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Dominion

June 9, 2005

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
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Rockville, MD 20852-2738

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DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3
10 CFR 50.55a REQUEST IR-2-38 REGARDING AN ALTERNATIVE BRAZED JOINT ASSESSMENT METHODOLOGY

Pursuant to the provisions of 10 CFR 50.55a(a)(3)(i), Dominion Nuclear Connecticut, Inc. (DNC) requests approval for the use of an alternative brazed joint assessment methodology. Enclosure 1 describes the proposed methodology. The approval of this request will provide the structural integrity analysis and acceptance criteria needed for the resolution of nonconforming conditions on ASME Code Class 3, moderate energy system piping with brazed joints, as part of the Millstone inservice inspection (ISI) program.

This request is an alternative to the requirements of ASME Code Section XI and Section III that do not have rules applicable to evaluation of weepage through brazed joints from defects in braze bonding between piping and fittings. It is based upon an acceptable level of quality and safety for the resolution of these nonconforming conditions.

If you should have any questions regarding this submittal, please contact Mr. Paul R. Willoughby at (804) 273-3572.

Very truly yours,

Eugene S. Grecheck
Vice President – Nuclear Support Services

Enclosure: 10 CFR 50.55a Request

Commitments made in this letter: None.

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ENCLOSURE 1

<u>10 CFR 50.55a REQUEST IR-2-38</u>
<u>ALTERNATIVE BRAZED JOINT ASSESSMENT METHODOLOGY</u>

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

ENCLOSURE 1

10 CFR 50.55a REQUEST IR-2-38
ALTERNATIVE BRAZED JOINT ASSESSMENT METHODOLOGY

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ENCLOSURE 1

10 CFR 50.55a REQUEST IR-2-38
ALTERNATIVE BRAZED JOINT ASSESSMENT METHODOLOGY

1.0 ASME CODE COMPONENTS AFFECTED:

System:	Service Water (limited to portions with brazed joints)
Components	Brazed piping joints
Piping Size:	3 inches nominal size and smaller
ASME Code Class:	Class 3

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

2.0 APPLICABLE CODE EDITION AND ADDENDA

Millstone Power Station Unit 3 (MPS3) is currently in the second 10-year inservice inspection (ISI) interval, which started on April 23, 1999. The 1989 Edition of Section XI with No Addenda applies to the ISI program and its evaluations and the 1998 Edition of Section XI with No Addenda is used as the primary ASME Code Edition for the Section XI Repair / Replacement Program activities.

Original construction Code is ASME Code Section III, 1971 Edition with Summer 1973 Addenda.

3.0 APPLICABLE CODE REQUIREMENT

In the course of plant operation, brazed joints are sometimes observed to be leaking at a 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)]

If 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.

If discovered during a scheduled leak test, the joint must be evaluated and repaired in accordance with IWD-3000 as clarified by the following:

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

- IWD-3000 does not have acceptance criteria for Class 3 components and refers to IWB-3000 acceptance standards.

- IWB-3522.1 is the acceptance standard for visual examination, in which leakage of non-insulated and insulated piping is listed as a relevant condition. IWB-3522.1 states that such relevant conditions "... 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.

- 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 replacement."

4.0 REASON FOR THE REQUEST

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.

Dominion Nuclear Connecticut, Inc. (DNC) believes that a safe alternative to the requirement to immediately repair a brazed joint with leakage can include a deferred, but planned, repair or 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 and without unnecessary unavailability of safety related systems or components as well as unnecessary plant shutdowns.

5.0 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 and that account 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.

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 or replacement. 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 (2 and 3 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 the ones 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]

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

The examination technique has been documented in a MPS3 procedure[3] that is included for reference in Attachment E. The procedure requires that technicians be certified in accordance with ANSI / ASNT CP-189, 1991 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 1 inch apart. For the actual examination 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 Millstone UT procedure provides 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.[4] 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 requires this work to be performed by certified UT technicians, using calibrated equipment and approved couplants. It requires examination at multiple locations around the circumference of the fitting. It requires review of the data by a Level II or III technician. The UT procedure itself has been reviewed and approved by a Level III in accordance with DNC quality requirements.

Trial demonstrations of the procedure show that individual bond readings at a location on the fitting may vary but the average reading is consistent among qualified examiners.

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(3) MP-UT-45, "Ultrasonic Examination Procedure for Examination of Brazed Joints – Millstone Unit 3 Service Water Piping", Rev 000-00

(4) NAVSEA 0900-LP-001-7000, "Fabrication and Inspection of Brazed Piping Systems", dated January 1, 1973.

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,
- a 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-513-1 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 3 inch pipe, the maximum possible flow area would be nominally 0.28 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:

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

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 is less than the allowable ($S_{eq} < S_{max}(b_{adj})$), 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 11.0 ksi nominal pipe stress. The 11.0 ksi load capability is adequate for the design basis loads of this example since the joint load demand is only 4.4 ksi. Therefore, the example structural assessment concludes the joint can be left in service provided it is monitored until its permanent repair or replacement.

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 or replacement of the joint, or temporary non-Code repairs subject to

NRC review and approval may still be an option, consistent with considerations in Generic Letter 91-18 for the resolution of degraded and nonconforming conditions.

Basis for Comparison of an Adjusted to Required Bonding:

Brazed joints with reduced bond levels can retain a significant strength that is adequate for the structural integrity of the joint. DNC 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 well above that which would be predicted for a 5 ksi braze shear strength. This also confirms the conservatism of the 5 ksi maximum braze shear stress assumption that is used as an input to the Equation 3, shown in Figure 2.

With the adjustment of bond readings imposed by this methodology, and a joint load capacity that is based on a 5 ksi shear stress, 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.[5] Appendix F, paragraph F1331.1(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 $(1.5)(0.7S_u) = 1.05S_u$. These result in a maximum FS of 1.4 relative to ultimate strength. In shear across a section, paragraph F1331.1(d) limits shear to $0.42S_u$ for a FS of 1.37 relative to $(1 / \sqrt{3})S_u$. The 5 ksi shear limit used at the braze bond is well below this Appendix F limit of $0.42S_u$.

The ASME Code, Section XI permits acceptance of planar flaws for which Appendix C in paragraph C-3320(b) requires a safety factor of 1.39 for circumferential flaws, and paragraph C-3420(a) requires a safety factor of 1.50 for axial flaws, both for emergency and faulted loads. These same safety factors are

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

also permitted in Code Case N-513-1, 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 personnel are observant for signs of leakage. The monitoring will be by visual observation of the appearance of the joint and its leak rate. The frequency of the monitoring will be approximately once every three months, not to exceed 120 days between observations. 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 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. DNC believes 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 had two specimens that had already been removed from Millstone seawater service, and that were reported to have low bonding, disassembled and examined. The surface exam 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 or replacement activity can be planned, commensurate with safety, and in accordance with 10 CFR Part 50, Appendix B. Consistent with the Millstone Station Corrective Action Program, the permanent Code repair or 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. However, a time frame for repair or replacement that could exceed the next refueling outage interval will be explicitly justified in the operability determination depending on factors that can include the time required for design, review, approval, or procurement of materials, availability of equipment, or the need to be in a hot or cold shutdown mode to implement the action.

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 or replacement of the joint, or temporary non-Code repairs subject to NRC review and approval may still be an option, consistent with considerations in Generic Letter 91-18 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 Station Corrective Action Program. These include but are not necessarily 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 Generic Letter 91-18 for the resolution of degraded and nonconforming conditions. The permanent repair or 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. Selection of fewer than five joints for an augmented examination is acceptable if the population of similar joints not previously examined is fewer than five. If leakage is observed in similar joints, the resolution of each nonconforming condition will be evaluated in accordance with the Millstone 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-513-1). Augmented examinations provide information regarding the extent of condition being evaluated and are consistent with current Millstone Station procedures for responding to leakage in service water piping.

6.0 DURATION OF THE PROPOSED ALTERNATIVE:

This proposal requests approval for the use of an alternative brazed joint assessment methodology for the second 10-year Inservice Inspection (ISI) interval, which started on April 23, 1999, and is expected to be completed on October 23, 2008.

7.0 PRECEDENTS:

DNC is not aware of any precedents for the proposed alternative. The UT procedure for characterization of braze joint bond was developed and used by the U.S. Navy.(6)

ATTACHMENTS:

See Attachments A through E.

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(6) NAVSEA 0900-LP-001-7000, "Fabrication and Inspection of Brazed Piping Systems", dated January 1, 1973.

ENCLOSURE 1

ATTACHMENT A

FIGURES

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

ENCLOSURE 1

ATTACHMENT A

FIGURES

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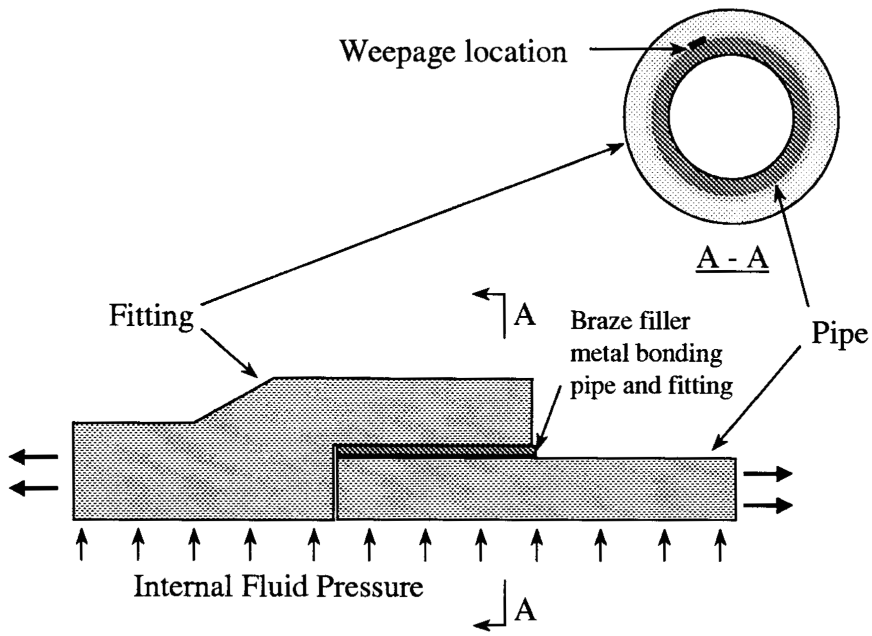


Figure 1: Typical Brazed Joint Configuration

$$S_{eq} < S_{max}(b_{adj}) \qquad (1)$$

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

S_{lp} = longitudinal pressure stress

S_{dl} = deadload stress — Unintensified pipe stresses from Code qualification analysis

S_{sse} = SSE seismic stress

S_{dyn} = dynamic stress (if defined)

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

D = pipe outside diameter

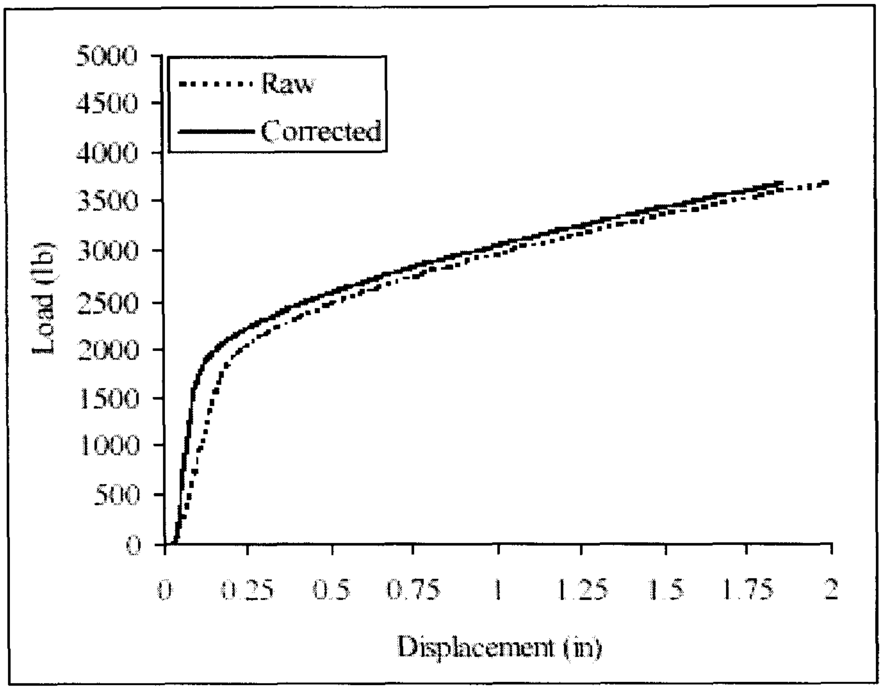
L_{ins} = insert depth of fitting socket excluding any insert groove

Z_{pipe} = piping section modulus

τ_{max} = 5000 psi (maximum braze shear stress)

b_{adj} = adjusted effective bond

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



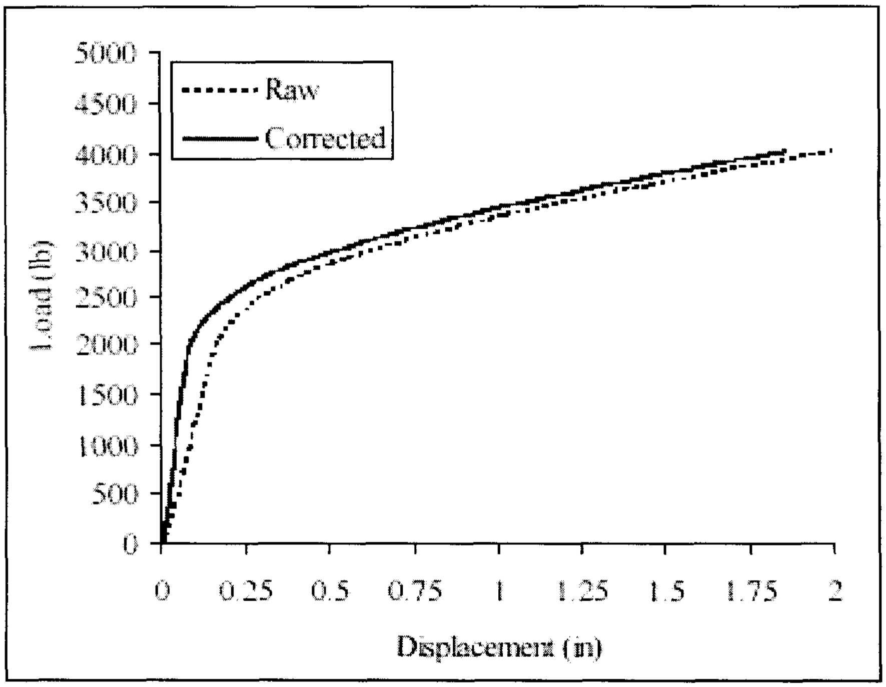


Figure 3: Two Inch Couplings: Fabricated Samples at (a) 30% (above) and (b) 60% bond

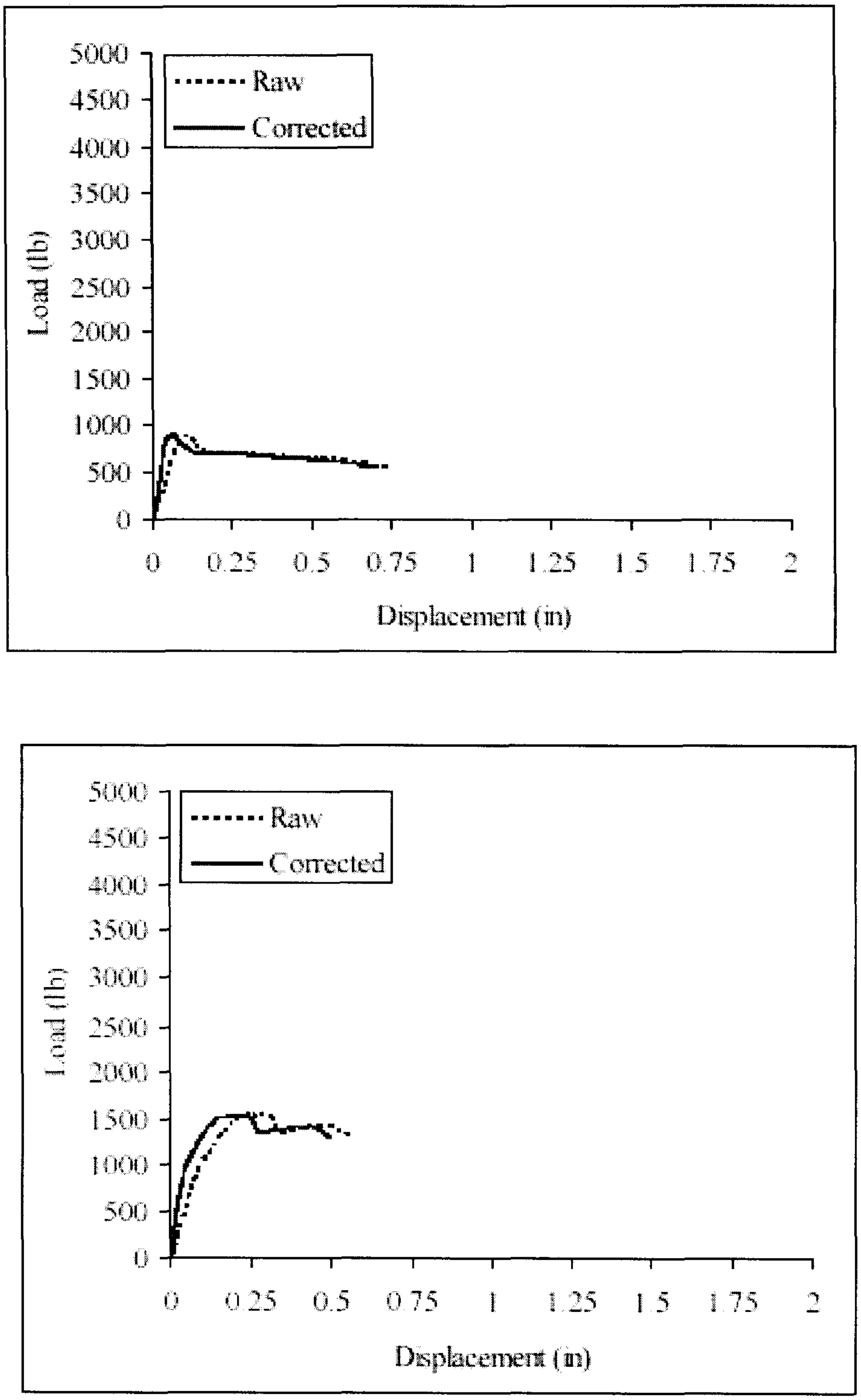


Figure 4: Two Inch Joints: Two Fabricated Samples with 12% Bond

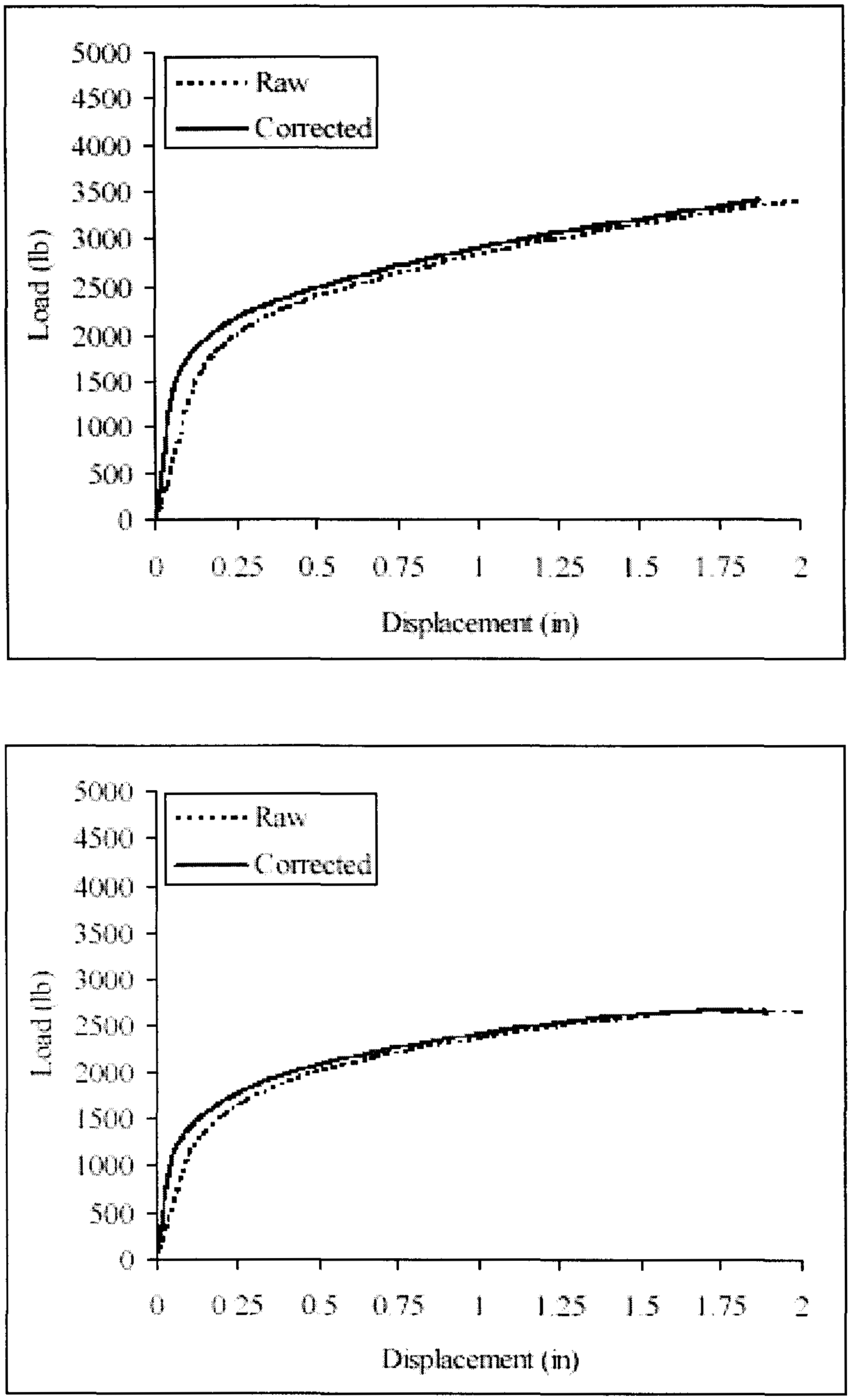


Figure 5: Arc Segment Disbondment, (a) 90 (above) and (b) 126 Degrees Arc

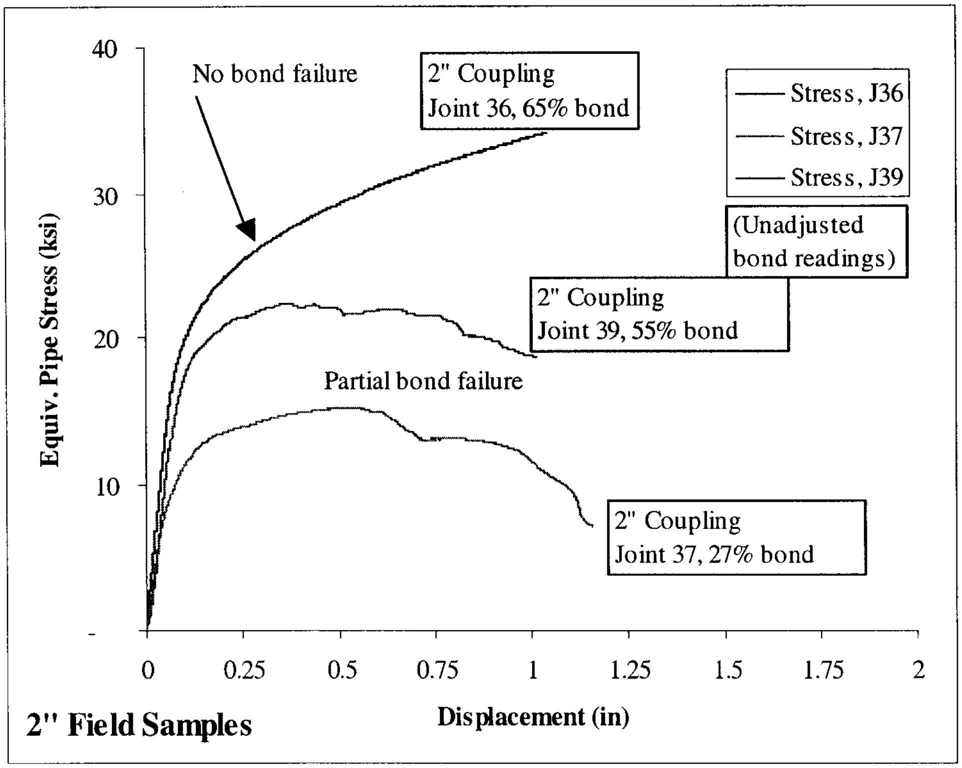


Figure 6: Two Inch Braze Field Sample Test Curve

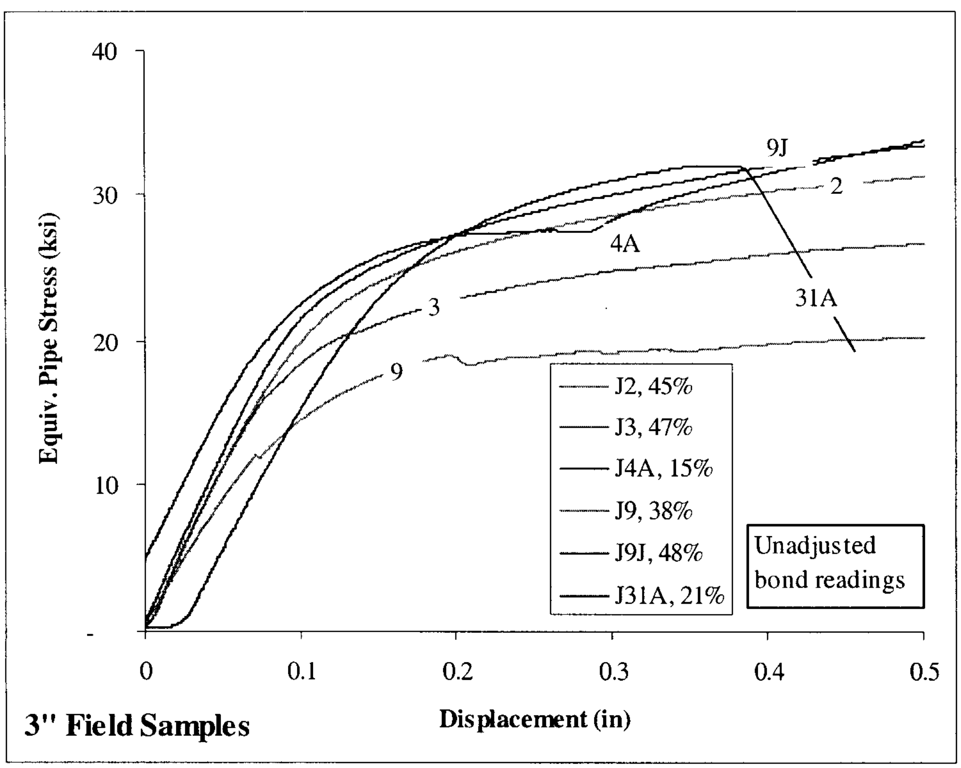


Figure 7: Three Inch Braze Field Sample Test Curve

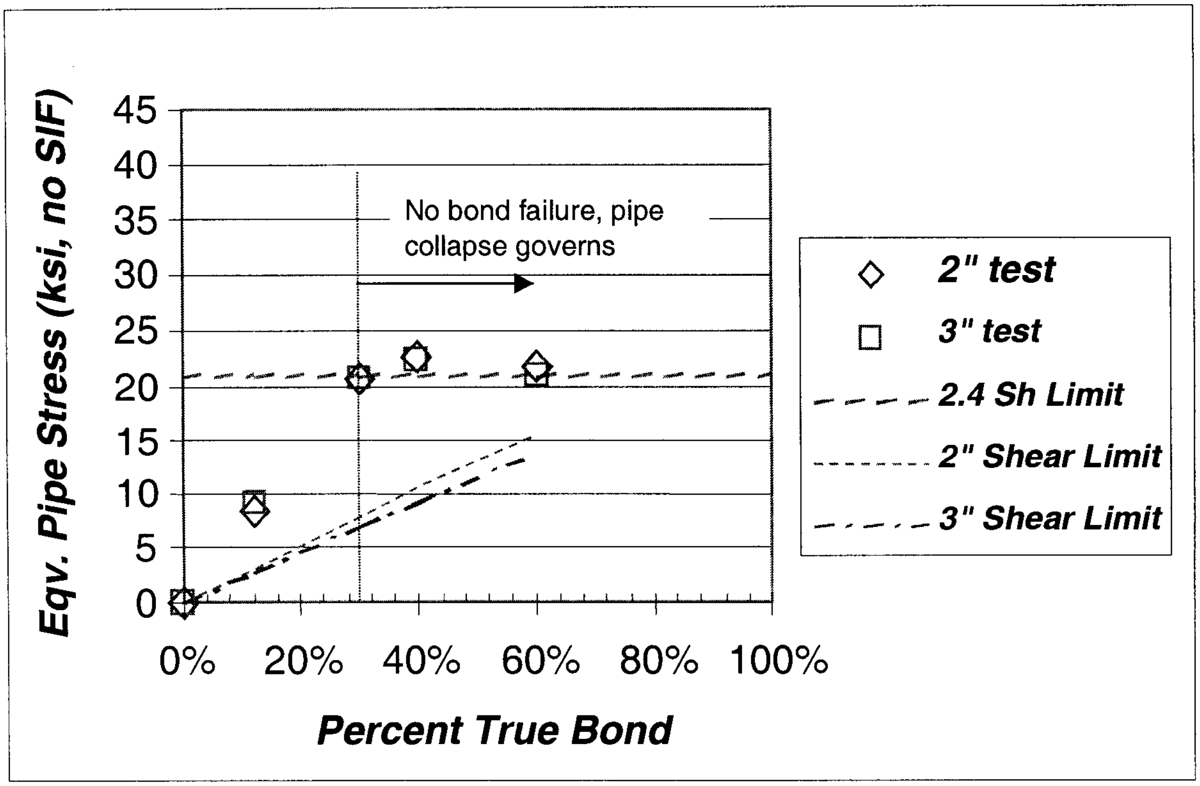


Figure 8: Test Results for Specially Fabricated Joints

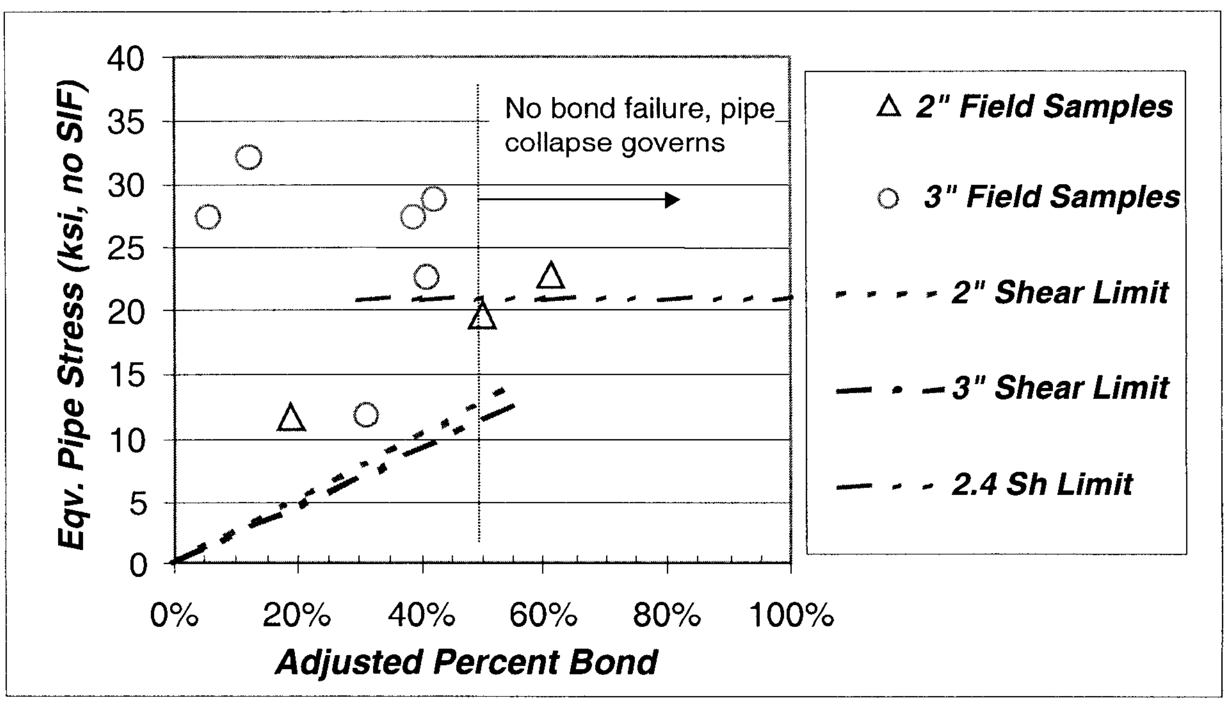


Figure 9 - Test Results for Joints Removed From Service

ENCLOSURE 1

ATTACHMENT B

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, BAg-1a, or BAg-7. Construction Code minimum properties of the piping and fitting materials are:

Material	Item	Sh, 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.[7]

> *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.*

---

(7) Crocker and King, *Piping Handbook*, 5th Edition, McGraw-Hill Book Company, page 7-212

For the standard braze joint fittings used at MPS3, the joint overlap is about four to one. The smallest overlap occurs in a 3 inch joint, with an overlap length of 3.6 times pipe wall thickness.

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 still 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-513-1 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.

ENCLOSURE 1

ATTACHMENT C

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:
Line No:	3SWP-002-999-3
Sys Function:	A supply to XXX-1A
Piping Iso:	CP-0123456
Joint:	1A
Side of Joint:	Upstream
Jt. Orientation:	Mark 1 is up

	inputs:
Pipe Dia	2.375 in
Nom. Wall Thk	0.156 in
Pipe Mat'l	SB 466 CDA 706
Fitting Mat'l	SB 61or 62
Ref. Bond Strength:	5,000 psi
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

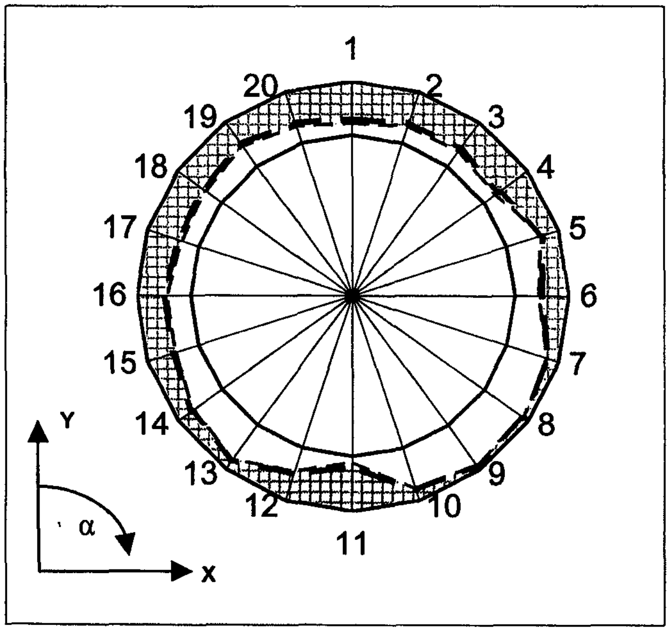
Offsets based on adjusted bond:

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 adusted 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
Smax(100%)	25,662	psi

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	14,997	13,746	psi
Syy	12,538	10,975	psi
Sallow	12,538	**10,975**	**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	NP-X1901
Rev / CCN	Rev. 5 CCN 4
Line No:	3SWP-002-999-3
Sys Function:	A supply to XXX-1A
Piping Iso:	CP-0123456
Joint:	1A

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^2

inputs:

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

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

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

inputs:

Design Pressure	100	psig
Max Op. Pressure	100	psig
Slp	761	psi
Eq. 8 (P+DL)	2500	psi
Eq. 9 (N/U)	4500	psi
Eq. 9F (Design Basis0	6500	psi

Calculated Nominal Stresses

Sp_offset	75	psi
Sust'd 8'	1830	psi
N/U 9'	3100	psi
Faulted 9F'	4370	psi
Max Nominal	**4370**	psi

Part 5 Structural Integrity Determination Joint 1A

Joint Load Capability	10,975	psi	(from Part 3)
Design Basis Load	4,370	psi	(from Part 4)

Check: **4,370 < 10,975 ===> 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	5.840
	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

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

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

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

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

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

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

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

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

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

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

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

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

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

Angle	Adj. Bond	cos(theta)	db*cos	db*cos^2	db*sin*cos	sin(theta)	db*sin	db*sin^2
0	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%

ENCLOSURE 1

ATTACHMENT D

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.

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 2-inch and for 3-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 arc, ranged from 90 percent down to 65 percent, respectively.

2.3 Field Sample Piping Joints:

These joints were salvaged from piping that were 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
2 inch couplings	3
3 inch couplings	2
3 inch tee (run sides)	1
3 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.

4.0 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.

4.1 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 still 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.

4.2 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.

4.3 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	9.5	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 are 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.

ENCLOSURE 1

ATTACHMENT E

ULTRASONIC TEST PROCEDURE

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. 000-00

Approval Date: 11/17/04

Effective Date: 11/24/04

STOP THINK ACT REVIEW

Level of Use
Reference

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 is to be used for Engineering information only until such time as NRC approval is obtained.

1.2.2 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 In addition, the 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.

2.3 **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:

% bond = <u>100 (bond amplitude</u>
(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 The appropriate supervisor shall enter the Exam Data Sheet No. (if applicable).

5.3 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.

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

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

5.3.3 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

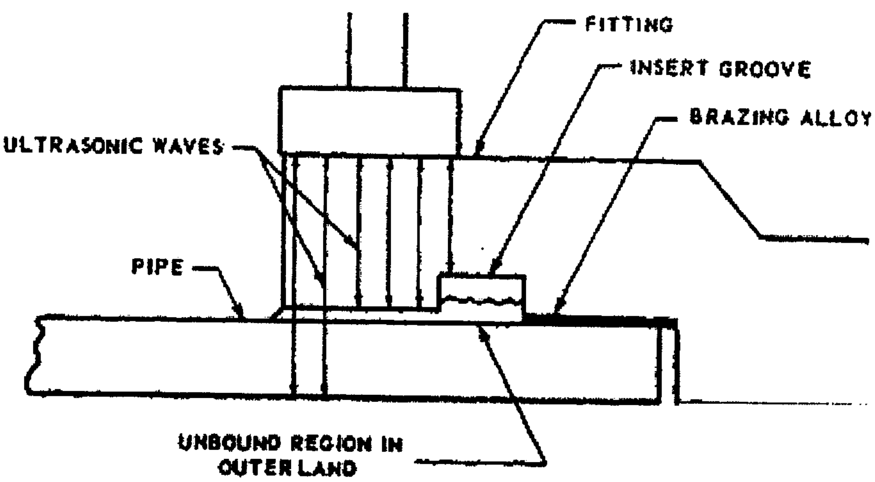
6.1 ANSI/ASNT CP-189, 1991 Edition

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

7. SUMMARY OF CHANGES

7.1 Initial Issue

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 ______

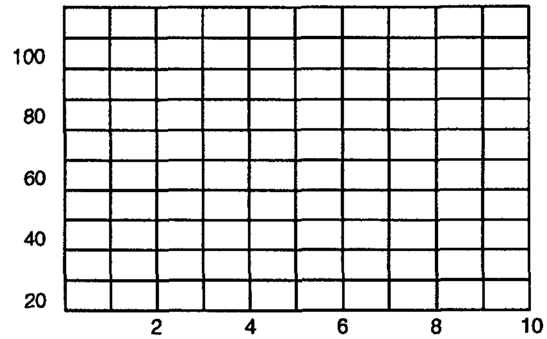
AWO Number: ________________________________

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 ______________