	cos 2alpha	sin 2alpha	tan check	alpha		
-0.071	-0.012	0.352	0.943	0.332	0.352	0.169 rad		
FALSE	FALSE					9.7 deg		

Measured Bonds

Bond values calculated at A_offset angle			
Yoffset	Byy	Xoffset	Bxx
-0.022	53%	-0.006	65%

Adjusted Bonds

Bond values calculated at A_offset angle			
Yoffset	Byy	Xoffset	Bxx
-0.026	47%	-0.008	62%

Independent Reviewer Comment and Resolution Sheet(s)

(ER/EV) No. M2-EV-08-0006 Rev. 0

Page 1 of 1

Independent Reviewer: Thomas Steahr *[signature]* Date 3/13/08

Comment No.	ER/EV Section	Comment
1	All	Minor edits

ATTACHMENT 2

Example of Application of Methodology

(10 CFR 50.55a(a)(3)(i) REQUEST IR-3-04, TAC NO. MC8893)

**DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3**

ATTACHMENT 1
ULTRASONIC CALIBRATION DATA SHEET

Plant: MILLSTONE Unit: 3

Purpose: ENGINEERING INFORMATION

Cal Block Number MTE-02015

DWG No. 25212-21001 SH.21

Page 1 of 1

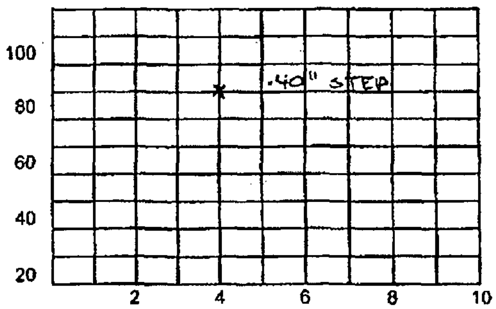
AWO Number: M3-08-04182

Cal Block Temp N/A

Thermometer S/N & Due Date N/A

Search Unit	
Manufacturer	KBA
Style or Type	GAMMA
Frequency	5.0 MHZ
Size & Shape	.25"
Mode T or C	C
Search Unit Angle	0°
Measured Angle	N/A
Serial Number	008XNY
Cable Type, Length	RG-174/6' DUAL
No. of Connectors	0

Instrument & Settings	
Mfg. / Model	KB
Serial Number	00CLRY5
Range	1.0"
Material Velocity	.1960
Delay	-0.375
Pulser	DUAL
Reject	0%
Frequency	2-8
Damping	1000 OHM
Zero Value	4.146
Pulse Rep Rate	HIGH
Gain Setting	N/A



Attachments (Check)	
Sketch Sheet	N/A
Supplements	✓

Calibrations	Time
Initial Calibration	1424
Final Calibration	N/A
Final Calibration	1436

CRT Setup	Inches
Metal Path	N/A
Depth	1.0"

Couplant Data	
Brand	SOUNDSAFE
Batch Number	06120A
SAP Batch Mgmt. No.	000075238

Component ID	Component Type	Comments
FW-38	BRAZED JOINT	FOLLOW-UP EXAM

Examiner (Print & Sign) TODD BOHNENKAMPER/ [signature] Level II Date 5/28/08

Examiner (Print & Sign) N/A Level N/A Date N/A

Reviewer (Signature) Michael Bolik Level II Date 5/28/08

Level of Use **Reference**

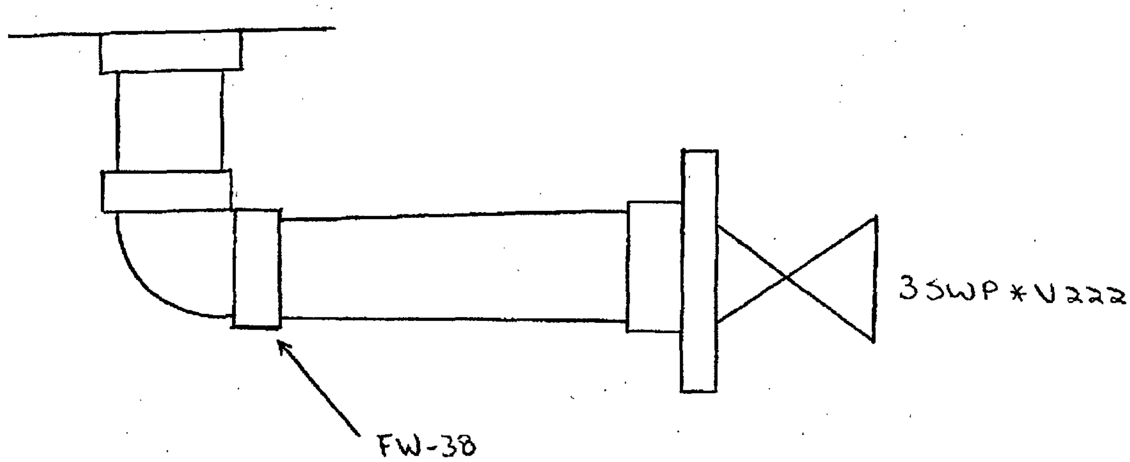
STOP THINK ACT REVIEW

INFORMATION ONLY

FW-38

AWO M3-08-04182

Point No.	1st Signal (no bond)	2nd Signal (bond)
1	60	40
2	60	40
3	70	30
4	65	35
5	60	40
6	70	30
7	70	30
8	65	35
9	60	40
10	60	40
11	70	30
12	70	30
Average	65 %	35 %



ATTACHMENT 3

Example of Application of Methodology

(10 CFR 50.55a(a)(3)(i) REQUEST IR-3-04, TAC NO. MC8893)

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

ATTACHMENT 1
ULTRASONIC CALIBRATION DATA SHEET

Plant: MILLSTONE Unit: 3

Purpose: ENGINEERING INFORMATION

Cal Block Number 98-7200

DWG No. 25212-21001 SH. 21

Page 1 of 2

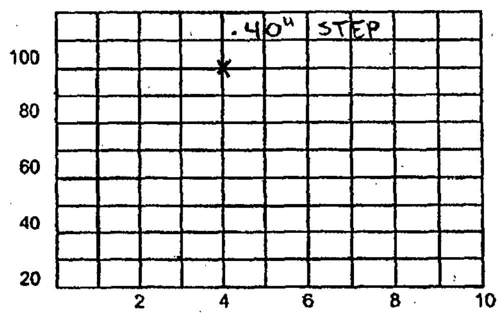
AWO Number: M3-08-04183

Cal Block Temp N/A

Thermometer S/N & Due Date N/A

Search Unit	
Manufacturer	KBA
Style or Type	GAMMA
Frequency	5.0 MHZ
Size & Shape	.25"
Mode T or C	C
Search Unit Angle	0°
Measured Angle	N/A
Serial Number	008KVY
Cable Type, Length	RG-174/6'
No. of Connectors	0

Instrument & Settings	
Mfg. / Model	KB/USN52L
Serial Number	00CNF2
Range	1.00"
Material Velocity	1920
Delay	-.242
Pulser	DUAL
Reject	0%
Frequency	2-8
Damping	1000 OHM
Zero Value	4.008
Pulse Rep Rate	HIGH
Gain Setting	N/A



Attachments (Check)	
Sketch Sheet	N/A
Supplements	✓

Calibrations	Time
Initial Calibration	0938
Final Calibration	N/A
Final Calibration	1000

CRT Setup	Inches
Metal Path	N/A
Depth	1.0"

Couplant Data	
Brand	SOUNDSAFE
Batch Number	06120A
SAP Batch Mgmt. No.	0000075238

Component ID	Component Type	Comments
FW-38	BRAZED JOINT	FOLLOW-UP EXAM

Examiner (Print & Sign) TODD BOHNENKAMPER/ [signature] Level II Date 8/26/08

Examiner (Print & Sign) N/A Level N/A Date N/A

Reviewer (Signature) [signature] Level II Date 8/28/08

Level of Use Reference

STOP THINK ACT REVIEW

FW-38 AWO M3-08-04183

Point No.	1st Signal (no bond)	2nd Signal (bond)
1	60	40
2	60	40
3	70	30
4	65	35
5	65	35
6	65	35
7	70	30
8	60	40
9	70	30
10	65	35
11	65	35
12	70	30
Total	785	415
Average	65%	35%