Assessment of how future results of Capsule B testing may influence compliance of the Diablo Canyon Unit 1 RPV with the NRC's 10 CFR 50.61 PTS Screening Criteria

Mark Kirk · 2 July 2024

Background

Currently there are five measurements of ΔT_{41J} for the Diablo Canyon Unit 1 limiting weld (weld wire heat 27204)[1]. Three of these data come testing performed as part of Diablo Canyon Unit 1's surveillance program while two data are available from the surveillance program of the "sister plant" Palisades. These data are available to a fluence higher than that anticipated for the Diablo Canyon Unit 1 RPV after 60 years of operation. Using these data along with the NRC's required analysis methodology produces an estimate that the Diablo Canyon Unit 1 will not exceed the NRC's PTS screening criteria of 132.3 °C (270 °F) unless operation continues long past 60 years (see Figure 1).

Additional data on weld wire heat 27204 will be become available when Capsule B is removed and tested, which is currently planned for the Spring of 2025. The purpose of this document is to assess the possible impact of the new data from Capsule B on weld wire heat 27204 on Diablo Canyon Unit 1's continued compliance with the NRC's PTS rule.

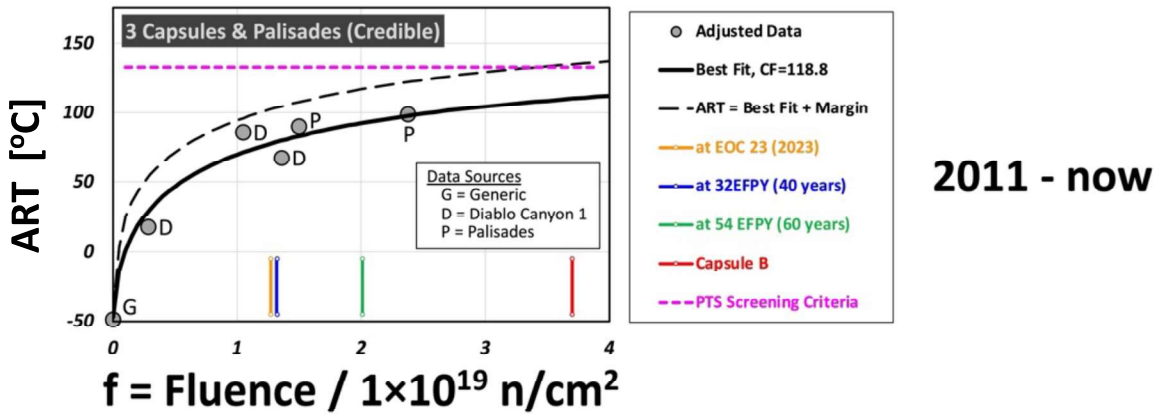

Figure 1. Current PTS evaluation of Diablo Canyon Unit 1. This figure is extracted from Figure 2 of the [Part 2 report].

[1] It should be noted that the PTS analysis that uses all five measurements reported in 2011 [WCAP-17315] is not the current analysis of record with the NRC because PG&E only recently submitted this analysis for review as part of their 2023 license renewal application [DCL-23-038]. Nevertheless, this document considers a PTS analysis based on the five measurements reported in 2011 [WCAP-17315] as the starting point for evaluation of the possible effects of new data from Capsule B because it represents the current state of knowledge on the embrittlement characteristics of the limiting weld wire heat in Diablo Canyon Unit 1.

Contents of Capsule B

Table 1 summarizes the contents of Capsule B; rows pertaining to weld wire heat 27204 are highlighted in yellow. Capsule B contains two sets of samples of weld wire heat 27204 that can be tested as Charpy specimens to estimate the T_{41J} values needed for the PTS analysis, as follows:

- Samples of the original Diablo Canyon Unit 1 surveillance weld are available in the form of the broken halves of Charpy specimens originally tested as part of the first surveillance capsule, Capsule S. Also re-encapsulated from Capsule S are two wedge-opening load (WOL) specimens. To be tested as Charpy specimens the broken halves would need to be re-constituted following established procedures [ASTM E1253]; WOL specimens could also potentially be turned into Charpy specimens if additional samples are needed. When these samples were placed into Capsule B, they already had a fluence of 2.8×10^{18} n/cm^2, so when they are removed from Capsule B their fluence will be (roughly) 3.98×10^{19} n/cm^2.
- Samples of a "surrogate" weld[2] fabricated from the same weld wire heat, flux type, and flux lot as the Diablo Canyon Unit 1 surveillance weld are available in the form of already machined Charpy specimens. These specimens have nearly identical chemistry to the Diablo Canyon Unit 1 weld. Because of this and the matching weld wire heat, flux type, and flux lot, data from these samples can be used as part of a data set to assess compliance with the PTS rule following NRC procedures. These samples were unirradiated when they were placed in Capsule B, so when they are removed their fluence will be (roughly) 3.7×10^{19} n/cm^2.

Because of the different fluence of these two sets of samples and their potentially different Charpy properties before irradiation it is most likely that data from tests performed from these samples will be characterized as producing two new ΔT_{41J} data for the PTS analysis.

Table 1. Diablo Canyon Unit 1 supplemental surveillance capsules [WCAP-13440]. This table is extracted from Table 2 of the [Part 2 report].

Material	Capsule B	Cu (wt%)	Ni (wt%)
Surrogate Weld from Nozzle Drop-Out. Weld heat (27204) and flux type (Linde 1092) same and flux lot (3714) as surveillance weld.	15 CVN, 3 Tensile	0.22	1
Lower Shell Plate B4107-1	15 CVN, 3 Tensile	0.13	0.56
Correlation Monitor Material	8 CVN	0.14	0.68
Surveillance Weld (from Capsule S), Heat 27204, Longitudinal Beltline Weld	2 WOL, 9 Charpy Inserts	0.21	0.98

Analysis of Influence of Capsule B Data

As stated in the preceding section, it is most likely that data from tests performed on samples of weld wire heat 27204 contained in Capsule B will be characterized as producing two new ΔT_{41J} data. Nevertheless, in the interest of simplicity this analysis considers that only one new ΔT_{41J}

[2] The "surrogate" weld described in [WCAP-13440] is the same exact weld as the "sister" plant weld data reported in [BAW-2398] and [BAW-2341 R2]. The information cited in all three references gives [CE-TR-MCC-189] as the original source for data on this single weld.

datum is produced by Capsule B. The impact of this simplifying assumption will be assessed as part of the discussion of results, which appears in the next section.

The analysis was conducted as follows (see Figure 2 for details):

(1) Assume a new ΔT_{41J} value at the anticipated Capsule B fluence (red circle).
(2) Use the assumed datum from Step (1) along with existing data on weld wire heat 27204 (black circles) to estimate the variation of adjusted reference temperature (ART) with fluence following NRC rules. Assess credibility and use this outcome to determine the chemistry factor and the margin. Use the chemistry factor and margin to determine both the best-fit relationship (solid black curve) and the upper bound relationship (black dashed curve) between ART and fluence.
(3) Determine the fluence at which the upper bound relationship (black dashed curve) exceeds the PTS screening criteria (horizontal dashed magenta line).

This analysis was repeated for a range of assumed new values of ΔT_{41J} in Step (1).

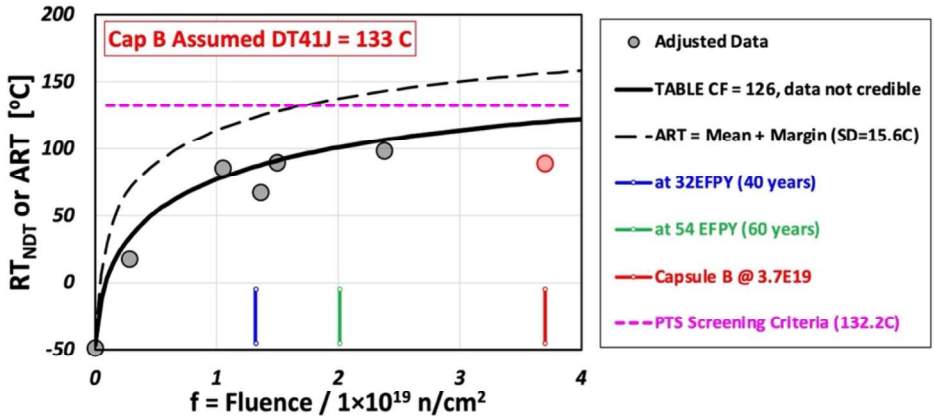

Figure 2. Illustration of the impact of a single new measurement (red circle) on the PTS analysis of weld wire heat 27204.

Discussion

The estimate of the fluence at which the PTS screening criteria is exceeded, which is the Step 3 result of the analysis described in the preceding section, appears as the solid black line in Figure 3. This black line quantifies how the value assumed for a single new ΔT_{41J} measurement from Capsule B (horizontal axis) will affect the fluence at which the Diablo Canyon Unit 1 RPV will be predicted to exceed the NRC's PTS screening criteria (vertical axis). Figure 3 also provides the following information:

- The RPV fluence after 40 years of operation (blue horizontal line).
- The RPV fluence after 60 years of operation (red horizontal line).
- The range of assumed ΔT_{41J} measurements that produce a credible data set following the NRC's procedures (grey shaded region).

The figure makes clear that whether or not the Diablo Canyon Unit 1 RPV can operate for 60 years before it is predicted to exceed the NRC's PTS screening criteria depends entirely on the credibility of the full data set (that is: existing data plus new data from Capsule B) for weld wire heat 27204.

- Credible Data Set: If the ΔT_{41J} measurement from Capsule B falls between 134-173 °C (the grey shaded region) the entire data set is characterized as being credible, which is the same as the current estimate before Capsule B is tested. In this situation the forecast value of fluence at which the Diablo Canyon Unit 1 RPV is predicted to exceed the NRC's PTS screening criteria remains well beyond 60 years.
- Not-Credible Data Set: Both lower (below 134 °C) and higher (above 173 °C) assumed values for the ΔT_{41J} measurement from Capsule B result in the entire data set being characterized as not-credible. In such a situation, the NRC's procedures require that the calculations include an added factor of conservatism, changing the fluence at which the plant is predicted to exceed the PTS screening criteria. The result this added conservatism is that the Diablo Canyon Unit 1 RPV would be predicted to exceed the NRC's PTS screening criteria after roughly 50 years of operation[3]. The value of approximately 50-years was determined by linear interpolation of the analysis result (black line) between the RPV fluence values associated with 40- and 60-years (blue and red lines, respectively).

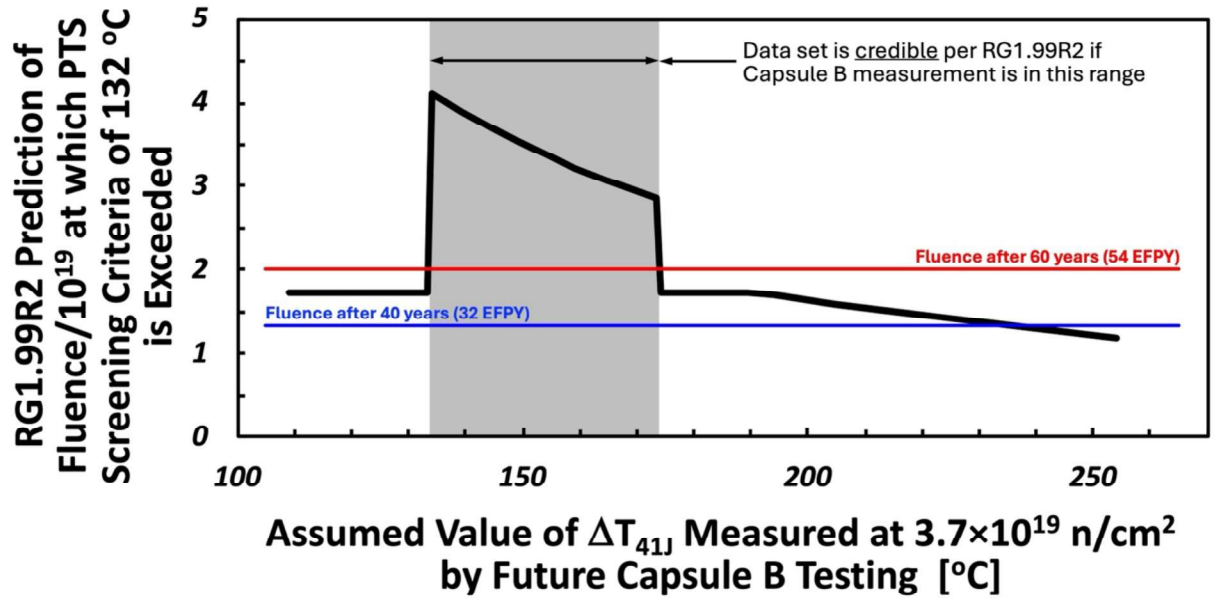

Figure 3. Effect of the assumed measured value of ΔT_{41J} from Capsule B (horizontal axis) on the fluence at which the PTS screening criteria is forecast to be exceeded (vertical axis).

As stated previously, it is most likely that data produced by testing of samples from Capsule B will be characterized as producing two new ΔT_{41J} measurements for the PTS analysis (seven measurements total): one from the surrogate weld and one from the Diablo Canyon surveillance weld. Having two new measurements rather than just one, as was considered in the simplified analysis just described, will increase the probability of obtaining a credible data set. This is

[3] Very high ΔT_{41J} measurements, above 134 °C, produce even smaller fluences, but such values are highly unlikely based on available information.

because a data set of seven measurements can have two values deviate by more than ±1σ from the best-fit curve and still be considered credible by NRC procedures. Conversely, a credible data set of six measurements may have only one value that deviates by more than ±1σ from the best-fit curve. The increased likelihood that the data set will be assessed as credible also increases the likelihood that Diablo Canyon Unit 1 will not be predicted to exceed the NRC's PTS screening criteria until well beyond 60 years of operation.

Summary

If the Capsule B ΔT_{41J} measurements produce a credible data set the Diablo Canyon Unit 1 will not be predicted to exceed the NRC's PTS screening criteria until well beyond 60-years of operation. Conversely, if the data set is characterized as being not-credible then Diablo Canyon Unit 1 will be predicted to exceed the NRC's PTS screening criteria after approximately 50-years of operation. In the latter situation PG&E could, among other things, use the alternate PTS rule [10CFR50.61a] or perform Master Curve [ASTM E1921] testing and use this as the basis to apply for an exemption to the PTS rule. Available information suggests that either approach could be successful. Finally, since the forecast date for PTS exceedance is 50-years in the event of a non-credible outcome there is sufficient time to plan for and execute either option.

Citations

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Part 2 Report Kirk, M.T., An Evaluation of the Status of Diablo Canyon Unit 1 With Respect to Reactor Pressure Vessel Condition Monitoring and Prediction, Part 2: Evaluation of Diablo Canyon Unit 1 Embrittlement, 2024, https://www.dcisc.org/download/library/an-evaluation-of-the-status-of-diablo-canyon-unit-1/report-part-2-evaluation-of-diablo-canyon-unit-1-embrittlement-76.pdf.

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