June 2, 2005

Mr. Jerald S. Holm
Director, Regulatory Affairs
Attn: Ronnie L. Gardner
3815 Old Forest Rd.
Lynchburg, VA 24501

SUBJECT: DRAFT SAFETY EVALUATION FOR TOPICAL REPORT (TR) BAW-2308, REVISION 1, "INITIAL RT_{NDT} OF LINDE 80 WELD MATERIALS" (TAC NO. MB6336)

Dear Mr. Holm:

On July, 26, 2002, Babcock and Wilcox Owners Group (B&WOG) submitted TR BAW-2308, Revision 1, "Intial RT_{NDT} Linde 80 Weld Materials," to the Nuclear Regulatory Commission (NRC) staff for review. Enclosed for the B&WOG review and comment is a copy of the NRC staff's draft safety evaluation (SE) for the TR.

Twenty working days are provided to you to comment on any factual errors or clarity concerns contained in the SE. The final SE will be issued after making any necessary changes and will be made publicly available. The NRC staff's disposition of your comments on the draft SE will be discussed in the final SE.

To facilitate the NRC staff's review of your comments, please provide a marked-up copy of the draft SE showing proposed changes and provide a summary table of the proposed changes.

If you have any questions, please contact Mr. Drew G. Holland at 301-415-1436.

Sincerely,

/RA/
Robert A. Gramm, Chief, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 693

Enclosure: Draft SE

cc w/encl: See next page

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cc:
Mr. Howard C. Crawford
AmerGen Energy Company
Route 441 South
P.O. Box 480
Middletown, PA 17057-0480

Mr. David J. Firth
Manager, B&W Owners Group Services
Framatome ANP
3315 Old Forest Road
Lynchburg, VA 24501

Mr. W. R. McCollum, Chairman
B&WOG Executive Committee
Duke Energy Corporation
Oconee Nuclear Station
MC ONO 1VP
7800 Rochester Highway
Seneca, SC 29672

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

FOR TOPICAL REPORT (TR) BAW-2308, REVISION 1,

"INITIAL RT_{NDT} OF LINDE 80 WELD MATERIALS"

BABCOCK AND WILCOX OWNERS GROUP

PROJECT NO. 693

1.0 INTRODUCTION

By letter dated July 26, 2002 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML022200546), Babcock and Wilcox Owners Group (B&WOG) submitted TR BAW-2308, Revision 0, “Initial RT_{NDT} of Linde 80 Weld Materials,” for Nuclear Regulatory Commission (NRC) staff review. The intent of the TR is to establish an alternative method for determining initial, unirradiated material reference temperatures for reactor pressure vessel (RPV) welds manufactured using Linde 80 weld flux (i.e., “Linde 80 welds”) and to establish weld wire heat-specific and Linde 80 weld generic values of this reference temperature. These weld wire heat-specific and Linde 80 weld generic values would be used in lieu of the nil-ductility reference temperature (RT_{NDT}) parameter, the determination of which is specified by Paragraph NB-2331 of Section III of the American Society for Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code).

By facsimile dated April 11, 2003, the NRC staff issued a request for additional information (RAI) regarding BAW-2308. The B&WOG responded to the staff’s RAI by letter dated August 19, 2003 (ADAMS Accession No. ML032380449). In the response, the B&WOG withdrew TR BAW-2308, Revision 0, provided answers to the staff’s RAI questions, and submitted for review TR BAW-2308, Revision 1, which incorporated the substantive changes resulting from the staff’s RAI. In addition, by letters dated June 30, 2004 (ADAMS Accession No. ML041880201) and March 25, 2005 (ADAMS Accession No. ML051320232), B&WOG provided information modifying the proposal outlined in TR BAW-2308, Revision 1.

2.0 REGULATORY EVALUATION

The determination of RPV material properties impacts regulations associated with the protection of the RPV from brittle failure or ductile rupture. These regulations include Appendix G to Part 50 of Title 10 of the *Code of Federal Regulations* (10 CFR) and 10 CFR 50.61, the pressurized thermal shock (PTS) rule. Appendix G to 10 CFR Part 50 and 10 CFR 50.61 require that the initial, unirradiated material reference temperature, RT_{NDT}, be determined in accordance with the provisions of ASME Code, Section III, Paragraph NB-2331. The determination of RT_{NDT} per ASME Code, Section III, Paragraph NB-2331 requires the performance of drop weight testing in accordance with American Society for Testing and Materials (ASTM) Standard Test Method E 208, "Standard Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels", and Charpy V-notch impact testing in accordance with ASTM Standard Test Method E 23, "Standard Test Methods for Notched Bar Impact Testing of Metallic Materials." Guidance provided in NRC Standard Review Plan Section 5.3.1, "Reactor Vessel Material," and Branch Technical Position MTEB 5-2, "Fracture Toughness Requirements," also reflect this dependence on drop weight and Charpy V-notch impact testing. In addition, regarding the implementation of alternatives to the requirements of Appendix G to 10 CFR Part 50, 10 CFR 50.60 states, "Proposed alternatives to the described requirements in Appendices G and H of this part or portions thereof may be used when an exemption is granted by the Commission...."

3.0 TECHNICAL EVALUATION

3.1 B&WOG Evaluation - General Description

In TR BAW-2308, Revision 1, the B&WOG proposed to perform fracture toughness testing based on the application of the "Master Curve" evaluation procedure, which permits data obtained from sample sets tested at different temperatures to be combined, as the basis for redefining the initial, unirradiated material properties of Linde 80 welds. Guidelines for the application of the Master Curve evaluation methodology used in TR BAW-2308, Revision 1 were given in the 1997 and 2002 Editions of ASTM Standard Test Method E 1921 (ASTM E 1921) "Standard Test Method for Determination of Reference Temperature, T_0, for Ferritic Steels in the Transition Range." Additional guidance on the application of reference temperature values based on Master Curve evaluation to the establishment of RPV material properties for regulatory applications was provided by ASME Code Case N-629, "Use of Fracture Toughness Test Data to Establish Reference Temperature for Pressure Retaining Materials of Section III, Division 1, Class 1." The B&WOG's motivation for pursuing this option of using a Master Curve-based approach to evaluate Linde 80 welds is related to the fact that, due to their generally low Charpy V-notch upper shelf energy behavior, the testing specified in ASME Code, Section III, Paragraph NB-2331 has been shown to be overly conservative when used to predict the transition from ductile to brittle failure in Linde 80 welds.

Fundamentally, the proposal by the B&WOG was that the testing of fracture toughness specimens, including compact tension (CT) specimens ranging in size from 0.5 inch thickness CTs (0.5T-CTs) to 2T-CTs and precracked Charpy-sized bend specimens (PCCS), could be used in lieu of "indirect" tests of fracture toughness (drop weight and Charpy V-notch tests) to establish acceptable initial, unirradiated material properties of Linde 80 welds. A reference temperature, T_0, would be derived from the testing of sets of 6 or more fracture toughness specimens for a given material, in this case, a Linde 80 weld made from a specific weld wire heat. The value of T_0 would be determined based on the application of ASTM Standard Test Method E 1921, and T_0 would be statistically related to the temperature at which fracture toughness specimens from a given weld wire heat exhibited a median fracture toughness of 100 Mega Pascals-square-root-meter (MPa / m) which is equivalent to 90 thousand pounds per square inch-square-root-inch (ksi / in). Proposed adjustments to the determined values of T_0 for each weld wire heat were then made to account for loading rate effects and PCCS bend specimen bias, when appropriate. An initial, unirradiated material reference temperature, IRT_{T0} (initial reference temperature based on T_0), would then be calculated per ASME Code Case N-629 using the adjusted values of T_0 as:

[Eqn. 1] $$IRT_{T0} = T_0 + 35\ \text{EF}$$

Statistical uncertainty in the values of T_0 (denoted as σ) due to the number of specimens tested was also determined as:

[Eqn. 2] $$\sigma = \beta / \quad / N$$

where β is implicitly related to the difference between the specimen test temperature and the value of T_0 and N is the number of specimens tested. In addition, contributions to material property uncertainty due to material variation and testing laboratory were evaluated by Monte Carlo simulation. All of the data for a Linde 80 weld wire heat was pooled and sample data sets selected to generate a distribution of T_0 values from which a standard deviation could be defined. The uncertainty contributions based on the sample size calculation and Monte Carlo results were then combined via a square-root-sum-of-squares method to determine a final value (σ_I) for the uncertainty associated with the heat-specific value of IRT_{T0}.

Tests from all available Linde 80 weld wire heats would then be combined to define “generic” values of IRT_{T0} and σ_I in a process equivalent to that which was used for each individual Linde 80 weld wire heat. These generic values would be assumed to be applicable for weld wire heats for which no weld wire specific values were generated.

A more detailed account of the Master Curve methodology is also given in Appendices A and B of TR BAW-2308, Revision 1.

3.2 Framatome ANP Evaluation - Data Analysis

Fracture toughness specimen test data from a variety of sources were available for seven Linde 80 weld wire heats: 406L44, 71249, 72105, 821T44, 299L44, 72442, and 72445. The material samples from weld wire heat 406L44 were acquired via the Oconee Nuclear Station (Oconee) Unit 1 and Rancho Seco Nuclear Generating Station reactor vessel surveillance programs. The material samples from weld wire heat 71249 were acquired via the Turkey Point Plant (Turkey Point) Unit 4 reactor vessel surveillance program. The material samples from weld wire heat 72105 were acquired from the beltline and nozzle dropouts from the canceled Midland (Midland) Unit 1. The material samples from weld wire heat 821T44 were acquired via the Davis-Besse Nuclear Power Station reactor vessel surveillance program. The material samples from weld wire heat 299L44 were acquired from Crystal River Nuclear Generating Plant (Crystal River) Unit 3 and Oconee Unit 3 nozzle dropouts as well as the 63W weld fabricated for Oak Ridge National Laboratory. The material samples from weld wire heat 72442 were acquired from Crystal River Unit 3 Nuclear Generating Plant and Midland Unit 1 nozzle dropouts. The material samples from weld wire heat 72445 were acquired from Arkansas Nuclear One Unit 1 nozzle dropouts. An accounting of the number of specimens of varying sizes and types is given in Table 1 below for each weld wire heat. A more detailed list of the available fracture toughness data sets, on a data point-by-data point basis, from the testing of unirradiated samples of Linde 80 welds is given in Appendix C to TR BAW-2308, Revision 1. Generally, the test data for each weld wire heat had been generated at more than one test temperature. Therefore, to make the use of the largest volume of data possible, the B&WOG made use of the “multi-temperature” Master Curve methodology documented in the 2002 Edition of ASTM E 1921, with one exception. The multi-temperature Master Curve methodology permits data from more than one test temperature to be combined in order to determine T_0 for a material. The exception that the B&WOG took to the multi-temperature Master Curve methodology in the 2002 Edition of ASTM E 1921 was with regard to the formula for converting between the fracture toughness parameters J (the J-integral of elastic-plastic fracture mechanics) and K_{JC} (linear elastic fracture mechanics fracture toughness). The 2002 Edition of ASTM E 1921 permits the use of a plane strain-based formulation for effecting this conversion while the 1997 Edition specifies the use of a slightly more conservative plane stress-based formulation. For TR BAW-2308, Revision 1 analysis, the B&WOG elected to use the plane stress-based conversion from the 1997 Edition of ASTM E 1921.

**Table 1 - Distribution of Specimens for Each Linde 80 Weld Wire Heat-
Table Developed by NRC Staff**

Weld Wire Heat	Specimen Type	Number of Specimens	Total Number of Specimens for Weld Wire Heat
299L44	0.5T-CT	12	42
	PCCS	30	
406L44	0.5T-CT	25	43
	PCCS	18	
71249	PCCS	11	11
72105	4T-CT	2	148
	2T-CT	14	
	1T-CT	78	
	0.5T-CT	21	
	PCCS	33	
72442	PCCS	17	24
	“Various” CTs	7	
72445	PCCS	22	22
821T44	0.5T-CT	18	24
	PCCS	6	

In addition to being generated at different temperatures, the data used in TR BAW-2308, Revision 1 were also generated at various loading rates within the regime classified as “quasi-static testing.” The range of loading rates associated with the Linde 80 weld tests was from about 0.21 MPa / m/s to 2.55 MPa / m/s. Based upon Master Curve results for a variety of ferritic RPV materials, a linear relationship between T_0 values and the natural logarithm of the loading rate was established to normalize the data to a loading rate of 1 MPa / m/sec:

[Eqn. 3] T_0 (@ 1 MPa / m/s) = T_0 (@ X MPa / m/s) + 5.33 *ln*(1 MPa / m/s ÷ X MPa / m/s)

The B&WOG demonstrated that this relationship could be used to adjust test temperature associated with each data point (test temperature and T_0 are related in such a way as to make this a reasonable method of adjusting for loading rate and other effects) prior to applying the multi-temperature Master Curve to determine final T_0 values for each heat of material. It should be noted, however, that the final RT_{T0} values recommended by Framatome ANP in BAW-2308, Revision 1 did not include this loading rate correction.

A specimen geometry correction was also applied to the fracture toughness data generated from PCCS specimens. A substantial amount of work has been completed recently to compare the Master Curve methodology results obtained from similar sized CT and bend specimens. As noted in a paper presented at the 2000 ASME Pressure Vessel and Piping Conference entitled, "T_0 Evaluation in Common Specimen Geometries," by Tregoning and Joyce, there may be a systematic, non-conservative bias in the T_0 values generated by the use of PCCS specimens when compared to those generated by CT specimens. The numerical value of this systematic bias may be about 18 EF. The B&WOG elected to address this bias by again adjusting the test temperature associated with each data point. This adjustment to correct for the use of PCCS specimen data was applied to each data set in a pointwise fashion prior to applying the multi-temperature Master Curve to determine final T_0 values for each heat of material.

In addition, by letter dated March 25, 2005, the B&WOG elected to conservatively include an additional 20 EF in the calculation of the Linde 80 weld generic value of IRT_{T0} to resolve potential concerns over whether this generic value would be adequately bounding. A detailed discussion of the basis for this modification to TR BAW-2308, Revision 1 is provided in the B&WOG's March 25, 2005, letter.

Based on the data analysis procedure outlined above and Eqn. 1, the B&WOG proposed in TR BAW-2308, Revision 1 that the following values be used to characterize the initial properties and associated uncertainties for Linde 80 welds (as modified by the aforementioned March 25, 2005 letter):

Table 2 - Proposed IRT_{T0} and σ_I Values for Linde 80 Weld Wire Heats

Linde 80 Weld Wire Heat	IRT_{T0} (EF)	Initial Margin, σ_I (EF)
406L44	-103.6	12.1
71249	-62	13
72105	-29.1	13.3
821T44	-90.8	10
299L44	-78.8	12
72442	-37.8	11.9
72445	-73.2	11.9
All Heats (Generic Value)	-47.9[1]	20.1

[1] Includes additional 20 EF correction proposed in March 25, 2005 letter.

3.3 Other Elements of the Framatome ANP Methodology

Given the method proposed by the B&WOG for determining Linde 80 weld unirradiated, initial material property values, the B&WOG also addressed other issues regarding how these values could be used by licensees. In particular, the B&WOG provided a basis for determining whether it would be appropriate to use material property changes based on the shift in Charpy V-notch 30 foot-pound (ft-lb) energy (ΔT_{30}) models with IRT_{T0} values based on fracture toughness data. This concern arises because, as opposed to the Master Curve-based approach used by

Kewaunee Nuclear Power Plant which was approved by the NRC staff in 2001, the B&WOG methodology does not rely on obtaining fracture toughness measurements in the irradiated condition for the purpose of monitoring changes due to irradiation.

To begin, the B&WOG cited work performed by the NRC's Office of Nuclear Regulatory Research (RES) which examined a large database of materials for which ΔT_{30} and the shift in Master Curve reference temperature (ΔT_0) existed (data to establish T_0 values based on irradiated Linde 80 weld specimen testing was included in Appendix D of TR BAW-2308, Revision 1). The RES work showed that for welds, including Linde 80 weld data, a linear relationship could be drawn between these two values:

[Eqn. 4] $$\Delta T_0 = 0.99 * \Delta T_{30}$$

and the standard deviation of the residuals between the ΔT_0 data and the ΔT_0 vs. ΔT_{30} regression line was 25.6 EF (see Figure 1).

The B&WOG performed a similar analysis for 12 Linde 80 weld data pairs. The correlation for the Linde 80 welds (see Figure 2) was:

[Eqn. 5] $$\Delta T_0 = 0.92 * \Delta T_{30}$$

Therefore in either case, on average, ΔT_{30} test data overpredicted ΔT_0 test data. Based on this information, the B&WOG concluded that the shift models in Regulatory Guide (RG) 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," which were developed based on $\Delta T_{30,}$ would continue to be adequate when combined with initial properties indexed to Master Curve T_0 values.

Finally, the B&WOG examined whether the shift model uncertainty (σ_Δ = 28 EF) from RG 1.99, Revision 2 was adequate when combined with initial properties based on T_0 values and material property shifts based on the RG 1.99, Revision 2, models. To do this, the B&WOG plotted the ΔT_0 values as a function of fluence for the 13 Linde 80 weld samples which had been tested in the irradiated condition. A RG 1.99, Revision 2 shift trend curve based on a chemistry factor of 167 EF (related to the average copper and nickel contents of Linde 80 welds) was plotted, along with curves representing the $+2\sigma_\Delta$ and $-2\sigma_\Delta$ bounds on the model (see Figure 3). This plot demonstrated that all of the Linde 80 weld ΔT_0 data points were bounded by the $+2\sigma_\Delta$ curve. Since the use of the RG 1.99, Revision 2 model with the $+2\sigma_\Delta$ margin bounds the Linde 80 weld ΔT_0 data points, B&WOG concluded that it is acceptable to use IRT_{T0} values with RG 1.99, Revision 2 embrittlement model predictions and a σ_Δ value of 28 EF as the "overall method" for implementing TR BAW-2308, Revision 1.

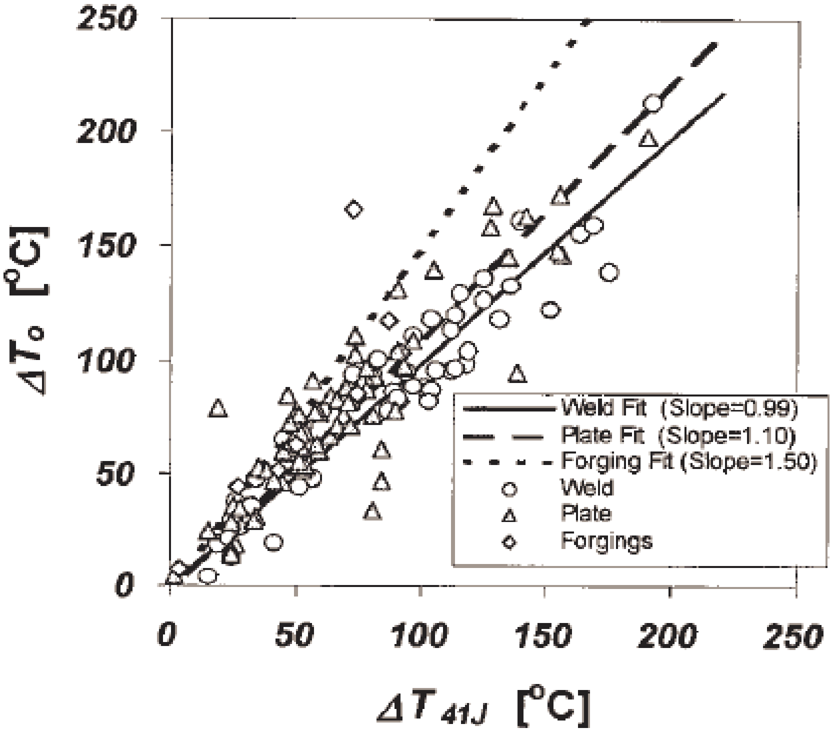

Figure 1 - Correspondence of ΔT_0 to $\Delta T_{30\ \text{ft-lbs}}$ (i.e., ΔT_{41J}) for RPV Welds, Plates, and Forgings

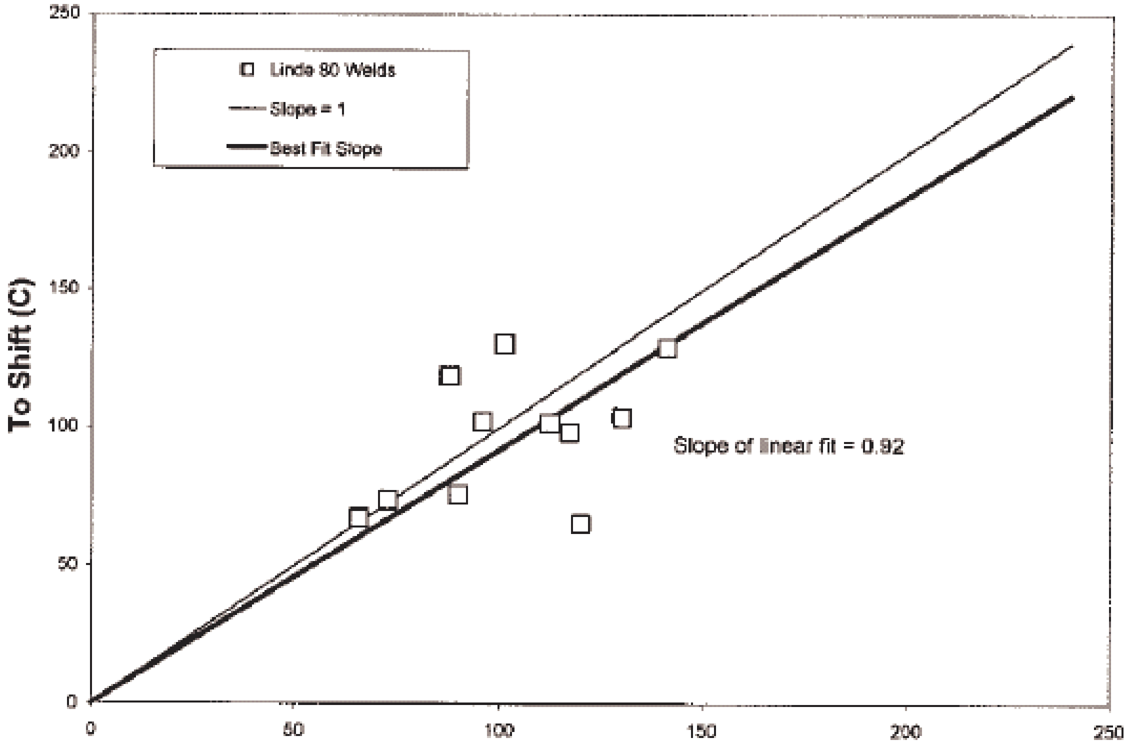

Figure 2 - Correspondence of ΔT_0 to $\Delta T_{30 \text{ ft-lbs}}$ For Linde 80 Welds

3.4 NRC Staff Evaluation

The NRC staff evaluated the methodology proposed by the B&WOG for determining Linde 80 weld initial, unirradiated material properties and the uncertainty in those properties. Further, the NRC staff reviewed the "overall method" proposed by the B&WOG for combining: (1) initial, unirradiated material property measurements based on T_0 values, (2) property shifts from models in RG 1.99, Revision 2 which are based on Charpy V-notch impact testing, and (3) a defined margin term to account for uncertainties.

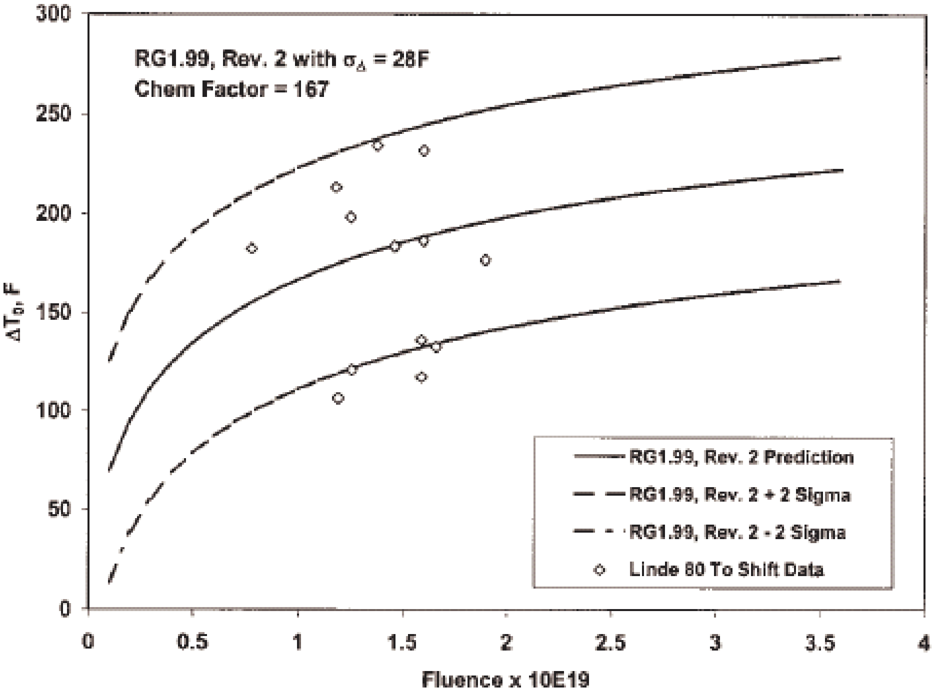

Figure 3 - Correlation of ΔT_0 data with Regulatory Guide 1.99, Revision 2 Prediction + Margin

3.4.1 Evaluation of BAW-2308, Revision 1 Database

The NRC staff reviewed the data base of unirradiated and irradiated fracture toughness test data from Linde 80 weld samples. Using an NRC RES database, the staff confirmed that there were no Linde 80 data known to the NRC staff which were not included in the B&WOG's TR BAW-2308, Revision 1 analysis. The NRC staff also confirmed that all of the available data were used in the TR BAW-2308, Revision 1 analysis, as appropriate, to establish Linde 80 weld wire heat-specific values of IRT_{To} as well as the Linde 80 generic values of IRT_{T0} shown in Tables 2 and 3 of this SE. This was consistent with the NRC staff's expectation that the use of all available data will provide the most accurate characterization of RPV material properties.

However, the B&WOG stated in their August 19, 2003, RAI response that fracture toughness data from one more heat of Linde 80 weld material are to be obtained (weld wire heat 61782). The NRC staff expects Framatome ANP to evaluate these data to determine whether or not the conclusions of TR BAW-2308, Revision 1 are non-conservative, and to communicate the B&WOG's conclusion to the NRC staff. Non-conservatism in TR BAW-2308, Revision 1 report would be evident if: (1) the IRT_{T0} value from the to-be-tested Linde 80 weld wire heat turns out to be higher than the generic IRT_{T0} value approved in this safety evaluation (SE), or (2) if the data from the to-be-tested Linde 80 weld wire heat results in an increase in the Linde 80 generic σ_I value.

3.4.2 Evaluation of BAW-2308, Revision 1 Methodology

The NRC staff evaluated the B&WOG's methodology for evaluating the available Linde 80 weld fracture toughness data. The NRC staff concluded that the use of the provisions from the 1997 and 2002 Editions of ASTM E 1921 as specified in Section 3.2 of this SE was acceptable. The NRC staff also concluded that the B&WOG's decision to apply a correction factor equivalent to a bias of 18 °F to the data obtained from PCCS specimens was consistent with the best current information on the differences between PCCS specimen and CT specimen test results. This bias factor applied to PCCS specimens was conservative (i.e., greater than) when compared to a similar bias factor that the NRC staff required be applied to support approval of the Kewaunee Master Curve-based approach in May 2001. By including this bias term, the NRC staff has concluded that results of the B&WOG analysis will be accurate or conservative with respect to the characterization of RPV weld material properties as far as specimen geometry effects are concerned.

The NRC staff evaluated the loading rate correction proposed by the B&WOG to adjust all of the available Linde 80 weld test data to a common loading rate of 1 MPa√m/sec. Based on known principles of fracture toughness testing, an effect of loading rate would be expected when comparing quasi-static and dynamic test data. The data provided by the B&WOG suggest that some loading rate effect does occur based on tests run at loading rates of 1 MPa√m/sec or less (quasi-static) and 10000 MPa√m/sec or more (dynamic) for a variety of materials, with the apparent effect for each tested material being slightly different. However, over the reduced range of loading rates addressed in TR BAW-2308, Revision 1 (0.21 MPa√m/s to 2.55 MPa√m/s) the staff has determined that the information provided is inconclusive with respect to establishing an unambiguous loading rate correction which should be applied to Linde 80 weld materials. Further, no action has yet been taken by the appropriate consensus codes and standards organizations (ASME, ASTM) to address the need for a loading rate correction over the range of rates applicable to the data in TR BAW-2308, Revision 1.

However, the NRC staff also noted that, in general, the application of the loading rate correction proposed by the B&WOG resulted in IRT_{T0} values which were more conservative than those determined without application of the loading rate correction. Therefore, at this time, the staff concludes that there is reasonable assurance that the use of IRT_{T0} values for Linde 80 weld materials which were determined using the proposed loading rate correction are acceptable for the purpose of RPV material property determination. These values, along with corresponding σ_I values, are given in Table 3. The staff also expects that action will be pursued within the appropriate consensus codes and standards organizations to address loading rate effects on a more generic basis (or determine that they do not need to be addressed) in the appropriate ASME Code Cases and/or ASTM Standard Test Methods. The staff requests that the B&WOG revise the recommended values in TR BAW-2308, Revision 1 in accordance with Table 3. When consensus codes and standards organizations address loading rate effects on a more generic basis, the staff also expects that the B&WOG will re-evaluate TR BAW-2308, Revision 1 to determine whether or not revision of the TR is warranted.

Table 3 - NRC Staff-Accepted IRT_{T0} and σ_I Values for Linde 80 Weld Wire Heats

Linde 80 Weld Wire Heat	**IRT_{T0} (EF)**	**Initial Margin, σ_I (EF)**
406L44	-94.9	11
71249	-47.4	12.9
72105	-32.7	11.8
821T44	-80.2	9.3
299L44	-81.8	11.6
72442	-30	11.9
72445	-72.5	12.3
All Heats (Generic Value)	-47.61[1]	17.2

[1] Includes additional 20 EF correction proposed in March 25, 2005 letter.

In summary, the NRC staff determined that the B&WOG methodology, utilizing the provisions from the 1997 and 2002 Editions of ASTM E 1921 as specified in Section 3.2 of this SE, a correction factor equivalent to a bias of 18 EF to the data obtained from PCCS specimens, and the loading rate correction for Linde 80 welds addressed in TR BAW-2308, Revision 1, represents an acceptable methodology for establishing weld wire heat specific and generic IRT_{T0} values for Linde 80 welds.

3.4.3 Evaluation of Weld Wire Heat Specific and Generic Linde 80 Weld Results

Based on the TR BAW-2308, Revision 1 methodology as summarized in Section 3.4.2 of this SE, the NRC staff reviewed the values given in Table 2 of this SE. Using the TR BAW-2308, Revision 1 methodology, the NRC staff performed a limited number of independent check calculations based on the information provided in TR BAW-2308, Revision 1 and got results which were consistent with those reported by the B&WOG (i.e., within calculational roundoff error). The NRC staff also performed independent calculations to confirm that the B&WOG approach to adjusting the data for loading rate and PCCS bias effects was acceptable (i.e., the NRC staff tried adjusting the data in other ways and concluded that the B&WOG approach resulted in equivalent or conservative results). Based on this assessment, the NRC staff concluded that the Linde 80 weld wire heat specific and generic IRT_{T0} and σ_I values cited in Table 3 of this SE are acceptable for the purpose of determining unirradiated, initial RPV material properties for the purpose of RPV integrity evaluations.

3.4.4 Evaluation of Other Elements of the B&WOG Methodology

Based on the NRC staff's acceptance of the IRT_{T0} and σ_I values from Table 3 of this SE, the NRC staff evaluated the approach proposed by the B&WOG for coupling material property changes based on ΔT_{30} models with IRT_{T0} values based on fracture toughness data. Considering the limited amount of data available for Linde 80 welds shown in Figure 2, the use of ΔT_{30} in lieu of ΔT_0 provides a small amount of additional conservatism based on the slope of the regression line, although this conservatism was not credited by the B&WOG in TR

BAW-2308, Revision 1. Based upon the information shown in Figures 1 and 2, the NRC staff concluded that there is sufficient evidence to conclude that for welds in general, and Linde 80 welds in particular, the use of models based on ΔT_{30} in lieu of obtaining test data on the shift in the Master Curve T_0 parameter is acceptable, provided that the margins used in the analysis adequately covered the scatter in the ΔT_{30} vs. ΔT_0 correlation.

The NRC staff evaluated the information presented in Figures 2 and 3 of this SE to determine if the proposed use of a $\sigma_\Delta = 28$ °F was acceptable in conjunction with IRT_{T0} and σ_I values based on Master Curve testing and shift values based on the RG 1.99, Revision 2 model for welds. When used in the margin term definition given in RG 1.99, Revision 2 and in Section 5 of TR BAW-2308, Revision 1:

[Eqn. 6] $$\text{Margin} = 2 / (\sigma_I^2 + \sigma_\Delta^2)$$

it is reasonable to consider whether a margin of $2\sigma_\Delta = 56$ °F is adequate to bound uncertainty in the assessment of the shift in T_0 due to irradiation. The NRC staff observed that if a parallel line is drawn offset by 56 °F (31 °C) above the one-to-one correlation line given in Figure 2 of this SE (i.e., a parallel line which would represent the 56 °F of margin), that the data points would be conservatively bounded. Further, the NRC staff observed that the data in Figure 3 of this SE demonstrate that the use of a mean trend curve from RG 1.99, Revision 2 based on average Linde 80 weld chemistry plus a $2\sigma_\Delta$ margin results in the measured ΔT_0 values being bounded, provided that, at a minimum, a chemistry factor of 167 °F is applied. Based on these observations, the NRC staff concluded that the use of $\sigma_\Delta = 28$ °F in conjunction with IRT_{T0} and σ_I values based on Master Curve testing and material property shifts based on the models in RG 1.99, Revision 2, with a minimum chemistry factor of 167 °F of provides an acceptable basis for RPV Linde 80 weld assessment.

The NRC staff has evaluated the issue of the appropriate regulatory process to be used when a licensee incorporates the use of BAW-2308, Revision 1, as modified by this staff SE, within a particular facility's licensing basis. The NRC staff has determined that in order to implement the use of BAW-2308, Revision 1, as modified, for the purpose of supporting RPV integrity evaluations required by 10 CFR 50.61 and 10 CFR Part 50, Appendix G, a licensee must submit exemptions to do so in accordance with 10 CFR 50.12. An exemption is required to address issues related to 10 CFR Part 50, Appendix G per the provisions of 10 CFR 50.60(b). An exemption is required to address issues related to 10 CFR 50.61 inasmuch as the methodology addressed in BAW-2308, Revision 1, as modified, represents a significant change to the methodology specified in 10 CFR 50.61 for determining the pressurized thermal shock reference temperature (RT_{PTS}) value for a Lind8 80 weld material.

4.0 CONCLUSION

In summary, the NRC staff determined that the B&WOG methodology, utilizing the provisions from the 1997 and 2002 Editions of ASTM E 1921 as specified in Section 3.2 of this SE, a correction factor equivalent to a bias of 18 °F to the data obtained from PCCS specimens, and the loading rate correction for Linde 80 welds addressed in TR BAW-2308, Revision 1, represents an acceptable methodology for establishing weld wire heat specific and generic IRT_{T0} values for Linde 80 welds.

5.0 CONDITIONS AND LIMITATIONS

Based on the information submitted by the B&WOG in TR BAW-2308, Revision 1, the August 19, 2003, response to an NRC staff RAI, and the B&WOG letter dated March 25, 2005, the NRC staff has concluded:

(1) The IRT_{T0} and σ_I values given in Table 3 of this SE may be used by a licensee to define the initial heat-specific or generic properties of its facility's Linde 80 welds. For those Linde 80 weld wire heats for which heat-specific values are given, those values must be used when applying TR BAW-2308, Revision 1 if the heat-specific IRT_{T0} value is more conservative than the generic "all heats" IRT_{T0} value.

(2) When the values from Table 3 of this SE are used by a licensee, the methodology of RG 1.99, Revision 2 may be used for the purpose of assessing the shift in initial properties due to irradiation, even though the RG 1.99, Revision 2 methodology is based upon Charpy V-notch 30 ft-lb energy level shift data. However, based on the information in TR BAW-2308, Revision 1 (see Figure 3 of this SE), a minimum chemistry factor of 167 EF must be applied when using initial properties given in Table 3 of this SE. A higher chemistry factor may be required if weld wire heat-specific chemical composition or Charpy V-notch surveillance data indicate, via the methodology of RG 1.99, Revision 2, that a higher chemistry factor should apply.

(3) When the values from Table 3 of this SE are used by a licensee, a value of σ_Δ = 28 EF must be used to determine the overall margin term, when the margin term per TR BAW-2308, Revision 1 is defined as:

$$\text{Margin} = 2 / (\sigma_I^2 + \sigma_\Delta^2)$$

(4) Any licensee who wants to utilize the methodology of TR BAW-2308, Revision 1 as outlined in items (1) through (3) above, must request an exemption, per 10 CFR 50.12, from the requirements of Appendix G to 10 CFR Part 50 and 10 CFR 50.61 to do so. As part of a licensee's exemption request, the NRC staff expects that the licensee will also submit information which demonstrates what values the licensee proposes to use for ΔRT_{NDT} and the margin term for each Linde 80 weld in its RPV through the end of its facility's current operating license.

(5) The B&WOG stated in their August 19, 2003 RAI response that fracture toughness data from one more heat of Linde 80 weld material (weld wire heat 61782) are to be obtained. The NRC staff expects the B&WOG to evaluate these data to determine whether or not the conclusions of TR BAW-2308, Revision 1 and this SE are non-conservative, and to communicate the B&WOG's conclusion to the NRC staff. Non-conservatism in TR BAW-2308, Revision 1 would be evident if: (1) the IRT_{T0} value from the to-be-tested Linde 80 weld wire heat turns out to be higher than the generic IRT_{T0} value approved in this SE, or (2) if the data from the to-be-tested Linde 80 weld wire heat results in an increase in the Linde 80 generic σ_I value.

(6) Although the NRC staff concludes that there is reasonable assurance that the use of IRT_{T0} values for Linde 80 weld materials, which were determined using the loading rate

correction addressed in TR BAW-2308, Revision 1, is acceptable for the purpose of RPV material property determination, the NRC staff expects that action will be pursued within the appropriate consensus codes and standards organizations to address loading rate effects on a more generic basis (or determine that they do not need to be addressed). The NRC staff also expects that when such action is completed the B&WOG will re-evaluate TR BAW-2308, Revision 1 to determine whether or not revision of the TR is warranted.

(7) The staff also expects that action will be pursued within the appropriate consensus codes and standards organizations to address loading rate effects on a more generic basis (or determine that they do not need to be addressed) in the appropriate ASME Code Cases and/or ASTM Standard Test Methods. The staff requests that the B&WOG revise the recommended values in TR BAW-2308, Revision 1 in accordance with Table 3. When consensus codes and standards organizations address loading rate effects on a more generic basis, the staff also expects that the B&WOG will re-evaluate TR BAW-2308, Revision 1 to determine whether or not revision of the TR is warranted.

Principal Contributor: Matthew Mitchell

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