Working Together to Economically Provide Reliable and Safe Electrical Power

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Document Control Desk
ATTN: Chief, Planning, Program and Management Support Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Request for Approval of BAW-2308(NP), Revision 1, "Initial RT_{NDT} of Linde 80 Weld Materials"

Ref.: 1. Letter, James F. Mallay (Framatome ANP) to Document Control Desk (NRC), "B&W Owners Group Reactor Vessel Working Group Submittal of Topical Report BAW-2308, 'Initial RT_{NDT} of Linde 80 Weld Material'," NRC:02:039, July 26, 2002.

Ref.: 2. Memo, Stephanie M. Coffin (NRC) to Steven Dembek (NRC), "Request for Additional Information Regarding Topical Report BAW-2308 (TAC No. MB6336)," April 11, 2003.

On behalf of the B&W Owners Group Reactor Vessel Working Group, Framatome ANP requests the NRC's review and approval for referencing in licensing actions the topical report BAW-2308(NP), Revision 1, "Initial RT_{NDT} of Linde 80 Weld Materials." This revised report incorporates comments received from the NRC after its preliminary review of Revision 0. Framatome ANP hereby withdraws BAW-2308(NP), Revision 0 (Reference 1). A CD is enclosed that contains a non-proprietary copy of BAW-2308, Revision 1.

In Reference 2, the NRC requested additional information to facilitate the completion of its review. The response to this request is contained in the attachment to this letter and has been incorporated into the new revision.

In summary, BAW-2308, Revision 1, proposes a methodology for utilizing the Master Curve technology to reset the initial material property parameter, IRT_{NDT}, for the Linde 80 welds for the purpose of evaluating reactor pressure vessel integrity.

We will appreciate your timely review.

Very truly yours,
Gerald L Holm for
James F. Mallay, Director
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Enclosures

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Attachment 1
Responses to the Request for Additional Information (RAI)
Regarding BAW-2308, "Initial RT_{NDT} of Linde 80 Weld Materials"

Question 1

In Table 1-1, the reference to "'Turkey Point 1, 2" should be changed to Turkey Point 3, 4."

Response to Question 1

This has been corrected.

Question 2

In Section 3.2 of the report, several conclusions are drawn from Figures 3-5 and 3-6 regarding how, for Linde 80 welds, they demonstrate that T_{NDT} (the nil-ductility temperature from drop-weight testing) correlates better to fracture toughness (as measured by T_0) than does IRT_{NDT} (the initial nil-ductility reference temperature based on Charpy V-notch transition temperature). The staff has reviewed Figures 3-5 and 3.6 in the report and finds them to be highly scattered and inconclusive, therefore, the staff cannot concur with the conclusions drawn by Framatome in Section 3.2. Further, the point which the graphs are apparently intended to demonstrate is of little or no consequence to the main topic of the report. The staff recommends removing Figures 3-5 and 3-6 as well as the text in Section 3.2, which refers to the figures from the report.

Response to Question 2

Figures 3-5 and 3-6 have been removed and the text is changed to reflect the removal of these figures.

Question 3

Regarding the statement in Section 3.2 on page 11 of the report, "all available archive Linde 80 welds were tested to determine T_0 (See Section 4)," does this refer only to Linde 80 weld archive materials which were available through the Babcock & Wilcox Owners Group Reactor Vessel Working Group or Linde 80 weld archive materials which were available from all domestic reactor pressure vessels fabricated by Babcock and Wilcox?

If all sources of Linde 80 weld archival material from domestic reactor pressure vessels fabricated by Babcock and Wilcox were not tested and/or evaluated in support of the development of BAW-2308, explain why the database in BAW-2308 should not be supplemented with additional data from these as-yet-unincorporated sources.

Response to Question 3

All available Linde 80 weld archive materials are tested except:

1) Foreign source: WF-233 Kori 1 unit
2) One more heat of Linde 80 welds which will be tested later this year
3) Low copper Linde 80 welds in Byron and Braidwood are not part of this database

Question 4

Regarding the information in Table 4-8, the NRC staff understands that all data sets used to generate the multi-temperature T_0 values in this table are provided in Appendix C to the report, thus most discrepancies between the number of specimens given for a particular weld wire heat in Table 4-3 versus the number given in Table 4-8 may be reconciled. However, what is not clear is why the specimens identified in Table 4-8 and in Appendix C for weld wire heat 72105 include only those from the Midland beltline weld. Table 4-3 indicates that at least 4 compact tension specimen sets comprising at least 27 individual specimens were fabricated from Midland nozzle dropouts.

A discussion is provided in Section 4.2.3 regarding the potential sources of initial material property differences between nozzle dropouts, beltline welds, and samples fabricated from reactor vessel surveillance program specimen blocks. In particular, longer stress relief times and thicker weld sections are apparently postulated to have a detrimental effect on material fracture toughness properties. In Section 4.2.3 it is stated that the Midland nozzle dropouts were from welds which were 12 inches thick and had a stress relief time of 25.5 hrs., whereas the Midland beltline weld was 8 inches thick and had a stress relief time of 22.5 hrs.

The NRC staff agrees that longer stress relief times may have such an effect, however the difference of 3 hours between the Midland nozzle dropouts and the beltline weld would not be expected to be significant. It is not apparent to the staff why a difference in weld thickness over a range of 8 to 12 inches, independent of any other difference in welding process, stress relief time, flux used, etc., would lead to systematic differences in material fracture toughness properties. Therefore, unless additional information can be provided to substantiate why a systematic difference should exist in the material fracture toughness properties of the Midland nozzle dropouts and Midland beltline weld samples of weld wire heat 72105, all sources of data for weld wire heat 72105 should be used in the multi-temperature To calculation, and the determination of an appropriate initial margin term.

In summary, the NRC staff requests that, at a minimum, the applicant provide:

(a) Data for the tests conducted on the Midland nozzle dropouts which is consistent with the level of information provided for other data sets in Appendix C.

(b) A revised analysis for weld wire 72105 which includes the data available from the Midland nozzle dropouts. In light of Question (5) below, the applicant may consider providing two revised analyses: one of which includes the loading rate effect adjustment proposed in BAW-2308 and one which does not. The revised analysis (or analyses) should provide new multi-temperature T_0, RT_{T0} and σ_I values for weld wire heat 72105.

Although not required, the applicant may also elect to provide additional information to substantiate the claim in BAW-2308 regarding the inherent effect of weld thickness on measured material fracture toughness properties.

Response to Question 4

The WF-70(N) data are added to the 72105 database and the data analyses have been redone. The re-analyses resulted in modifications to Tables 4-3 through 4-8.

<u>Question 5</u>

It was noted that an explicit correction was imposed to normalize the available data in Table 4-3 for loading rate. Based on a physical understanding of the fracture process in these materials, one would reasonably expect that there would be some influence of loading rate on the test results. However, the NRC staff is not aware of any consensus which has been reached in the American Society for Testing and Materials (ASTM) or American Society of Mechanical Engineers (ASME) regarding how such loading rate effects should be accounted for over the range of loading rates which (although not explicitly given, this appears to be a range of 0.21 to 2.55 MPa$\sqrt{m}$/second) applies to the data in Table 4-3. It should be noted that, at this time, the NRC staff has not made a final determination regarding whether the proposed loading rate adjustment is or is not acceptable.

Provide a revised version of the information given in Table 7-1, columns 2 and 3 (i.e., proposed values of heat specific and generic initial RT_{T0} and associated initial margin terms) based on the data from Table 4-3 which has not been adjusted to account for loading rate effects. Any other adjustments to the data which were made in Table 4-3 may continue to be included. This information will permit the NRC staff to better understand the overall impact of the loading rate adjustment that is being proposed in BAW-2308.

Any effects from the addition of additional data for weld wire heat 72105 as addressed in question (4) above should be implicitly included in the applicant's response to this question as well.

<u>Response to Question 5</u>

Table 7-1 has been revised in accordance with the changes in Table 4-3, which is provided on the following page. The original table columns in Table 7-1 are also provided for comparison.

Table 4-3 Linde 80 Weld Adjusted T_0 Data

Wire Heat	Weld Metal	Source	Specimen Type	Test Temp (°F)	T_0 (°F)	PCCS Adj. T_0 (°F)	PCCS + Rate Adj. T_0 (°F)	No. Valid Spec.	Average Adjusted T_0 (°F)	Comments
299L44	SA-1526	CR3 ND	0.5TCT	-70	-96	-96	-105	6	-102 (-101)[a]	
	WF-25	OC3 ND	PCCS	-145	-126	-108	-94	7		
			0.5TCT	-70	-99	-99	-106	6		
406L44	WF-112	OC1 RVSP	PCCS	-160	-141	-123	-108	8	-129 (-135)[a]	
			0.5TCT	-70	-119	-119	-127	8		
	WF-193	RS1 RVSP	PCCS	-180	-176	-158	-144	10		
			0.5TCT	-150	-146	-146	-132	9		
			0.5TCT	-70	-126	-126	-134	8		
71249	SA-1094	TP4 RVSP	PCCS	-140	-115	-97	-83	11	-83 (-97)[a]	
72105	WF-70(B)	MD Beltline	PCCS	-120	-108	-90	-75	7	-70 (-67)[a]	
			2TCT	-13	-72	-72	-78	6		ORNL
			1TCT	-13	-78	-78	-84	7		ORNL
			0.5TCT	-13	-74	-74	-80	8		ORNL
			2TCT	-58	-72	-72	-78	6		ORNL
			1TCT	-58	-53	-53	-59	6		ORNL
			0.5TCT	-58	-72	-72	-78	6		ORNL
			1TCT	-103	-47	-47	-53	6		ORNL
			1TCT	-148	-42	-42	-48	6		ORNL
	WF-70(N)	MD ND	1TCT	-13	-22	-22	-28	8	-29 (-23)[a]	ORNL
			1TCT	-58	-2	-2	-8	6		ORNL
			0.5TCT	-58	-36	-36	-42	7		ORNL
			1TCT	-148	-31	-31	-37	6		ORNL
72442	SA-1484	CR3 ND	PCCS	-100	-91	-73	-75	7	-63 (-72)[a]	
	WF-67	MD ND 11 hr SR	PCCS	-120	-101	-83	-68	7		
		MD ND 50 hr SR	Various CTs	-51 to -74	-60	-60	-45	7		Multi-temp.
72445	SA-1585	ANO1 ND	PCCS	-150	-107	-89	-75	10	-75 (-89)[a]	
821T44	WF-182-1	DB1 RVSP	PCCS	-180	-163	-145	-131	6	-118 (-125)[a]	
			0.5TCT	-70	-105	-105	-113	6		
			0.5TCT	-140	-124	-124	-110	12		

RVSP = Reactor Vessel Surveillance Program Weld
ND = Nozzle Drop-Out
PCCS = Pre-Cracked Charpy Size Specimen
TCT = Compact Fracture Toughness Specimen
SR = Stress Relief
[a] = Average with PCCS adjustment only

Table 7-1 Heat Specific and Generic Initial RT_{To} with Associated Initial Margin

	W/ Loading Rate Effect and W/O WF70(N) Data		W/O Loading Rate Effect and W/ WF70(N) Data	
Linde 80 Heat	RT_{To} (°F)	Initial Margin σ_I (°F)	RT_{To} (°F)	Initial Margin σ_I (°F)
406L44	-94.9	11.0	-103.6	12.1
71249	-47.4	12.9	-62.0	13.0
72105	-38.4	11.8	-29.1	13.3
821T44	-80.2	9.3	-90.8	10.0
299L44	-81.8	11.6	-78.8	12.0
72442	-30.0	11.9	-37.8	11.9
72445	-72.5	12.3	-73.2	11.9
All heats	-63.6	17.2	-67.9	20.1

Question 6

Regarding Section 5 of the report which specifies the applicant's justification for combining initial material properties determined from Master Curve measurements (i.e., IRT_{T0}) with material property changes due to irradiation (i.e., ART_{NDT} or ΔTT_{30}) values based on Charpy V-notch impact test data, the NRC staff has found the applicant's approach to be, in general, acceptable. The staff understands your position to be that the ΔRT_{NDT} and σ_Δ margin term from Regulatory Guide 1.99, Revision 2 may be applied directly even when the methodology of BAW-2308 is used to establish the initial material properties for a Linde 80 weld.

However, in the applicant's demonstration of why this position should be acceptable, it is noted that an additional step must be added which compares the shift in Charpy V-notch 30 ft-lb energy to the shift in the Master Curve T_0 (ΔT_0) values for specimens which have been exposed to identical irradiation conditions. For RPV weld samples, the applicant cites a correlation which can be expressed as:

$$\Delta To = 0.99 * \Delta TT_{30}$$

Provide an assessment of the uncertainty in this correlation (call it σ_{corr}) based on the number of data points used in its development and their deviations from the fi1line. Explain why this model or correlational uncertainty should not be included in the typical definition of the σ_Δ, the margin term associated with modeling shifts in material properties due to irradiation, as:

$$\sigma_{\Delta(modified)} = \sqrt{(\sigma_\Delta^2 + \sigma_{corr}^2)}$$

when the methodology of BAW-2308 is used to establish the initial material properties for a Linde 80 weld.

Response to Question 6

The approach taken in this report (alternative IRT_{NDT} plus Regulatory Guide 1.99 Rev. 2 ΔRT_{NDT}) is compared to the RT_{To} obtained from T_0 values of irradiated Linde 80 data in Table 5-3. There are five alternative IRT_{NDT} plus Regulatory Guide 1.99 Rev. 2 shift points that under-predict the irradiated RT_{To} points. The five that under-predict the irradiated RT_{To} points are all within the expected uncertainty limits, which are covered by the margin term (well within 2σ range). Excluding WF-70(N) at 1.59E+19 n/cm^2 and SA-1585 which had insufficient data for a valid reference temperature, the approach taken in this report averaged 18°F higher than the irradiated RT_{To}.

The standard deviation (σ_{fit}) of the residuals between the ΔT_0 data and the correlation shown in Figure 5-1 is 25.6°F for the welds. This σ_{fit} includes both the correlation uncertainty (σ_{corr}) and the measurement uncertainties. The measurement uncertainties are already included in the margin term in σ_I and σ_Δ. Therefore, adding the σ_{fit} to the margin term would double count the measurement uncertainties. To determine the actual uncertainty difference between ΔT_0 and ΔTT_{30} correlation, the measurement uncertainty already included in the margin term needs to be removed from the σ_{corr}. The σ_Δ of Regulatory Guide 1.99 Rev. 2 of 28°F is the σ of a population of irradiated data ΔTT_{30}s and the Regulatory Guide 1.99 Rev. 2 prediction, which includes both the measurement uncertainty of initial and irradiated TT_{30} ($\sigma_{\Delta TT30}$) and the uncertainty of the

Regulatory Guide 1.99 Rev. 2 correlation to the ΔTT_{30} data. An appropriate approximation of the ΔTT_{30} uncertainty is 14°F ($\sigma_{\Delta TT30}$) as determined through a statistical analysis of pairs of longitudinal and transverse ΔTT30 data irradiated in the same capsule. The uncertainty of T_0 can be calculated using the procedure in ASTM E1921-97. For eight specimens (the typical group size used in this section), the σ is 11°F using the equation in Section 4.3.2. A Materials Property Council (MPC) round robin using weld 72W data also showed a σ of around 11°F for T_0. By subtracting the measurement uncertainties that are already included in the Regulatory Guide 1.99 Rev. 2 margin term, the uncertainty σ_{corr} can be calculated.

$$\sigma_{corr}^2 = \sigma_{fit}^2 - \sigma_{Tounirr}^2 - \sigma_{Toirr}^2 - (0.99\ \sigma_{\Delta TT30})^2$$

where:
σ_{fit} = 25.6°F
$\sigma_{Tounirr}$ = 11°F (already in BAW-2308 σ_I margin term)
σ_{Toirr} = 11°F
$\sigma_{\Delta TT30}$ = 14°F (already in σ_Δ margin term)

The resulting σ_{corr} is 14.9°F.

Based on the summary given below, it is concluded that it is appropriate and conservative to combine the alternative IRT_{NDT}, based on Code Case N-629, with the Regulatory Guide 1.99 Rev. 2 shift prediction with no added σ_Δ.

- The current Regulatory Guide 1.99 Rev. 2 approach combines an IRT_{NDT} determined from either T_{NDT} or Charpy TT_{50} with a shift based on TT_{30}. These are different measures of transition temperature. Substituting a different appropriate measure of transition temperature (Code Case N-629) for IRT_{NDT} does not affect the shift term. Both the IRT_{NDT} and the ΔRT_{NDT} have their own independent measures of uncertainty as captured in the margin term. Since ΔRT_{NDT} is unchanged with the resetting of the IRT_{NDT}, the current σ_Δ is appropriate.

- Since best-fit slope of ΔTT_{30} verses ΔT_0 is less than 1, the use of the ΔTT_{30} is conservative relative to ΔT_0 for Linde 80 welds. Therefore, using a T_0-based initial RT_{To} with the Regulatory Guide 1.99 Rev. 2 predicted RT_{NDT} shift is conservative and acceptable.

- On average, Regulatory Guide 1.99 Rev. 2 over-predicts the ΔT_0 by 23°F. The greatest under-prediction of Regulatory Guide 1.99 Rev. 2 is 33°F, which is near the Regulatory Guide 1.99 Rev. 2 weld σ_Δ, while the greatest over-prediction is 136°F.

- The approach taken in BAW-2308 (alternative IRT_{NDT} plus Regulatory Guide 1.99 Rev. 2 Table ΔRT_{NDT}) is compared to the measured RT_{To} obtained from T_0 values of irradiated Linde 80 data. There are five with alternative IRT_{NDT} plus Regulatory Guide 1.99 Rev. 2 shift that under-predict the irradiated RT_{To}. The five that under-predict the irradiated RT_{To} are all within the expected uncertainty, which is covered by the margin term (well within the 1σ range). The irradiated RT_{To} averaged 18°F lower than the approach taken in BAW-2308, which shows that the BAW-2308 approach is conservative.

- The BAW-2308 methodology does not use the correlation between ΔTT_{30} and ΔT_0, therefore, no uncertainty is introduced through the uncertainty of this correlation and σ_Δ need not be modified.

For the reasons described above, it is appropriate and conservative to combine the alternative IRT_{NDT}, based on Code Case N-629, with the Regulatory Guide 1.99 Rev. 2 shift prediction with no added σ_Δ.

A full revised report is attached to this response.