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BAW-2308-NP, Rev. 2
Project Number 694

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U.S. Nuclear Regulatory Commission
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Subject: Pressurized Water Reactor Owners Group
Responses to the NRC Request for Additional Information (RAI) on PWR Owners Group (PWROG) Report BAW-2308-NP, Revision 2, "Initial RT_{NDT} of Linde 80 Weld Materials" (TAC NO. MD4241) PA-MSC-0229

References:

1. Submittal of BAW-2308-NP, Revision 2 "Initial RTNDT of Linde 80 Weld Materials", PA-MSC-0229 (PWOG Letter OG-07-47), dated February 5, 2007.
2. Acceptance for Review of Pressurized Water Reactor Owners Group (PWROG) Topical Report BAW-2308-NP, Revision 2 "Initial RT_{NDT} of Linde 80 Weld Materials" (TAC NO. MD4241) PA-MSC-0229, (PWROG Letter OG-07-175), dated April 17, 2007.
3. NRC Letter from H. Cruz to G. Bischoff, Request For Additional Information Re: Pressurized Water Reactor Owners Group (PWROG) Topical Report (TR) BAW-2308, Revision 2, "Initial RTNDT of Linde 80 Weld Materials" (TAC NO. MD4241), dated July 20, 2007.

In February 2007, the Pressurized Water Reactor Owners Group (PWROG), submitted Topical Report BAW-2308-NP, Revision 2 "Initial RTNDT of Linde 80 Weld Materials", for review and approval (Reference 1). On April 12, 2007, the NRC accepted the topical report (Reference 2) and provided a formal Request for Additional Information (RAIs) (Reference 3) on July 20, 2007.

Enclosure 1 to this letter provides RAI responses to the 3 questions received in Reference 3.

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If you have any questions, please do not hesitate to contact me at (630) 657-3897, or if you require further information, please contact Mr. Jim Molkenthin of the PWR Owners Group Project Management Office at (860) 731-6727.

Regards,

Frederick P. "Ted" Schiffley, II, Chairman
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FPS:JPM:las

Enclosures (1) – RAI Responses to BAW-2308-NP, Revision 2

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REQUEST FOR ADDITIONAL INFORMATION
BY THE OFFICE OF NUCLEAR REACTOR REGULATION
TOPICAL REPORT (TR) BAW-2308-NP, REVISION 2
"INITIAL RTNDT OF LINDE 80 WELD MATERIALS"
PRESSURIZED WATER REACTOR OWNERS GROUP (PWROG)
PROJECT NO. 694

1. Loading rate effect on the reference temperature, T_0, is discussed in Section 3 of TR BAW-2308, Revision 2. It was stated on Page 10, "Using the above equations [the proposed ASTM E1921 equations] to adjust the loading rates of the five data sets that were tested faster than 2 Mpa$\sqrt{m}$/s to the limit of 2 Mpa$\sqrt{m}$/s, results in a reduction of 0.9°F in T_0. This model predicts a loading rate effect of 13.3°F on T_0 from the slowest to the fastest loading rate extremes shown in Table 5, while the AREVA model predicts an effect of 22.9°F."

- Provide information regarding the calculation of the reduction of 0.9°F in T_0 as a result of adjusting the loading rate to 2 Mpa$\sqrt{m}$/s for the five data sets mentioned in the quote. Explain the use of this reference loading rate of 2 Mpa$\sqrt{m}$/s here for the five data sets, while both the BAW-2308 and the proposed E1921 use a reference loading rate of 1 Mpa$\sqrt{m}$/s to derive their adjusted T_0 values. Further, "loading rate extremes shown in Table 5," which is part of the above quote, should be revised to "loading rate extremes shown in Table 4."

Response:

The statement regarding the effect on T_0 due to the loading rate being above 2 Mpa$\sqrt{m}$/s for the five data sets was simply to demonstrate that the effect on T_0 being above the loading rate allowed in E1921-05 is minor. Adjustment to 2 Mpa$\sqrt{m}$/s was not used in the subsequent calculations. All data was adjusted to the reference loading rate of 1 Mpa$\sqrt{m}$/s. Reference to Table 5 will be corrected to Table 4 on page 10 in the approved version of this topical report.

- Provide information regarding the calculation of the loading rate effect of 13.3°F on T_0 using the proposed ASTM E1921 equations and the effect of 22.9°F on T_0 using the BAW-2308 model. Table 4-3 of BAW-2308, Revision 1, does not support the stated effect of 22.9°F on T_0. Please clarify that this calculation is based on T_0 values for all data sets shown in Table 4, not just the five data sets.

Response:

The comparison of the AREVA model, which shows a loading rate effect of 22.9F between 0.22 Mpa$\sqrt{m}$/s and 2.35 Mpa$\sqrt{m}$/s, and the proposed ASTM E1921 model (13.3F) was to simply show the difference between the two models. For the AREVA model: T_0 adjustment = 5.33 ln (R2/R1) = 5.33 ln (2.35/0.22) = 12.6C (or 23F). Selecting the slowest test data set (71249; SA-1094 at 0.22 Mpa$\sqrt{m}$/s) and the fastest (299L44; SA-1526 at 2.35 Mpa$\sqrt{m}$/s) from Table 4 and finding these in Table 4-3 of BAW-2308, Revision 1, it can be seen that the PCS adj. T_0 for SA-1094 is -97F and the PCS+rate adjusted is -83F, a rate effect of 14F. For SA-1526, the PCS adj. T_0 is -96F and the PCS+rate adjusted is -105F, a rate effect of -9F. These were both adjusted to a loading rate of 1 Mpa$\sqrt{m}$/s using the AREVA model, so the difference between these values is 14F – (-9F) = 23F, the same as that reported on page 10 of BAW-2308, Revision 2.

The loading rate effect of the proposed ASTM E1921 model is less (13.3F) between 0.22 Mpa√m/s and 2.35 Mpa√m/s. All the data in BAW-2308, Revision 2 was adjusted to 1 Mpa√m/s using the proposed ASTM E1921 model:

$$T^{est}_{o,X} = \frac{(T_o + 273.15)\cdot\Gamma}{\Gamma - \ln(X)} - 273.15$$

Or, rearranging to solve for T_0 (at 1 MPa√m/s)

$$T_0 = \frac{(T^{est}_{0,X} + 273.15)\cdot(\Gamma - \ln(X))}{\Gamma} - 273.15$$

with X in MPa□m/s and temperatures in °C. The function □ is given by:

$$\Gamma = 9.9\cdot\exp\left[\left[\frac{(T_o + 273.15)}{190}\right]^{1.66} + \left(\frac{\sigma_{ys,To}}{722}\right)^{1.09}\right]$$

and where:

T_0 refers to the quasi-static loading rate of dK/dt = X = $\dot{K}_I$ = 1 MPa√m/s, and

$\sigma_{ys,To}$ = quasi-static yield strength measured or estimated at T_o in MPa.

For the slowest and fastest data sets:

Weld	$T_{0,X}$	X = $\dot{K}_I$ (MPa√m/s)	$\sigma_{ys,To}$ (MPa)	□	T_0	ΔT_0 (F)
SA-1094	-97.2F (-72C)	0.22	559	64	-88.5F (-67C)	8.7F
SA-1526	-96.4F (-71C)	2.35	567	65	-101.2 (-74C)	-4.8F

The total change in T_0 from the loading rate extremes using in BAW-2308, Revision 2 in adjusting the slowest test and the fastest data sets to 1 MPa√m/s results in 8.7F - (-4.8F) = 13.5F.

2. There are inconsistent information on Pages 5, 6, 7, and 13 regarding the number of additional data that was used in the proposed analysis.

- It was stated on Page 5 that, "Two 0.394 TC(T), four 0.500 TC(T), and two 0.936 TDC(T) specimens also from SA-1135 with an average fluence of 1.368 x 10^{19} n/cm^2 (E > 1 MeV) were also tested per ASTM E1921-02." Table 2 (Page 6) and Table 3 (Page 7) show, however, that there are three irradiated 0.936 DC(T) specimens from SA-1135. Please clarify the number of the 0.936 DC(T) specimens.

Response:

There is an error in the text on page 5 as indicated. Tables 2 and 3 are correct. This error will be corrected in the approved version of this topical report. The "two 0.936TDC(T) specimens" will be changed to "three 0.936TDC(T) specimens."

- Table 7 (Page 13) uses the following wording to describe the revised sample size of the Linde 80 weld for Heat 299L44: "299L44 with 8 added tests from TMI2-LG2." This suggests that results from eight additional specimens are included in the proposed sample size uncertainty analysis. However, the Table 7 data show that the uncensored specimen number for 299L44 for the corresponding BAW-2308, Revision 1 analysis was 22 and the uncensored specimen number for 299L44 for the proposed analysis is 29, suggesting that seven additional uncensored specimens are included in the proposed analysis. Please confirm that one of the 8 added specimens is censored, and it is not used in any data analyses described in BAW-2308, Revision 2.

Response:

One of the eight added tests for heat 299L44 taken from RVSP capsule report TMI2-LG2 (BAW-2439 Table 5-2) is censored data. The censored test was on a precracked Charpy size specimen tested at -100F with a resulting J_c of 536 lb/in (K_{Jc} = 126.7 ksi$\sqrt{in}$). It is treated as a censored data point in the multi-temperature T_0 calculation method as described in ASTM E1921-05 section 10.2.2. It is not used in the sample size uncertainty calculation as indicated in Table 7, where it lists the number of uncensored data used. The Monte Carlo analysis treats this data point as censored per the ASTM E1921-05 section 10.2.2 also.

3. It was stated on Page 11 that the Monte Carlo analyses use the same procedure in BAW-2308, Revision 1, suggesting that the results shown in Table 6 (Page 12) are based on all the specimens." Please confirm that the entire specimen set used in the analysis consists of 314 existing specimens, 8 added specimens for Heat 299L44, and 7 added specimens for Heat 61782. The sample size uncertainty shown in Table 7 (Page 13) indicates that the sample uncertainty results are based on uncensored specimens, i.e., 249 existing specimens and 14 added specimens. Provide the basis for this inconsistent approach of using different data sets for the Monte Carlo and sample size uncertainty analyses.

Response:

All the data (including the censored data) is included in the Monte Carlo data set. The procedure selects eight specimens at random from the data set. These eight specimens must have enough valid (uncensored) data to meet the criteria in ASTM E1921 section 10.4.1, if not then this simulation is discarded and another eight specimens is selected at random. This calculation of T_0 for eight randomly selected specimens is repeated until 1000 or 5000 T_0 calculations meet the ASTM E1921 section 10.4.1 validity criteria. The standard deviation is then calculated for these T_0 values and is shown for each heat in Table 6.

The σ calculation (Table 7) comes from ASTM E1921-05 section X4.2:

$$\sigma = \beta / \sqrt{r}$$

where r is defined as the total number of valid specimens used to establish the value of T_0. Therefore, only the uncensored data is considered in this calculation.

The total population consisted of 329 data points with 263 that were not censored.