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FINAL SAFETY EVALUATION

BY THE OFFICE OF NUCLEAR REACTOR REGULATION

PRESSURIZED WATER OWNERS GROUP TOPICAL REPORT

PWROG-17090-NP, REVISION 0,

"GENERIC ROTTERDAM FORGING AND WELD INITIAL UPPER-SHELF ENERGY DETERMINATION"

EPID: L-2018-TOP-0017

1.0 INTRODUCTION

By letter dated April 6, 2018 (Ref.1), as supplemented by letter dated June 12, 2019 (Ref. 2), the Pressurized Water Reactor Owners Group (PWROG) transmitted Topical Report (TR) PWROG-17090-NP, Revision (Rev.) 0, "Generic Rotterdam Forging and Weld Initial Upper-Shelf Energy Determination" (Ref. 3, non-proprietary version) to the U.S. Nuclear Regulatory Commission (NRC) for review and approval.

For reactor vessels (RVs) that were fabricated by the Rotterdam Dockyard Company (Rotterdam), the TR provides generic values of the unirradiated Charpy Upper-Shelf Energy (USE) for American Society of Mechanical Engineers (ASME) SA508[1], Class 2 (or the corresponding American Society of Testing and Materials (ASTM) A508, Class 2 (Ref. 4)) RV forgings; and generic values of unirradiated Charpy USE, weight percentage copper (Cu) content, and weight percentage nickel (Ni) content for RV Submerged Arc Welds (SAWs) and Shielded Metal Arc Welds (SMAWs). The PWROG's transmittal letter identifies that licensees will reference the PWROG-17090-NP, Rev. 0 report as the basis for the generic USE, Cu content, and Ni content values to demonstrate compliance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix G requirements for extended operating license terms when plant-specific RV material information is not available or incomplete.

As addressed in the PWROG's transmittal letter dated April 6, 2018, this TR is for implementation by all U.S. PWRs with RVs fabricated by Rotterdam in the late 1960's and early 1970's timeframe. This statement identifies the limitation on the applicability of the TR, which is addressed in the transmittal letter.

[1] Logsdon, W.A., Begley, J.A., and Gottshall, C.L. Dynamic fracture toughness of American Society of Mechanical Engineers (ASME) SA508 Class 2a ASME SA533 grade A Class 2 base and heat affected zone material and applicable weld metals. United States: N. p., 1978. Web.

Enclosure

2.0 BACKGROUND AND REGULATORY EVALUATION

Background – Generic RV Properties, Application to RV Fracture Toughness Evaluations

Terms such as "generic values," "generic data," or "best estimate values," etc. are often used in industry reports and in NRC staff publications for addressing certain RV material properties that are based on statistical evaluation of a set of original fabrication data for a "class" of RV material[2]. Data sets such as those provided in the TR are developed from available RV fabrication records for multiple plants and are often applicable to certain plant and/or RV material categories. When used in licensing applications for meeting regulatory requirements discussed below, generic RV material properties are subject to review and approval by the NRC staff.

When approved by the NRC staff, generic RV material properties may be implemented in plant-specific licensing applications to demonstrate compliance with the requirements of 10 CFR Part 50, Appendix G, "Fracture Toughness Requirements." For PWR plants, generic RV material properties may also be implemented in applications for addressing the requirements of 10 CFR 50.61, "Fracture toughness requirements for protection against pressurized thermal shock events," or the requirements of 10 CFR 50.61a, "Alternate fracture toughness requirements for protection against pressurized thermal shock events," as appropriate. In applications for License Renewal (LR) and Subsequent License Renewal (SLR) under 10 CFR Part 54, generic properties may be used in RV neutron embrittlement evaluations to meet the technical information requirements for TLAAs, as set forth in 10 CFR 54.21(c)(1). TLAA evaluations related to RV neutron embrittlement, pursuant to 10 CFR 54.21(c)(1), rely upon demonstrations that the above 10 CFR Part 50 fracture toughness requirements are satisfied (or will be satisfied) for proposed extended license terms. It should be noted that while generic properties are used as inputs into time-dependent neutron embrittlement analyses, the properties themselves are fixed based on the evaluation of available RV fabrication data for the preservice (unirradiated) condition, and once approved they become incorporated into a plant's licensing basis documentation[3].

Fracture Toughness Requirements and Guidance – Ferritic RCPB and RV Beltline Materials

Pursuant to Section IV.A of 10 CFR Part 50, Appendix G, pressure-retaining components of the reactor coolant pressure boundary (RCPB) that are made of ferritic materials must meet the requirements of the ASME Boiler and Pressure Vessel Code (Code), Section III, as supplemented by the additional requirements set forth in paragraph IV.A.1, "Reactor Vessel Charpy Upper-Shelf Energy Requirements," and paragraph IV.A.2, "Pressure-Temperature

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[2] For generic values of the initial (unirradiated) reference temperature (RT_{NDT}), 10 CFR 50.61, 50.61a; and NRC Regulatory Guide 1.99, Revision 2, state that the "class" of material is generally determined for welds by the type of welding flux (e.g., Linde 80 or other), and for base metal by the material specification. The material specification is generally the ASTM or ASME standard specification (e.g., ASME Section II, SA508, Class 2 or other).

[3] NRC Branch Technical Position 5-3, Position 1.3, "Reporting Requirements," states "Fracture toughness information identified by the ASME Code and by Appendix G, 10 CFR Part 50, should be reported in the final safety analysis report (FSAR) to provide a basis for evaluating the adequacy of the operating limitations given in the [technical specifications] or [pressure-temperature limits report]."

Limits and Minimum Temperature Requirements," of the Rule. With respect to Charpy USE requirements, paragraph IV.A.1.a of 10 CFR Part 50 Appendix G states:

> *Reactor vessel beltline materials must have Charpy upper-shelf energy[1] in the transverse direction [i.e., weak direction] for base metal and along the weld for weld material according to the ASME Code [Section III], of no less than 75 ft-lbs. (102 J) initially and must maintain Charpy upper-shelf energy throughout the life of the vessel of no less than 50 ft-lbs., unless it is demonstrated in a manner approved by the Director, [NRR] or Director, [NRO], as appropriate, that lower values of Charpy upper-shelf energy will provide margins of safety against fracture equivalent to those required by Appendix G of Section XI of the ASME Code.*

Note 1 of this paragraph states that Charpy USE is defined in ASTM Standard E185-82, "Standard Practice for Conducting Surveillance Tests for Light Water Cooled Nuclear Power Reactor Vessels" (Ref. 3) which is incorporated by reference in 10 CFR Part 50, Appendix H. Section 4 of ASTM E185-82 provides the following definitions that are applicable to the determination of Charpy USE based on actual Charpy V-Notch Impact Tests (also referred to in this SE as "measured" values of Charpy USE).

- Paragraph 4.17 defines the "*Charpy transition curve*" as a graphic presentation of Charpy data, including absorbed energy, lateral expansion, and fracture appearance, extending over a range including the lower shelf energy (less than (<) 5 percent shear), the transition region, and the upper-shelf energy (greater than (>) 95 percent shear).

- Paragraph 4.18 defines the "*upper shelf energy level*" as the average energy value for all Charpy specimens (normally three) whose test temperature is above the upper end of the transition region. For specimens tested in sets of three at each test temperature, the set having the highest average may be regarded as defining the upper-shelf energy.

Section IV.A of 10 CFR Part 50, Appendix G states that for ferritic materials that are part of the RV "*Beltline Region*," as defined[4] in Section II of the Rule, the values of the reference temperature (RT_{NDT}, also defined in Section II of the Rule) and Charpy USE must account for the effects of neutron radiation, including the results of the RV surveillance program required by 10 CFR Part 50, Appendix H. For protection of PWR RVs against pressurized thermal shock (PTS) events, 10 CFR 50.61 also requires that the RT_{NDT} for RV beltline materials account for the effects of neutron radiation. The regulation at 10 CFR 50.61 defines RT_{PTS} as the RT_{NDT} evaluated for the "EOL Fluence" for each of the RV beltline materials, using the procedures in 10 CFR 50.61(c). The regulation of 10 CFR 50.61 defines EOL Fluence as the best-estimate neutron fluence projected for a specific RV beltline material at the clad-base-metal interface at the location where the material receives the highest fluence on the expiration date of the operating license. For PWR plants implementing the alternate PTS protection requirements of 10 CFR 50.61a, 10 CFR 50.61a(c)(1) requires that each licensee shall have projected values of RT_{MAX-X}, as defined in 10 CFR 50.61a(a)(6), for each RV beltline material for the EOL fluence of the material.

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[4] Section II of 10 CFR Part 50, Appendix G defines the RV beltline as the region of the RV (including welds, heat affected zones, and plates or forgings) that directly surrounds the effective height of the active core and adjacent regions of the RV that are predicted to experience sufficient neutron radiation damage to be considered in the selection of the most limiting material with regard to radiation damage.

The NRC Regulatory Issue Summary (RIS) 2014-11 (Ref. 4) identifies that the beltline definition in 10 CFR Part 50, Appendix G is applicable to all RV ferritic materials with projected neutron fluence values greater than 1.0 x 10^{17} n/cm^2 (E > 1.0 MeV), and this fluence threshold remains applicable throughout the licensed operating period. Accordingly, RIS 2014-11 states that the effects of neutron radiation must be considered for any RV locations that are predicted to experience a neutron fluence exposure greater than 1.0 x 10^{17} n/cm^2 (E > 1.0 MeV) at the end of the licensed operating period; this includes periods of extended operation for LR and SLR.

In order to account for the effects of neutron embrittlement on RV beltline materials, Regulatory Guide (RG) 1.99, Rev. 2 (Ref. 5) specifies methods for calculating projected values of Charpy USE and adjusted RT_{NDT} due to neutron fluence exposure. Procedures for calculating RT_{PTS} are specified directly in 10 CFR 50.61(c); and procedures for calculating RT_{MAX-X} are specified in paragraphs (f) and (g) of 10 CFR 50.61a. For RV beltline materials that are not represented in the RV surveillance program, RG 1.99, Rev. 2 provides methods for direct calculation of projected values of Charpy USE and adjusted RT_{NDT} based on the weight percentage Cu and Ni content and projected neutron fluence exposure of the RV beltline materials. The regulation at 10 CFR 50.61 specifies methods for direct calculation of RT_{PTS} based on weight percentage Cu and Ni content and EOL fluence. Per RG 1.99, Rev. 2, only the Cu content is needed to determine the projected percentage decrease in USE as a function of projected neutron fluence per Figure 2 of the RG. Per RG 1.99, Rev. 2 and 10 CFR 50.61, both Cu and Ni content are needed in order to determine the chemistry factor (CF) for the material using CF Tables provided therein. For RV beltline materials, the product of the CF and the neutron fluence factor (FF) determines the projected mean value of the shift in RT_{NDT} (ΔRT_{NDT}). These procedures specify that the projected value of the adjusted RT_{NDT} (or RT_{PTS} under 10 CFR 50.61) is equal to the sum of the values of unirradiated (initial) RT_{NDT}, ΔRT_{NDT}, and a margin term (M). For PWR plants implementing the alternate PTS protection requirements of 10 CFR 50.61a, calculation procedures in Paragraphs (g) and (f) of this Rule specify more detailed inputs and equations for calculating RT_{MAX-X}; these inputs include, among other things, Cu content, Ni content, phosphorus (P) content, manganese (Mn) content, and EOL neutron fluence.

If the RV beltline materials are represented in the RV surveillance program, RG 1.99, Rev. 2 and 10 CFR 50.61 specify methods for calculating projected USE, adjusted RT_{NDT}, and RT_{PTS} that are based on measurements of percentage decrease in Charpy USE and ΔRT_{NDT} from Charpy impact tests of irradiated surveillance materials. For PWR plants implementing the alternate PTS protection requirements of 10 CFR 50.61a, paragraph (f)(6)(i) of this Rule specifies that the licensee shall evaluate the results from a plant-specific or integrated surveillance program if the surveillance data satisfy the criteria described in paragraphs (f)(6)(i)(A) and (f)(6)(i)(B) of this section.

Requirements and Guidance, Preservice Fracture Toughness Tests, and Analysis of Test Data

Pursuant to 10 CFR Part 50, Appendix G, Section III, “Fracture Toughness Tests,” ferritic materials for pressure-retaining components of the RCPB must be tested in accordance with the ASME Code, Section III and, for RV beltline materials, the RV surveillance program test requirements of 10 CFR Part 50, Appendix H, in order to demonstrate compliance with the fracture toughness requirements in Section IV.A of the Rule. For an RV that was constructed to an Edition and Addenda of the ASME Code, Section III earlier than the Summer 1972 Addenda of the 1971 Edition, Section III of 10 CFR Part 50, Appendix G states the fracture toughness data and data analyses must be supplemented in a manner approved by the NRC to demonstrate equivalence with these fracture toughness requirements.

The NRC guidance in NUREG-0800, Branch Technical Position (BTP) 5-3 (Ref. 6), states that the preservice fracture toughness test requirements for plants with construction permits issued prior to August 15, 1973, may not comply with the later Codes and Regulations in all respects. Accordingly, Section B.1, "Preservice Fracture Toughness Test Requirements," of BTP 5-3 recommends that the preservice fracture toughness properties—specifically, unirradiated RT_{NDT} and unirradiated Charpy USE—of the ferritic materials for these plants should be assessed by using the available test data to estimate the preservice fracture toughness properties in the same terms as the new requirements.

With respect to estimation of Charpy USE for the preservice (unirradiated) condition, Position 1.2 of BTP 5-3 specifies that if Charpy impact tests were only conducted on longitudinal specimens (i.e., Charpy V-Notch specimens oriented in the strong direction), the Charpy USE values should be reduced to 65 percent of the measured longitudinal values to estimate the transverse USE (i.e., USE for the weak direction).

For cases where there is insufficient test data in "*Certified Material Test Reports*" (CMTRs[5]) to establish measured values of these properties for a plant's own RV materials[6] using BTP 5-3 methods, the implementation of NRC-approved generic estimates based on generic data for a material "class" may be appropriate, especially for older plants. The regulations at 10 CFR 50.61, 10 CFR 50.61a, and RG 1.99, Rev. 2 have provisions that address the use of generic data to demonstrate compliance with these fracture toughness requirements. The staff's overview of criteria for use of generic data, as applied to the determination of generic values of unirradiated Charpy USE, Cu content, and Ni content, is provided below.

Generic Values for Unirradiated Charpy USE, Cu Content, and Ni Content

The NRC regulations and guidance in 10 CFR Part 50, Appendix G and RG 1.99, Rev. 2 do not provide explicit criteria regarding the implementation of generic unirradiated USE values for a "class" of material for the preservice condition. However, with respect to generic values of initial (unirradiated) RT_{NDT} that are used for P-T limits and PTS evaluations, 10 CFR 50.61 and RG 1.99, Rev. 2 both state that if a measured value of initial RT_{NDT} is not available, a generic mean value of initial RT_{NDT} for the "class" of material (as specified above) may be used if there are sufficient test results to establish a mean and standard deviation (σ) for the class. Per RG 1.99, Rev. 2 and 10 CFR 50.61, the standard deviation on initial RT_{NDT} is "σ_i" (referred to as "σ_U" in 10 CFR 50.61) and is incorporated into the calculation of the adjusted RT_{NDT} (or RT_{PTS}) due to the effects of neutron embrittlement by using a margin term, "M." Equation (4) of the RG

[5] For later Editions and Addenda of the ASME Code, Section III, *Certified Material Test Reports*, as defined in NCA-9200 of ASME Section III, are required for Class 1 pressure-retaining materials, as specified in NB-2130. For impact testing of ferritic RPCB materials in accordance with NB-2300, the test results, test temperatures, specimen orientation and location, etc., as applicable, for all impact tests (Charpy V-Notch Tests and Drop Weight Tests) performed to meet the requirements of NB-2330 shall be reported in the CMTR, as specified in NB-2321 (later Editions and Addenda of ASME Section III).

[6] For the regulatory applications addressed herein, plant-specific RV materials are often identified using a specific component identifier and an identifier for the specific "heat" (stated tonnage of metal obtained from a period of continuous melting) of material used to fabricate the plant's RV weld, forging, or plate.

and Equation (2) of 10 CFR 50.61 specify the same expression for the margin term, which is shown below:

$$M = 2 \times \sqrt{\sigma_I^2 + \sigma_\Delta^2}$$

If only the preservice condition for the RV material is considered, the ΔRT_{NDT} term and the standard deviation on ΔRT_{NDT} (σ_Δ) are eliminated, and the expression for the margin term on initial RT_{NDT} reduces to twice the standard deviation on initial RT_{NDT} ($2\sigma_i$). Thus, the generic value of initial RT_{NDT} for the material class equals the mean value plus $2\sigma_i$. Equivalently, for determinations of a generic value of unirradiated Charpy USE, where only the standard deviation on the unirradiated property is considered, the appropriate value for a bounding statistical representation of the property for a class of material is the mean value minus two standard deviations (Mean – 2σ), since lower USE values are more bounding (as opposed to RT_{NDT}, where higher values are more bounding).

If measured values of Cu and Ni content for plant-specific RV beltline materials are not available, Position 1.1 of RG 1.99, Rev. 2 and 10 CFR 50.61(c)(1)(iv)(A) provide equivalent criteria regarding the use of generic values. Specifically, if measured Cu and Ni content are unknown, "*the upper limiting values given in the material specifications*" may be used. If the material specifications provide no upper limiting values, conservative estimates (Mean + 1σ) based on generic data may be used if justification is provided. If there is no information available based on measured content, material specifications, or conservative estimates (Mean + 1σ) from generic data, "*0.35 percent copper and 1.00 percent nickel*" must be assumed. For calculations of RT_{MAX-X}, 10 CFR 50.61a(f)(3) states that if measured values of Cu, Ni, P, and Mn content are not available for the specific RV material, either the upper limiting values given in the material specifications to which the RV material was fabricated, or conservative estimates (i.e., mean plus one standard deviation) based on generic data must be used. Table 4 of 10 CFR 50.61a provides the generic values for P and Mn content, which must be used, if measured values are unknown for the specific RV material.

Finally, with respect to determination of generic values of Cu and Ni content based on evaluation of Mean + 1σ for generic data, Note 4 of 10 CFR 50.61(c)(1)(iv)(A) and Note 4 of 10 CFR 50.61a(f)(3) state: "*Data from reactor vessels fabricated to the same material specification in the same shop as the vessel in question and in the same time period is an example of 'generic data.'*"

The NRC staff applied these criteria to determine whether the TR evaluations provide acceptable generic estimates of unirradiated Charpy USE, Cu Content, and Ni content for use in plant licensing applications to demonstrate compliance with the requirements of 10 CFR Part 50, Appendix G; 10 CFR 50.61 or 50.61a; and 10 CFR 54.21(c)(1).

3.0 OVERVIEW OF PWROG-17090-NP, REVISION 0

For RVs fabricated by Rotterdam, the TR provides generic values of unirradiated Charpy USE for ASME SA508, Class 2 (or the corresponding ASTM A508, Class 2) forgings and generic values of unirradiated Charpy USE, Cu content, and Ni content for SAWs and SMAWs when no or limited plant-specific material information is available. These generic values are developed using baseline (unirradiated) test data from RV material surveillance program records and CMTRs that are available to Westinghouse. The TR identifies that the need for these generic properties is prompted by the difficulty in identifying plant-specific material information needed to establish measured values for these properties for Rotterdam RVs fabricated in the "late 1960's to early 1970's." The proposed generic values for these material properties are as follows:

- For an SA508, Class 2 Rotterdam RV forging supplied by Rheinstahl Huttenwerke AG, the TR provides a generic lower bound Charpy USE value of 56 ft-lbs., based on the mean minus two standard deviations (Mean – 2σ) evaluation of measured USE values for the Rheinstahl Huttenwerke AG data set.

- For an SA508, Class 2 Rotterdam RV forging supplied by Fried-Krupp Huttenwerke AG, or an unknown Rotterdam RV forging supplier, the TR provides a generic lower bound Charpy USE value of 52 ft-lbs. based on the Mean – 2σ evaluation of measured USE values for the Fried-Krupp Huttenwerke AG data set, and consideration of additional Charpy USE data for other forging suppliers addressed in Section 4.3 of the TR and discussed below.

- For a Rotterdam RV SAW, the TR provides a generic lower bound Charpy USE value of 75 ft-lbs. based on the Mean – 2σ evaluation of measured USE values for the Rotterdam RV SAW data set. The TR also provides a generic upper bound Cu content of 0.23 percent by weight, and a generic upper bound Ni content of 0.56 percent by weight, both of which are based on the mean plus one standard deviation (Mean + 1σ) evaluation for the Rotterdam RV SAW Cu and Ni chemistry data.

- For a Rotterdam RV SMAW, the TR provides a generic lower bound Charpy USE value of 72 ft-lbs., which is the lowest of the "lower bound USE values" (as described in Sections 3.2 and 5.2 for the Rotterdam SMAW evaluation) for the non-outlier SMAW weld heats. The lower bound USE values are determined from measured absorbed impact energies for the SMAW Charpy V-Notch tests, which are established to be below an undetermined USE based on Charpy test temperatures at 10.4 °F or below and available percent shear data. The TR recommends a generic Cu content of 0.35 percent per RG 1.99, Rev. 2, and it provides a generic upper bound Ni content of 1.13 percent (greater than the generic Ni content of 1.00 percent provided in the RG) based on the Mean + 1σ evaluation for the Rotterdam RV SMAW Ni chemistry data.

Section 3.0 of the TR describes the methodology for analyzing the material property data for the subject Rotterdam RV forgings and welds. Section 4.0 of the TR provides the actual data sets and statistical analyses for determining the generic values of unirradiated Charpy USE for Rotterdam RV forging materials. Section 5.0 provides the data sets and analyses for determining the generic values of unirradiated Charpy USE, Cu content, and Ni content for Rotterdam RV weld materials. The NRC staff's independent evaluation of these methods and data analyses is documented in Section 4.0 of this SE. The key aspects of the methodology and data analyses, as reported in TR, are summarized below.

Generic Charpy USE Values for SA508, Class 2 Forgings in Rotterdam RVs

The TR identifies that its generic Charpy USE values are determined by calculating the Mean – 2σ for two independent sets of measured Charpy USE values in the weak direction. The two independent data sets correspond to two Rotterdam RV forging suppliers: Rheinstahl Huttenwerke AG and Fried-Krupp Huttenwerke AG. The TR indicates that measured USE values were determined by reviewing Charpy impact test records from available CMTRs and baseline (unirradiated) Charpy test data from RV material surveillance program records. The total number of Charpy test records for forgings supplied by Rheinstahl Huttenwerke AG is 38, and the total number of test records for Fried-Krupp Huttenwerke AG-supplied forgings is 67. Each Charpy test record corresponds to a subset of Charpy impact tests on samples (i.e., Charpy V-Notch specimens) of a specific forging material for an unnamed plant (e.g., “Inlet Nozzle 09” for “Plant D,” “Upper Shell” for “Plant C,” etc.). For each test record, the TR reviewed measurements of absorbed Charpy impact energies, test temperatures, and measurements of percentage shear fracture surface areas (percent shear) for the fractured Charpy specimens (i.e., the broken pieces).

For each Charpy test record, the TR determined either a measured value of the USE for that forging material—or where this is not possible due to less stringent impact testing criteria prior to 1973—a measured value of the absorbed Charpy impact energy, which is considered in the TR to be a lower bound on actual USE for that forging. For these cases, the USE is identified in the TR as being greater than or equal to (≥) the reported absorbed impact energy.

Only measured USE values for Charpy tests on forging specimens oriented in the weak direction (transverse specimens) are used to calculate the recommended Mean – 2σ values for the two forging supplier data sets. For cases where measured USE values are available only in the strong direction (longitudinal specimens), or where the strong direction must be assumed because the Charpy V-Notch specimen orientation was not reported in the CMTR, the TR estimates USE in the weak direction using Position 1.2 of BTP 5-3; specifically, the weak direction USE is estimated to be 65 percent of the measured strong direction USE. These reduced values of measured strong direction USE are reported in the data sets as the “BTP 5-3” USE values. Separate Mean – 2σ calculations are also reported for both the measured “BTP 5-3” USE values and the full complement of measured USE values and estimated lower bound USE values to contextualize and justify the recommended generic values. However, it must be emphasized that the TR’s recommended generic USE values are set equal to the calculated Mean – 2σ values only for Charpy USE data that is measured in the weak direction.

The TR states that all measured USE values for Charpy tests in both the strong and weak directions are determined as per the following criteria:

- For a given forging Charpy test record, the TR attempts to determine a value for USE based on available percent shear measurements in a manner that is consistent with ASTM E185-82. Specifically, if the Charpy test data for the forging material contains *at least one* impact energy measurement with greater than or equal to 95 percent shear (i.e., “≥ 95 percent shear”), but some of the impact energy measurements report no percent shear values, all impact energies approximately greater than or equal to those that are known to exhibit ≥ 95 percent shear are assumed to have ≥ 95 percent shear. All “non-outlier” impact energy measurements with ≥ 95 percent shear are averaged to determine the measured USE, which is reported in the TR for the forging test record.

- TR states that if the Charpy test record contains limited or no percent shear data, however the upper-shelf region of the Charpy curve can be clearly determined from the data provided, the USE is identified by an approximately constant energy versus temperature region. As an example, the TR identifies cases where data points at four temperatures over a 50 °F range exhibited impact energy values within a scatter of 10°F or less. TR states that the existence of the upper-shelf region is confirmed by plotting the impact energy data and identifying if the plot levels off at higher temperatures. The reported USE represents an average of all Charpy energy values considered to be in the upper-shelf region.

In addition to measurements of actual USE, the TR also reports measured values of the absorbed Charpy impact energy in the strong direction for which actual USE is undetermined. For these cases, the reported Charpy impact energy is considered to represent a lower bound on actual USE for the forging, and the unknown USE is therefore reported to be *greater than or equal to* the reported Charpy impact energy. Further, since these impact energies are all measured in the strong direction, the TR provides BTP 5-3 estimates of absorbed impact energies in the weak direction, which are 65 percent of the measured impact energies in the strong direction. These cases are all designated in the TR as "USE ≥ XX," where the value of "XX" is a number that equals the reported Charpy impact energy, and they are also reported as "BTP 5-3" values. The TR's criteria for determining that "USE ≥ XX," where "XX" is a number that equals the reported impact energy are as follows:

- The TR states that if the test record reports percent shear values, but all data indicates a percent shear less than 95 percent, the USE is reported to be greater than or equal to the maximum Charpy impact energy. The reported impact energy is not incorporated into the calculation of the recommended Mean – 2σ value since this recommended generic value is based exclusively on the measured weak direction USE values.

- The TR states that if the test record included limited shear data or did not include shear data, and Charpy impact energies are increasing throughout the temperature range available, it is unknown if the upper-shelf has been reached. The TR states that the USE is reported to be greater or equal to the highest Charpy impact energy value available; or if the highest data point is determined to be a potential 'outlier' or a non-representative data point, the USE is reported as greater than or equal to a value less than the highest energy value based on the average of the comparable preceding data points. In these instances, the reported impact energy is not incorporated into the calculation of the generic USE.

In addition to data sets for SA508, Class 2 forgings supplied by Rheinstahl Huttenwerke AG and Fried-Krupp Huttenwerke AG, the TR also reports Charpy impact energies and USE data for several other firms who supplied SA508, Class 2 forgings to Rotterdam; these include Klöckner-Werke AG, Terni, Marrèl-Freres, and an unknown supplier. The Charpy test data from these other suppliers is independently evaluated in Section 4.3 of the TR, but due to more limited data sets for each of the other suppliers, a statistical evaluation to determine generic USE values for the other suppliers is not performed. Instead the TR shows that all measured USE values and Charpy impact energies (where USE is reported as greater than or equal to the reported Charpy impact energy, as per the above), are greater than the recommended Mean – 2σ values from the Rheinstahl Huttenwerke AG and Fried-Krupp Huttenwerke AG data sets. Based on this comparison, this section of the TR concludes that an SA508, Class 2 forging from an unknown supplier in a Rotterdam-fabricated RV would be expected to have an unirradiated Charpy USE value of at least 52 ft-lbs. Therefore, the TR recommends 52 ft-lbs. as the generic unirradiated Charpy USE value to be used for SA508, Class 2 forgings in Rotterdam RVs if the forging supplier is unknown.

Generic Charpy USE, Copper Content, and Nickel Content for Rotterdam RV Welds

The TR states that the Rotterdam CMTRs identify two types of welds used in the fabrication of the RVs: SMAWs and SAWs. Each type is evaluated separately. The TR states that the industry practice at the time of Rotterdam RV fabrication was to perform Charpy tests at a limited number of temperatures to show 30 ft-lbs. or more of absorbed energy at 10 °F. These tests were considered sufficient to satisfy ASME Code requirements at that time; however, the CMTRs often contain insufficient Charpy impact data to determine measured values of USE. The TR recommends a generic unirradiated Charpy USE value of 75 ft-lbs. for Rotterdam RV SAWs; this is the Mean – 2σ value for the set of seven measured unirradiated USE values from RV material surveillance programs. The TR states that the Rotterdam RV SAW data set represents every SAW material vendor and every flux type, with the exception of Linde 80 flux type. The TR emphasizes that the SAW welds of the Linde 80 flux type are specifically excluded from the Rotterdam weld analyses. The TR identifies that outside of the baseline USE measurements from the RV material surveillance programs, there is no meaningful USE information available in the CMTRs for Rotterdam SAWs. Therefore, only the seven measured USE values for SAWs from RV surveillance programs are reported in the TR.

The TR states that out of 38 SMAW Charpy test records, actual measured USE values are available for only three heats of SMAW material. The three measured USE values are 116, 130, and 134 ft-lbs. The TR does not determine a Mean – 2σ value for these three due to the statistically insignificant size of the data set. For the remaining 35 Charpy test records, the TR determined a lower bound on the USE for each SMAW based on the available Charpy impact energy data using methods similar to those described above for SA508, Class 2 forgings. If no percent shear data is available, the USE is reported as "greater than or equal to" the average of the Charpy impact energies at the test temperature, typically around 10 °F. When percent shear values are reported, and each is less than 95 percent, then the TR reports maximum Charpy impact energy for the weld test. Based on these methods, the TR determined that its recommended generic unirradiated Charpy USE value for Rotterdam SMAWs is 72 ft-lbs., which is based on the non-outlier weld heat showing the lowest of the "lower bound USE values."

In addition to the generic USE, the TR determines generic Cu and Ni weight percentages for both SAWs and SMAWs based on the calculation of Mean + 1σ for the data sets. The TR identifies this method as consistent with RG 1.99, Rev. 2, which states that conservative estimates of Cu and Ni content based on generic data may be used if justification is provided; the TR notes that for Cu and Ni content, the RG identifies "*conservative estimates*" as "*mean plus one standard deviation*." The TR further states that if a common weld metal heat and flux type combination is shared between multiple welds, the average chemistry value for the heat is considered as one data point when determining the generic weld chemistry values so as not to assign undue weight to multiple samples of weld material of the same heat. The chemistry data used in the evaluation consists of measurements from RV surveillance programs, supplemented with all available chemistry data for heats outside the surveillance programs. The TR states that the data is limited to deposited weld chemistry results, unless otherwise noted. The TR notes that the Cu content for one SAW material (Smit-Weld Heat No. 25006) is based on the weld wire analysis since deposited weld chemistry is not available.

4.0 STAFF EVALUATION

The NRC staff's review of PWROG-17090-NP, Rev. 0 addressed whether the TR evaluations for determining the generic properties for Rotterdam RVs are acceptable as a basis for implementation of these properties in plant licensing applications for demonstrating compliance with RV fracture toughness requirements in 10 CFR Part 50, Appendix G; 10 CFR 50.61 or 50.61a; and TLAAs related to RV fracture toughness per 10 CFR 54.21(c)(1). The staff applied the regulatory guidance regarding the use of generic data, as set forth in Section 2.0 of this SE, to determine whether the TR evaluations provide reasonably conservative generic estimates of these properties for use in plant licensing applications that address these requirements.

4.1 Generic Unirradiated Charpy USE for SA508, Class 2 Forgings in Rotterdam RVs

The TR determines generic unirradiated Charpy USE values for SA508, Class 2 RV forgings based on calculating the Mean – 2σ value for the set of measurements of Charpy USE in the weak direction, consistent with the criteria addressed in Section 2.0 of this SE. The staff identified that the TR's evaluation of generic data sets for determining generic USE values for the ASME SA508, Class 2 forging specification is consistent with the definition of the material "class" provided in 10 CFR 50.61, 10 CFR 50.61a, and RG 1.99, Rev. 2.

The TR identifies that several firms manufactured and supplied SA508, Class 2 RV forging components to Rotterdam; the TR indicates that Rotterdam procured the forgings to fabricate the welded RVs in the late 1960's and early 1970's timeframe. The Charpy test data sets used to establish the TR's generic USE values are based on the forging suppliers. Note 4 of 10 CFR Sections 50.61 and 50.61a states: "*Data from reactor vessels fabricated to the same material specification in the same shop as the vessel in question and in the same time period is an example of 'generic data.'*" The staff determined that for multiple suppliers of SA508, Class 2 forgings to the RV fabricator (Rotterdam), the "same shop" is appropriately considered in the TR to be the same firm responsible for manufacturing the forging component. Therefore, the staff determined that these generic data sets and corresponding generic USE values are appropriately delineated for plant-specific application in a manner that is consistent with Note 4 of 10 CFR 50.61 and 50.61a.

Although this Note 4 is specifically cited for the use of generic Cu and Ni content data to demonstrate compliance with applicable PTS requirements, the NRC staff finds that the criteria in Note 4 are also relevant to the TR's application of generic data for determining generic values of unirradiated Charpy USE. The NRC staff also finds there are no criteria in 10 CFR Part 50, Appendix G or NRC guidance related to Charpy USE that would prohibit or otherwise preclude the application of Note 4 to the determination of generic unirradiated Charpy USE based on forging manufacturer. Therefore, the staff finds that the TR's classification of the generic data sets for SA508, Class 2 forgings based on the forging manufacturer, consistent with Note 4 of the PTS requirements, is acceptable.

The RV forging suppliers and the number of Charpy test records for each forging supplier are listed below:

Forging Supplier	**Number of Charpy Test Records For Forging Components Supplied to Rotterdam**
Rheinstahl Huttenwerke AG	38
Fried-Krupp Huttenwerke AG	67
Klöckner-Werke AG	8
Terni	6
Marrèl-Freres	2
Unknown	1

The staff reviewed the TR methods for evaluating Charpy impact test data to determine either a measured value of the USE for the forging—or where a measured USE value could not be determined—the methods for determining a lower bound on the USE for the forging based on available Charpy test data. The staff's review of these methods is documented below.

For cases where Charpy impact energy data is accompanied by at least 1 percent shear measurement greater than or equal to 95 percent shear, the staff reviewed the TR methods for determining USE based on the definitions in ASTM E185-82. Specifically, upper-shelf energy is defined as the region in the Charpy transition curve where the broken specimens exhibit greater than 95 percent shear; and upper-shelf energy level is defined as the average of absorbed impact energy values for Charpy specimens whose test temperature is above the upper end of the transition region, which is below the USE region. This definition also states that for specimens tested in sets of three at each temperature, the set having the highest average impact energy may be regarded as defining the USE. The staff determined that the TR's statement that the reported USE is the average of all "*non-outlier*" impact energy values greater than or equal to the value(s) with greater than or equal to 95 percent shear is sufficiently consistent with this definition, provided that the staff could confirm, based on review of examples, that the elimination of the outlier data point is reasonable. Therefore, in RAI correspondence, the staff requested that the PWROG provide examples of both high and low outliers that were eliminated from this calculation of the average.

In its June 12, 2019, RAI-3 response (Ref. 2), the PWROG provided an example of an uncharacteristically low impact energy and an example of an uncharacteristically high impact energy, both of which are considered to be outliers and eliminated from the calculation of the average, which is the USE reported in TR. For both the high and low outlier impact energies, the RAI response identified all the other impact energies that went into the calculation of the average, as well as the test temperatures and the available percent shear measurements. The PWROG compared the outlier impact energies with the non-outlier data that was used to determine applicable USE values for these forging components, as reported in the TR. As described below, based on its review of the high and low outlier impact energies, and its review of PWROG's comparison of the outliers to the other data that was used to determine USE, the NRC staff was able to verify that appropriate engineering judgement was used in the elimination of the high and low outlier impact energies to determine the reported USE for these components. Therefore, the staff finds that this method for determining measured USE is acceptable.

If a Charpy test record includes no percent shear data for identifying USE, the staff reviewed the TR's reported method of determining USE by identifying an *"approximately constant energy versus temperature region"* in the Charpy data. The staff noted that the TR's example of four data points over a 50 °F temperature range exhibiting impact energy values within a scatter of 10 °F or less is appropriate for identifying the upper-shelf region because at temperatures above the transition region, impact energy values become approximately constant at or near the USE level. The staff noted that ASTM E185-82 defines the upper-shelf energy level as the average energy value for Charpy specimens whose test temperature is above the upper end of the transition region. Therefore, the staff confirmed that the USE value can be determined as the average of impact energies that are determined to be in the upper-shelf region based on low scatter over a large temperature range. The staff finds that this method for determining measured USE is acceptable.

When measured USE for the forging test record cannot be determined based on the above methods, the staff reviewed the two methods described in the TR for establishing a lower bound on the USE based on the available absorbed impact energy data.

- Based on the definitions in ASTM E185-82, the staff noted that if the test record includes percent shear values, and all are less than 95 percent, then the corresponding impact energies are not in the upper-shelf region; therefore, the staff identified that USE would be greater than or equal to the maximum absorbed impact energy with percent shear less than 95 percent. Based on the definitions in the ASTM standard, the staff finds this method for determining a lower bound on USE for the available test data to be acceptable.

- If shear data are not available, and it is seen, based on examination of impact energy data, that energies are increasing throughout the temperature range available, the staff confirmed that it would be unknown whether the USE region has been reached. The staff noted that for RV materials that were fabricated to earlier ASME Code editions, Charpy impact testing may not have occurred at temperatures above the transition region. Thus, it is reasonable for the TR to determine that USE for the material would be greater than or equal to absorbed impact energy in the transition region. The staff's review of specific cases for this situation is documented below based on its audit of Charpy test data for one of the forging suppliers.

The TR performed independent evaluations of Charpy test data for SA508, Class 2 forgings supplied by Rheinstahl Huttenwerke AG and Fried-Krupp Huttenwerke AG. The TR performed a third evaluation that addressed the other forging suppliers, which collectively includes Klöckner-Werke AG, Terni, Marrèl-Freres, and the unknown supplier. The staff's review addressed the three TR evaluations for establishing the recommended generic USE values.

Unirradiated USE Evaluation of RV Forgings Supplied by Rheinstahl Huttenwerke

The NRC staff confirmed that of the 38 Charpy test records that are available for Rheinstahl Huttenwerke AG forgings, there are 11 test records where measured values for unirradiated

Charpy USE were able to be determined based on the methodologies described above. The staff noted that 8 of the 11 forgings have measured USE values for both the strong and the weak directions; one forging has a measured USE value only in the strong direction; and two forgings have measured USE values only in the weak direction. For the 9 measured USE values in the strong direction, the staff confirmed that the TR correctly used Position 1.2 of BTP 5-3 to estimate the USE values in the weak direction; specifically, BTP 5-3 estimates of weak direction USE are equal to 65 percent of the measured USE values in the strong direction.

For the 11 forgings with measured values for Charpy USE, the staff's independent calculations showed the following.

- For the 10 measured USE values in the weak direction, the staff confirmed that the Mean – 2σ value for this data set is 56 ft-lbs., which is the recommended generic USE value for forgings supplied by Rheinstahl Huttenwerke AG. The staff noted that this bounds (i.e., is more conservative than) the lowest measured weak direction USE value of 64 ft-lbs.

- For the 9 BTP 5-3 estimates of USE in the weak direction, the staff confirmed that the Mean – 2σ value is 70 ft-lbs., which bounds the lowest BTP 5-3 USE value of 75 ft-lbs. The staff noted that the TR's recommended generic USE value of 56 ft-lbs. bounds these BTP 5-3 USE estimates. Therefore, based on review of all available USE data for Rheinstahl Huttenwerke AG forgings, the staff verified that the recommended generic USE value of 56 ft-lbs. is the most conservative.

BTP 5-3 Estimates of Lower Bound USE for Rheinstahl Huttenwerke Forgings

The NRC staff also confirmed that out of the 38 Charpy test records for the Rheinstahl Huttenwerke AG data set, there are 27 for which measured USE could not be established, but the available impact energy data were used to determine a lower bound on USE in the strong direction using the methods summarized above. Since all of the absorbed impact energies were measured in the strong direction, the TR determined estimates of absorbed impact energy in the weak direction to be 65 percent of the measured impact energies in the strong direction by applying BTP 5-3. The staff noted that 23 of these 27 estimates of lower bound USE are considered along with measured weak direction USE values and BTP 5-3 USE values in a separate Mean – 2σ calculation, which is 40 ft-lbs. The TR does not recommend 40 ft-lbs. as the generic USE value for Rheinstahl Huttenwerke AG forgings because the 23 BTP 5-3 estimates of lower bound USE included in this Mean – 2σ calculation do not represent actual USE for that test record. Specifically, Note "b" of the data set states that it is unknown whether the upper-shelf was reached during the test since the Charpy impact energies are increasing throughout the temperature range available, and "*the actual USE value is likely higher*."

The staff noted that the four lowest of the 23 lower bound USE estimates that were included in the Mean – 2σ calculation of 40 ft-lbs. are lower than the TR's recommended generic USE value of 56 ft-lbs. These values, which are annotated with Note "b" in the Rheinstahl Huttenwerke AG data set are 53 ft-lbs., 52 ft-lbs., and two values at 47 ft-lbs. The staff also noted that the calculation of 40 ft-lbs. excludes the four lowest of the 27 available lower bound USE estimates, which are 44 ft-lbs., 42 ft-lbs., and two values at 39 ft-lbs. Note "f" of the Rheinstahl Huttenwerke AG data set explains that the four lowest values of 44 ft-lbs., 42 ft-lbs., and two values at 39 ft-lbs. are "*excluded from statistical analysis*" because the values "*do not provide* *accurate representation of USE*," and "*the actual USE is likely much higher since a Charpy test with a similar absorbed impact energy has a shear value much less than 95 percent*."

The NRC staff identified that the Charpy test data used to determine the eight lowest estimates of lower bound USE needed to be reviewed to assess whether the reported impact energies are below the upper-shelf region. Therefore, as part of its TR review, the staff audited Charpy test records for the following Rheinstahl Huttenwerke AG forgings, which had the eight lowest reported absorbed impact energies:

Four Lowest Impact Energies, Rheinstahl Huttenwerke AG Forgings with Note "b" (Included in Mean – 2σ of 40 ft-lbs.; 40 ft-lbs. is not the recommended USE)		
Component Identification	Measured Absorbed Impact Energy, Strong Direction	BTP 5-3 Estimate of Absorbed Impact Energy, Weak Direction (i.e., "Lower Bound USE Estimates")
Plant D, Intermediate Shell	82 ft-lbs.	82 ft-lbs. X 65% = 53 ft-lbs.
Plant E, Inlet Nozzle 11	80 ft-lbs.	80 ft-lbs. X 65% = 52 ft-lbs.
Plant D, Inlet Nozzle 09	72 ft-lbs.	72 ft-lbs. X 65% = 47 ft-lbs.
Plant F, Inlet Nozzle 09	72 ft-lbs.	72 ft-lbs. X 65% = 47 ft-lbs.

Four Lowest Impact Energies, Rheinstahl Huttenwerke AG Forgings with Note "f" (Excluded from All Statistical Evaluations)		
Component Identification	Measured Absorbed Impact Energy, Strong Direction	BTP 5-3 Estimate of Absorbed Impact Energy, Weak Direction (i.e., "Lower Bound USE Estimates")
Plant E, Upper Shell	68 ft-lbs.	68 ft-lbs. X 65% = 44 ft-lbs.
Plant F, Outlet Nozzle 13	64 ft-lbs.	64 ft-lbs. X 65% = 42 ft-lbs.
Plant D, Inlet Nozzle 11	60 ft-lbs.	60 ft-lbs. X 65% = 39 ft-lbs.
Plant D, Outlet Nozzle 14	60 ft-lbs.	60 ft-lbs. X 65% = 39 ft-lbs.

The staff's audit of the Charpy test records for the eight forging materials included review of test temperatures, absorbed impact energies, and available percent shear measurements. The staff's review identified that the maximum absorbed impact energies in the eight Charpy test records correspond to the measured impact energy values for the strong direction that are reported in the TR. The staff's audit generally confirmed TR statements that the eight lowest impact energies are not representative of the USE for those forgings since the impact energies were increasing throughout the temperature range shown in the test record. Based on the increasing energy trends, available test temperatures, and the limited amount of shear data, the staff found that there is sufficient evidence that the materials were likely in the transition region at the highest test temperatures documented in the records. Thus, the staff confirmed that the actual USE values for these forgings, while unknown (because it was likely not reached during the test evolution), can reasonably be expected to be higher than the measured values of absorbed impact energy for the strong direction, as reported in the TR for these eight forgings. Based on its audit of the test records, the staff found that the eight lowest impact energies do not need to be considered in the statistical evaluation of the measured USE values for determining the TR's recommended generic USE value.

The staff also noted that the other 19 BTP 5-3 estimates of lower bound USE are all greater than the TR's recommended generic value of 56 ft-lbs.; this provides additional evidence that the Mean – 2σ value for the ten measurements of Charpy USE in the weak direction is a conservative generic estimate of unirradiated Charpy USE for this forging supplier. Therefore, the staff confirmed that 40 ft-lbs. does not warrant implementation as a generic estimate of USE for Rheinstahl Huttenwerke AG forgings. Accordingly, the staff finds that 56 ft-lbs. is acceptable for implementation as a generic unirradiated Charpy USE value for SA508, Class 2 RV forgings supplied by Rheinstahl Huttenwerke AG for Rotterdam RVs.

Unirradiated USE Evaluation of RV Forgings Supplied by Fried-Krupp Huttenwerke AG

The NRC staff confirmed that of the 67 Charpy test records that are available for Fried-Krupp Huttenwerke AG forgings, there are 38 test records where measured values for unirradiated Charpy USE were able to be determined based on the methodologies described above. For the 38 forgings with measured USE values, the staff noted that 5 of the 38 forgings have measured USE values for both the strong and the weak directions, and the other 33 have measured USE values only in the strong direction. For all 38 measured USE values in the strong direction, the staff confirmed that the TR correctly used Position 1.2 of BTP 5-3 to estimate USE values in the weak direction. For the 38 forgings with measured values for Charpy USE, the staff's independent calculations showed the following.

- For the 5 measured USE values in the weak direction, the staff confirmed that the Mean – 2σ value for this data set is 52 ft-lbs., *which is the recommended generic USE value for forgings supplied by Fried-Krupp Huttenwerke AG*. The staff noted that this bounds (i.e., is more conservative than) the lowest measured weak direction USE value of 62 ft-lbs.

- For the 38 BTP 5-3 estimates of USE in the weak direction, the staff confirmed that the Mean – 2σ value is 61 ft-lbs., which is equal to the lowest of the 38 BTP 5-3 USE estimates. The staff noted that the TR's recommended generic USE value of 52 ft-lbs. bounds this BTP 5-3 USE estimate. Therefore, based on review of all available USE data for Fried-Krupp Huttenwerke AG forgings, the staff verified that the recommended generic USE value of 52 ft-lbs. is the most conservative.

BTP 5-3 Estimates of Lower Bound USE for Fried-Krupp Huttenwerke AG Forgings

The NRC staff also confirmed that out of the 67 Charpy test records for the Fried-Krupp Huttenwerke AG data set, there are 29 for which measured USE could not be determined, but BTP 5-3 estimates of the lower bound on USE could be determined, as per the criteria above. All of the 29 estimates of lower bound USE are considered along with the measured USE values in a separate evaluation that calculates a Mean – 2σ value of 51 ft-lbs. The TR does not recommend 51 ft-lbs. as the generic USE value for these forgings because the 29 BTP 5-3 estimates of lower bound USE included in this Mean – 2σ calculation do not represent actual USE for that test record. The 29 BTP 5-3 estimates of lower bound USE are annotated with either Note "b" or Note "f". Note "b" states that it is unknown whether the upper-shelf was reached during the test since the Charpy impact energies are increasing throughout the temperature range available, and "*the actual USE value is likely higher*." Note "f" states that *"reported shear values are less than 95 percent shear, and the reported* [impact energy] *value is less than or equal to the maximum energy value of a Charpy specimen with less than 95 percent shear,"* and as a result, *"the USE is higher than the Charpy data reported."* The staff identified that there are no lower bound USE estimates that are excluded from the Mean – 2σ calculation of 51 ft-lbs. Further, just two of the 29 lower bound USE estimates (51 ft-lbs. and 50 ft-lbs.) are lower than the TR's recommended generic USE value of 52 ft-lbs. The staff determined that actual USE values for these two forgings, while unknown, would likely be higher than their reported lower bound values given that these impact energies are annotated with Note "b" identifying that impact energies are increasing throughout the temperature range available. The staff noted that all of the other 27 lower bound USE estimates are greater than the TR's recommended generic USE value of 52 ft-lbs. for this forging supplier. Therefore, the staff finds that 52 ft-lbs., based on the Mean – 2σ for the 5 measured USE values in the weak direction, is acceptable for implementation as a generic unirradiated Charpy USE value for SA508, Class 2 RV forgings supplied by Fried-Krupp Huttenwerke AG for Rotterdam RVs.

Unirradiated USE Evaluation of RV Forgings from Other Suppliers

The staff noted that there are 17 Charpy test records represented in a single data set provided in TR Table 7 for the other forging suppliers, which includes Klöckner-Werke AG, Terni, Marrèl-Freres, and an unknown company. In RAI correspondence, the NRC requested that the PWROG resolve the apparent inconsistency in the TR regarding the number of Charpy test records from an unknown company because in Table 2 the TR identifies that there are two forging components from an unknown supplier, whereas Table 7 of the TR lists one impact energy measurement for the unknown supplier. In its June 12, 2019, RAI-2 response (Ref. 2), the PWROG indicated that there are two SA508, Class 2 forging materials with an unknown supplier, as shown in TR Table 2 – however, only one such material is listed in TR Table 7 because the Charpy test record is not available for the other "unknown supplier" material. Accordingly, Charpy data for the other SA508, Class 2 forging component from an unknown supplier could not be included Table 7.

Out of these 17 test records, the staff noted there are two with measured USE values in the weak direction; these USE values are 134 ft-lbs. and 141 ft-lbs. There are 10 measured USE values in the strong direction, for which the TR applied BTP 5-3 to estimate weak direction USE; the staff identified that the lowest of the BTP 5-3 USE estimates is 94 ft lbs. The USE is unknown for 7 test records, but a lower bound on USE in the strong direction was established based on evaluation of available absorbed impact energy data that is established to be in the transition region (i.e., the energies are increasing throughout the temperature range available); this is same method as that used for the Rheinstahl Huttenwerke AG and Fried-Krupp Huttenwerke AG data sets, as identified in Note "b" for these data sets. As with the other SA508, Class 2 data sets, the lower bound USE values are reduced per BTP 5-3 to determine estimates of lower bound USE in the weak direction. The lowest of these BTP 5-3 estimates of lower bound USE for the other forging suppliers is 75 ft-lbs.

Considering the smaller number of records covering the three known suppliers and the unknown supplier, the staff confirmed that it is reasonable for the TR to select a lower generic USE value that could be used for SA508, Class 2 forgings in Rotterdam RVs if the forging manufacturer is unknown. For this purpose, the TR recommended that a generic USE value of 52 ft-lbs. be used for SA508, Class 2 forgings in Rotterdam RVs if the forging manufacturer is unknown. In its June 12, 2019, RAI-7 response (Ref. 2) the PWROG clarified that the generic value of 52 ft-lbs. is not intended for the suppliers Klöckner-Werke AG, Terni, or Marrèl-Freres because data for all known and applicable Rotterdam RV forgings from these suppliers are provided in Table 7 of the TR for this data set. The PWROG stated that there is sufficient data in Table 7 for these components to justify a component-specific USE value that is higher than 52 ft-lbs. The staff reviewed this RAI response and confirmed that the applicable component-specific USE value (or lower bound USE estimate, as applicable) should be used for plants that can identify their forgings from among the components listed in Table 7.

With respect to a generic USE value of 52 ft-lbs. for an unknown forging supplier in a Rotterdam RV, the NRC staff considered all Charpy test data for all SA508, Class 2 forging manufacturers evaluated in the TR and noted the following:

- There are 122 Charpy impact test records evaluated in the TR.
- 52 ft-lbs. is the most bounding of the two Mean – 2σ values for the two largest suppliers, Rheinstahl Huttenwerke AG and Fried-Krupp Huttenwerke AG.
- 52 ft-lbs. bounds all available Charpy impact test data (measured weak direction USE data, BTP 5-3 USE data, and lower bound USE estimates) from the three other known suppliers and the unknown supplier.
- For all forging suppliers, 52 ft-lbs bounds all measured USE values in the weak direction and all BTP 5-3 USE estimates for the weak direction (i.e., USE estimates based on application of BTP 5-3 to USE measurements in the strong direction).
- 52 ft-lbs bounds 21 of the 27 BTP 5-3 estimates of lower bound USE in the Rheinstahl Huttenwerke AG data set and 27 of the 29 lower bound USE estimates in the Fried-Krupp Huttenwerke AG data set.
- For the those several BTP 5-3 estimates of lower bound USE in the two largest data sets that are less than 52 ft-lbs, the staff determined based on review TR methods and audit of Charpy test records that actual USE values for these forgings, while unknown, would likely be higher than their reported lower bound values given that these impact energies are increasing throughout the temperature range available.

Therefore, based on its review of all the SA508, Class 2 Charpy test data, the staff determined that for a Rotterdam RV with SA508, Class 2 forging(s) from an unknown supplier, there is reasonable assurance the USE value for that forging would be at least 52 ft-lbs. Accordingly, the staff finds that 52 ft-lbs is acceptable for implementation as a generic unirradiated Charpy USE value for SA508, Class 2 RV forgings from an unknown supplier in Rotterdam RVs.

4.2 Generic Charpy USE, Cu Content, and Ni Content for Rotterdam RV Submerged Arc Welds and Shielded Metal Arc Welds

The TR determined generic values of unirradiated Charpy USE, Cu content, and Ni content for Rotterdam SAWs and SMAWs. Data sets for Charpy USE, Cu content, and Ni content were separately evaluated in the TR to determine the recommended generic properties for these two weld types. The NRC staff's review of these data sets and data analyses follows below.

Rotterdam RV Submerged Arc Welds

The NRC staff reviewed Charpy USE values and chemistry data for Rotterdam SAWs, which are provided in TR Tables 9 and 10, respectively. These tables also identify the flux types and weld wire vendors. The TR indicates that the two flux types ("SAF89" and "LW320") and six weld wire vendors identified in these tables are generically applicable to SAW materials for Rotterdam RVs, except for welds with Linde 80 flux type. SAWs with Linde 80 flux type are excluded from these generic analyses since welds with Linde 80 flux have been generically analyzed previously. The staff found that the TR adequately defined the material class for Rotterdam SAWs based on its identification of the two flux types and six wire vendors used to fabricate these welds.

The TR determines the generic unirradiated Charpy USE value for Rotterdam SAWs by calculating the Mean – 2σ for the set of seven measured values of unirradiated Charpy USE for the "Non-Linde 80" SAWs included in Rotterdam RV surveillance programs. The seven USE values are listed in TR Table 9. Note "a" of Table 9 identifies that these USE values are determined as the average of all available absorbed energy values with percent shear greater than or equal 95 percent, as per the ASTM E185-82 method that was used to determine USE for the RV forgings. As with the forgings, the staff determined that the TR's application of the ASTM E185-82 definitions for determining the seven USE values is acceptable.

The staff noted that for six of the seven Charpy USE values in Table 9, the reported USE value corresponds to a SAW for a specific unnamed plant (e.g., "Plant B"). One USE value in Table 9 corresponds to SAWs at four plants (Plants "A", "G", "H", and "I"). In its June 12, 2019, RAI-5 response (Ref. 2), the PWROG identified that each of the seven unirradiated Charpy USE values in Table 9 represents a unique heat of weld material.

The staff confirmed that the Mean – 2σ value for the set of seven baseline Charpy USE values for SAWs in Rotterdam RV surveillance programs is 75 ft-lbs. The staff noted that this recommended generic USE value bounds (i.e., is more conservative than) the lowest of the seven measured USE values, which is 82 ft-lbs. Considering that surveillance welds were selected from the amongst the core region welds (i.e., welds located in the original 40-year beltline region), the staff noted that the Mean – 2σ value of 75 ft-lbs may be reasonable for generic application to the non-Linde 80 core region SAWs in Rotterdam RVs. Additional considerations regarding the applicability of this data to *all* Rotterdam SAWs are discussed below.

The TR identifies that outside of the baseline USE measurements from RV surveillance programs, no USE information is available for Rotterdam SAWs. The TR states that the industry practice at the time of Rotterdam RV fabrication was to test Charpy specimens at 10 °F or lower to show 30 ft-lbs or more of absorbed energy, and the reporting of this test information in the Rotterdam CMTRs was considered sufficient to satisfy the fracture toughness requirements of the ASME Code at that time. The TR also states that the core region welds had the same specification requirements as the other RV welds, but for core region welds, Rotterdam was required to "aim for" both a Charpy V-Notch Transition Temperature (TTCV) and a Nil-Ductility Transition Temperature (NDTT) based on drop weight testing less than 10 °F, and to furnish additional test results relevant to TTCV and NDTT. The TR also states "*the TTCV and NDTT do not occur near the upper-shelf region, and thus, the surveillance capsule program test results are generically representative of the SAWs produced at Rotterdam for USE calculations*." Considering this information, the staff surmised that CMTRs for non-surveillance welds would show low test temperatures and correspondingly low impact energies, which could not be used to further support the generic USE value of 75 ft-lbs based on the surveillance weld USE data in Table 9.

The NRC staff identified that additional information was needed to confirm that the seven USE values for Rotterdam SAWs in Table 9 are representative for Rotterdam SAWs in general. In its RAI, the staff requested that the PWROG address how specification requirements and test criteria for Rotterdam SAWs support the TR determination that the baseline USE data for surveillance program SAWs in Table 9 is representative of Rotterdam SAWs in general. In its June 12, 2019, RAI-6 response (Ref. 2), the PWROG stated that based on acceptance criteria for Rotterdam RV welds, the flux/wire welds (SAWs) did not have chemistry requirements, but all welds had the same mechanical requirements, which included a minimum tensile strength of 80 ksi, a minimum absorbed Charpy impact energy of 30 ft-lbs for the average of three specimens, and a minimum absorbed Charpy impact energy 25 ft-lb for one individual specimen. The PWROG emphasized that these requirements were identical for the beltline and non-beltline SAWs; however, the core region welds had *additional* requirements to establish both the TTCV based on Charpy testing and NDTT based on drop weight testing, and to “aim for” a transition temperature of 10° F. The PWROG emphasized that these additional testing requirements for core region welds would not affect the USE, since these properties are associated with ductile-to-brittle transition, not the ductile region. Since the requirements for tensile strength and absorbed Charpy impact energy were equivalent, the PWROG stated that it is expected that all Rotterdam RV SAWs were taken from the same set of available weld metals. The PWROG identified that this is further supported by the known instances where a core region weld and a non-core region weld share the same heat number. Therefore, the PWROG concluded that the statistical analysis of the core region surveillance program SAW materials are also applicable to the non-core region SAWs.

The staff considered the RAI response statement that the same set of requirements for minimum tensile strength and absorbed Charpy impact energy were applicable to all Rotterdam RV SAW materials (core region welds and welds outside of the region), and the TR information indicating that the six SAW weld wire vendors and two flux types identified in Tables 9 and 10 are applicable to all Rotterdam SAWs (excluding Linde 80 flux type). The staff also took into consideration the RAI response statement that applicability of SAW generic USE data in Table 9 is supported by known instances where a core region weld and a non-core region weld share the same heat number. Based on consideration of this information, the staff determined that the Mean – 2σ value of 75 ft-lbs, for the seven heat-specific unirradiated USE measurements for SAWs in Rotterdam RV surveillance programs is reasonable as a conservative estimate of the unirradiated Charpy USE for Rotterdam SAWs. Therefore, the staff finds that 75 ft-lbs is acceptable for implementation as a generic unirradiated Charpy USE value for non-Linde 80 SAWs in Rotterdam RVs.

Based on its review of chemistry data provided in Table 10, the staff confirmed that measured values of Cu content are specified for 14 SAW heats. Where multiple Cu measurements (corresponding to specific flux lot numbers) are listed for a specific SAW heat and flux type, the staff confirmed that the Cu content value used in the Mean + 1σ calculation is the average of the measured Cu content values for that heat and flux type. One of the 14 Cu content values (0.17 percent) is identified as being based on the weld wire analysis, whereas all the other 13 values (as well as all Ni values addressed below) are based on the deposited content. The staff confirmed that the Mean + 1σ for the set of 14 Cu content values for Rotterdam SAW materials listed in Table 10 is 0.23 percent. Therefore, the staff determined that a generic Cu content of 0.23 percent may be used for non-Linde 80 Rotterdam SAWs if the measured value is unknown for the specific SAW material.

The staff confirmed that measured values of Ni content are available for 10 SAW heats. All 10 Ni content measurements are identified as based on the deposited weld content. The staff confirmed that the Mean + 1σ for the set of 10 Ni content values for Rotterdam SAW materials listed in Table 10 is 0.56 percent. Therefore, the staff determined that a generic Ni content of 0.56 percent may be used for non-Linde 80 Rotterdam SAWs if the measured value is unknown for the specific SAW material.

Rotterdam RV Shielded Metal Arc Welds

The NRC staff reviewed the available Charpy impact energy data, percent shear data, chemistry data, and weld identification information for Rotterdam SMAWs, which are provided in TR Table 12. The staff noted that there are 38 Rotterdam SMAWs addressed in TR Table 12, each of which has a unique heat number associated with it. Table 12 identifies four weld types corresponding to four vendors for the 38 heats of SMAW material listed therein. The TR states that all SMAW heats that were used in RV fabrication by Rotterdam, and that are available in the Westinghouse records, are included in Table 12. The staff determined that this information is sufficient to define the material class for Rotterdam SMAWs.

Of the 38 absorbed impact energy values reported in Table 12, the staff confirmed that there are only three measured values for Charpy USE for Rotterdam SMAWs. These values are: 130 ft-lbs, 116 ft-lbs, and 134 ft-lbs. All three USE values have percent shear values of 100 percent. The staff agreed with the TR determination that the three measured USE values do *not* constitute a data set of sufficient size to define a generic USE value based on Mean – 2σ. Therefore, the TR used a different approach to determine its recommended generic Charpy USE value of 72 ft-lbs for Rotterdam SMAWs.

As addressed in Section 2.0 of this SE, RG 1.99, Rev. 2, does not explicitly specify "Mean – 2σ" as a recommended method for determining a generic unirradiated USE based on evaluation of generic data for a "class" of material, and the USE requirements of 10 CFR Part 50, Appendix G are generally silent on this issue. Further, Position 1.3 of BTP 5-3 states that "*in the case of older plants, the* [preservice fracture toughness] *data may be estimated using procedures listed above* [Position 1.2 for plant-specific USE measurements] *or other methods that can be shown to be conservative* [emphasis added]"

For Rotterdam RV SMAWs, the staff reviewed the TR evaluation for determining a generic USE value of 72 ft-lbs by assessing whether the evaluation has been shown to be conservative, as specified in Position 1.3 of BTP 5-3. While only 3 of the 38 impact energies in Table 12 are determined to be the actual USE, the other 35 absorbed impact energies in Table 12 are reported to represent a lower bound on the USE for the test record. As with the lower bound USE values for SA508, Class 2 forgings, the actual USE values for these 35 SMAW materials are unknown, and they are identified as being "*greater than or equal to*" the reported impact energy. Of these 35 lower bound USE values, four of them have percent shear measurements that are less than 95 percent, and 31 do not have percent shear measurements. The TR identifies that all 35 lower bound USE values are based on Charpy tests completed at 10.4 °F or lower and shear values which are either unknown or less than 95 percent. The TR states that USE is typically reached at a temperature greater than 10 °F, as demonstrated by the welds with actual measured USE values, which reached the upper-shelf at temperatures of approximately 70 °F or higher.

Considering all 38 impact energies reported in Table 12 (35 lower bound USE values plus 3 actual USE values), the staff noted 72 ft-lbs for Heat No. 9092 is the second lowest value.

The staff also noted that 72 ft-lbs is the lowest of the 31 lower bound USE values that do not have percent shear measurements reported in Table 12. The staff confirmed that the lowest impact energy value in Table 12 is 63 ft-lbs for Heat No. 7359.6708; this impact energy has a corresponding percent shear value of 52 percent. Considering this percent shear measurement, and the low temperature range reported for the Charpy impact test (10.4 °F or lower), the staff found that it is reasonable to expect that actual USE for Heat No. 7359.6708 would be significantly greater than 63 ft-lbs if testing of this SMAW material had continued at higher temperatures into the upper-shelf region. On this basis, the staff determined that 63 ft-lbs for Heat No. 7359.6708 does not warrant consideration for determining the generic USE value for Rotterdam SMAWs based on the lower bound USE values listed in Table 12. Therefore, the staff finds that the lower bound USE value of 72 ft-lbs is acceptable for implementation as a generic unirradiated Charpy USE value for SMAWs in Rotterdam RVs.

Based on its review of chemistry data provided in Table 12, the staff confirmed that measured values of Cu content are available for only two SMAW heats. The staff agreed with the PWROG determination that this is insufficient data to determine a generic Cu content value. Accordingly, the staff confirmed that the default Cu content of 0.35 percent, as specified in RG 1.99, Rev. 2, would be the correct value to use if no other information is available (i.e., no heat-specific measurements, no Cu content requirements in material specifications, and no conservative estimates (Mean + 1σ) based on generic data). The staff noted that the default Cu content of 0.35 percent is conservative relative to the measured values, 0.01 percent and 0.023 percent, for Rotterdam SMAWs. Therefore, the staff finds that the RG 1.99, Rev. 2, default Cu content of 0.35 percent is acceptable for Rotterdam SMAWs if the measured value is unknown for the specific SMAW material.

The staff noted that 32 of the 38 SMAW heats listed in Table 12 have measured values of Ni content. The staff determined that this constitutes a sufficient set of measurements to determine a generic value based on Mean + 1σ for Rotterdam SMAWs, as per RG 1.99, Rev. 2. The staff confirmed that the Mean + 1σ for the set of 32 Ni content values for Rotterdam SMAW materials listed in Table 12 is 1.13 percent. Therefore, the staff finds that a generic Ni content 1.13 percent is acceptable for Rotterdam SMAWs if the measured value is unknown for the specific SMAW material.

The TR also recommends that if insufficient data exists to determine whether a Rotterdam RV weld is a SAW or a SMAW, then the generic values for unirradiated Charpy USE, Cu content, and Ni content for Rotterdam SMAWs can be utilized. The staff confirmed that the above generic values for unirradiated Charpy USE, Cu content, and Ni content for Rotterdam SMAWs are bounding relative to those for Rotterdam SAWs. The staff also noted that the TR affirmatively states that Rotterdam CMTRs specify only these two weld types for Rotterdam RVs. Therefore, the staff finds that the generic properties for Rotterdam SMAWs are acceptable for Rotterdam RV welds if the weld type (SAW or SMAW) is unknown and if measured values of the applicable properties are unknown for the specific weld materials.

5.0 CONDITIONS AND LIMITATIONS

There is no NRC staff-imposed condition or limitation on the use of this TR in licensing applications for addressing regulatory requirements in 10 CFR Part 50, Appendix G; 10 CFR 50.61 or 50.61a; and/or TLAA requirements in 10 CFR 54.21(c)(1). However, PWR plants referencing the TR as the basis for the generic Rotterdam RV material properties provided therein must ensure that their RV materials meet the criteria specified in the TR, as set forth below.

The generic properties provided in the TR are for implementation as conservative generic estimates for the material classes identified below *only if no measured values of unirradiated Charpy USE, Cu content, and/or Ni content are available* for the specific RV material under consideration. PWR plants that implement these generic estimates must identify their RV materials as follows:

- A PWR plant with a Rotterdam RV proposing to use the generic unirradiated Charpy USE value of 56 ft-lbs. for its RV forging(s) must identify that its forging(s) are of the SA508, Class 2 or A508, Class 2 specification and that the forging(s) were supplied by Rheinstahl Huttenwerke AG.

- A PWR plant with a Rotterdam RV proposing to use the generic unirradiated Charpy USE value 52 ft-lbs. for its RV forging(s) must identify that its forging(s) are of the SA508, Class 2 or A508, Class 2 specification. This generic unirradiated Charpy USE value may be used if the Rotterdam RV forging supplier is identified as Fried-Krupp Huttenwerke AG or if the forging supplier is unknown.

- A PWR plant with a Rotterdam RV proposing to use the generic unirradiated Charpy USE value of 75 ft-lbs. for its RV weld(s) must identify that the weld(s) are of the SAW type, that the SAWs are <u>not</u> of Linde 80 flux type, and that its SAW(s) were fabricated by Rotterdam.

- A PWR plant with a Rotterdam RV proposing to use the generic Cu content of 0.23 percent and generic Ni content of 0.56 percent for its RV weld(s) must identify that the weld(s) are of the SAW type, that the SAWs are <u>not</u> of Linde 80 flux type, and that its SAW(s) were fabricated by Rotterdam.

- A PWR plant with a Rotterdam RV proposing to use the generic unirradiated Charpy USE value of 72 ft-lbs. for its RV weld(s) must identify that the weld(s) were fabricated by Rotterdam. This generic unirradiated Charpy USE value may be used if the Rotterdam RV weld is identified as a SMAW or if the Rotterdam RV weld type is unknown.

- A PWR plant with a Rotterdam RV proposing to use the RG 1.99, Rev. 2, default Cu content of 0.35 percent and generic Ni content of 1.13 percent for its RV weld(s) must identify that the weld(s) were fabricated by Rotterdam. These values may be used if the Rotterdam RV weld is identified as a SMAW or if the Rotterdam RV weld type is unknown.

6.0 <u>CONCLUSION</u>

As set forth above, the NRC staff has reviewed the PWROG-17090-NP, Rev. 0, TR and has determined that the TR is acceptable for providing conservative estimates of generic unirradiated Charpy USE for ASME SA508, Class 2 (or the corresponding ASTM A508, Class 2) forgings in Rotterdam RVs; and conservative estimates of generic unirradiated Charpy USE, Cu content, and Ni content for Rotterdam SAWs and SMAWs based on the material classes specified in the TR. When measured values of unirradiated Charpy USE, Cu content, and/or Ni content are available for the specific RV materials under consideration, the measured values should be used.

The NRC staff's review has concluded that when measured values of unirradiated Charpy USE, Cu content, and/or Ni content are not available for the plant-specific Rotterdam RV materials under consideration, the generic values for the Rotterdam RV material classes identified in the TR may be used in PWR plant licensing applications for addressing regulatory requirements in 10 CFR Part 50, Appendix G; 10 CFR 50.61 or 50.61a; and/or TLAA requirements in 10 CFR 54.21(c)(1).

7.0 REFERENCES

1. Letter from Ken Schrader, Pressurized Water Reactor Owners Group, to USNRC Document Control Desk, April 6, 2018, Transmittal of Westinghouse Electric Company Report PWROG-17090-NP, Revision 0, "Generic Rotterdam Forging and Weld Initial Upper-Shelf Energy Determination," Westinghouse Non-Proprietary Class 3, March 2018 (ADAMS Accession No. ML18114A173).

2. Letter from Ken Schrader, Pressurized Water Reactor Owners Group, to USNRC Document Control Desk, June 12, 2019, Transmittal of the Response to Request for Additional Information, RAI 1-3 and 5-7 Associated with PWROG-17090, Revision 0, "Generic Rotterdam Forging and Weld Initial Upper-Shelf Energy Determination," Westinghouse Non-Proprietary Class 3, June 2019 (ADAMS Accession No. ML19170A106).

3. PWROG Topical Report, PWROG-17090-NP, Rev.0, "Generic Rotterdam Forging and Weld Initial Upper-Shelf Energy Determination", March 30, 2018 (ADAMS Accession No. ML18114A183).

4. American Society of Testing and Materials (ASTM) Standard E185-82, "Standard Practice for Conducting Surveillance Tests for Light Water Cooled Nuclear Power Reactor Vessels," 1982.

5. USNRC Regulatory Issue Summary 2014-11, "Information on Licensing Applications for Fracture Toughness Requirements for Ferritic Reactor Coolant Pressure Boundary Components," October 14, 2014 (ADAMS Accession No. ML14149A165).

6. USNRC Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," May 1988 (ADAMS Accession No. ML003740284).

7. USNRC NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, Branch Technical Position 5-3, Draft Revision 3, "Fracture Toughness Requirements," September 2018 (ADAMS Accession No. ML18254A090).

Attachment: Comment Resolution Table

Principle Contributor: Christopher R. Sydnor, NRR/DMLR

Date: December 12, 2019

TOPICAL REPORT PWROG-17090-NP, REVISION 0
COMMENT RESOLUTION TABLE

Comment No.	DSE Text Location		PWROG Comment	NRC Response
	Page No.	Line No.		
1	1	27	Revise the text “SA508, Class 2” to “ASME SA508, Class 2 (or the corresponding ASTM A508, Class 2)”.	The staff finds the proposed change acceptable because ASME SA508, Class 2 and ASTM A508, Class 2 are equivalent material specifications, and the change does not affect the staff’s findings or conclusions.
	6	38		
	23	37		
2	8	33	Add “or equal to” after “greater than.” The text “or equal to” will also be added to the corresponding location in the first sentence in PWROG-17090-NP Section 3.1, Bullet 1 in the NRC-approved version of the topical report that will be issued after the Final SE is issued. This is consistent with discussions in footnote (g) of PWROG-17090-NP Table 5 and footnote (e) of PWROG-17090-NP Table 7.	The staff finds the proposed change acceptable because it ensures technical consistency and does not affect the staff's findings or conclusions.
3	8	34 & 37	Revise “>” to “≥” to be consistent with PWROG-17090-NP Section 3.1, Bullet 1.	The staff finds the proposed change acceptable because it ensures technical consistency and does not affect the staff's findings or conclusions.
4	12	7 & 16	Add “or equal to” after “greater than.”	The staff finds the proposed change acceptable because it ensures technical consistency and does not affect the staff's findings or conclusions.
5	22	47	Add “of unirradiated Charpy USE, Cu content, and/or Ni content” after “measured values.”	The staff finds the proposed change acceptable because it provides additional clarification for this issue, and it does not affect the staff's findings or conclusions.
6	23	3 & 8	Add “or A508, Class 2” after “SA508, Class 2.”	The staff finds the proposed change acceptable because these are equivalent material specifications, and the change does not affect the staff’s findings or conclusions.