NON-PROPRIETARY RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION: COLUMBIA MUR

EVIB RAI 3.2-1 Upper Shelf Energy (USE)

Background:

Enclosure 9, "General Electric-Hitachi Nuclear Energy Report, NEDO-33853, Revision 0, Safety Analysis Report for Columbia Generating Station Thermal Power Optimization," to the license amendment request (LAR) dated June 28, 2016, contains the USE information and associated input values of the reactor pressure vessel (RPV) components for the MUR. This information is provided in MUR LAR Table 3-1, "CGS Upper Shelf Energy 60-Year License (51.56 EFPY [effective full-power year])", Table 3-2, "RPV Beltline Plate USE Equivalent Margin Analysis (51.56 EFPY)," and Table 3-3, "RPV Beltline Plate [Weld] USE Equivalent Margin Analysis (51.56 EFPY)."

The information in the MUR LAR, Enclosure 9, tables include:

> The USE projections and Equivalent Margin Analysis (EMA) performed at 51.56 EFPY for a 60-year license,

The CGS [Columbia] License Renewal Application (LRA) was evaluated and approved by NUREG-2123; "Safety Evaluation Report Related to the License Renewal of Columbia Generating Station" dated May 2012 (ADAMS Accession No. ML12139A300). The NRC staff's approval of the USE information and associated input values for the current 60-year operating license is based partially on its review of LRA Table 4.2-2, "USE Projections for 54 effective full-power year (EFPY)," Table 4.2-3, "RPV Beltline Plate USE Equivalent Margin Analysis for 54 EFPY," and Table 4.2-4, "RPV Beltline Weld USE Equivalent Margin Analysis for 54 EFPY," as revised by the applicable RAI responses.

The information in the licensee's LRA includes:

> License Renewal (LR) Commitment No. 70, stating that CGS [Columbia] will perform a 54 EFPY equivalent margin analysis for the embrittlement (upper shelf energy) of the reactor vessel N12 (instrumentation) nozzle forgings in letter dated December 14, 2011 (ADAMS Accession No. ML11354A097),

Sections 2.C(34) and 2.C(35) of Renewed Facility Operating License No. NPF 21 (ADAMS Accession No. ML053130319), specifies that the LR commitments and information in the final safety analysis report (FSAR) Supplement are henceforth part of the FSAR. Appendix A of NUREG-2123 lists the LR commitments. The CGS [Columbia] FSAR Supplement is located in Appendix A of the LRA, dated January 2010, as revised by the applicable RAIs.

FSAR Supplement Section A.1.3.1.2, as revised by letter dated December 14, 2011 (ADAMS Accession No. ML11354A097), provides a summary description for the USE evaluation described in LRA Section 4.2.2. The time-limited aging analysis (TLAA) evaluation performed in LRA Section 4.2.2 and described in FSAR Supplement Section A.1.3.1.2 is for 54 EFPY and a 60-year operating license. The staff's evaluation of the TLAA is documented in Section 4.2.2 of NUREG-2123.

Issue:

There are inconsistencies between the information provided in the MUR LAR and that provided in the LRA.

Request:

Describe the impact of the MUR on LR Commitment No. 70. If the commitment is no longer going to use 54 EFPY, justify the use of the new value. If the commitment is no longer, applicable state the basis for its elimination.

ENERGY NORTHWEST RESPONSE TO EVIB RAI 3.2-1:

There is no impact on License renewal Commitment No. 70 as a result of MUR. The equivalent margin analysis (EMA) will be performed as stated in the commitment. The EMA will be performed two years prior to reaching the period of extended operation (PEO) and use the fluence based on 54 EFPY. Using this EFPY for the analysis will bound the MUR stated EFPY of 51.56.

EVIB RAI 3.2-2 Adjusted Reference Temperature (ART)

Background:

In the LAR dated June 28, 2016, Enclosure 7, "Safety Analysis Report for Columbia Generating Station Thermal Power Optimization," Revision 0, Proprietary Version contains the [adjusted reference temperature] ART information and associated input values for the [reactor pressure vessel] RPV components for the MUR. This information is provided in MUR LAR Table 3-4, "CGS Adjusted Reference Temperatures 60-Year License (51.56 EFPY)."

The information in the MUR LAR, Enclosure 7, Table 3-4 includes:

> ART projections performed at 51.56 EFPY for a 60-year license,
>
> A percent nickel of [[ ]] for the N12 nozzle, Heat lot 2199721/1.

The staff's approval of the ART information and associated input values for the current 60-year operating license is based partially on its review of [license renewal application] LRA Table 4.2-5, "ART Values for 54 EFPY"; as revised by the applicable RAI responses.

The information in the licensee's LRA includes:

> A percent nickel of 1.00 for the N12 nozzle, Heat/Lot 219972 is provided in LRA Table 4.2-5, as revised by letter dated January 28, 2011.

[Final Safety Analysis Report] FSAR Supplement Section A.1.3.1.3, as revised by letter dated January 28, 2011, provides a summary description for the ART evaluation described in LRA Section 4.2.3. The [time-limited aging analysis] TLAA evaluation performed in LRA Section 4.2.3 and described in FSAR Supplement Section A.1.3.1.3 is for 54 [effective full power years] EFPY and a 60-year operating license. The staff's evaluation of the TLAA is documented in Section 4.2.3 of NUREG-2123.

Issue:

There are inconsistencies between the information provided in the MUR LAR and that provided in the LRA.

Request:

Reconcile the inconsistences between the ART information submitted in the MUR LAR and the ART information submitted in the LRA, with emphasis given to the:

1. Percent nickel for the N12 nozzles, 2199721/1.

Justify the values provided in the MUR LAR if they have not been previously evaluated by the NRC staff. Update the MUR LRA Tables and FSAR, as appropriate.

ENERGY NORTHWEST RESPONSE TO EVIB RAI 3.2-2:

Insufficient plant-specific chemistry information is available for the N12 Nozzle – Heat 219972/1. In the safety Evaluation Report (SER) for License renewal (NUREG-2123 Volume 2 (Reference 1, page 4-38), the chemistry values reported for Heat 219972/1 are assumed to be 0.35% Cu and 1.0% Ni consistent with the values prescribed in US NRC Regulatory Guide (RG) 1.99, Revision 2 (Reference 2) for heats where no chemistry information is available.

During the thermal power optimization (TPO) evaluation, GE-Hitachi Nuclear Energy Americas LLC (GEH) determined that these chemistry values were overly conservative as they were based on the RG 1.99 bounding methodology. GEH has a chemistry study database applicable to SA-508 Class 1 material; consistent with the methodology described in RG 1.99, the chemistry based on generic fleet Certified Material Test Report (CMTR) chemistry data could be used.

The GEH chemistry study contains % Ni values of all available SA-508 Class-1 forging materials in the boiling water reactor (BWR) fleet. Consistent with RG1.99, the chemistry value was determined using mean plus one standard deviation.

Below is a summary table of the GEH SA-508 Class-1 chemistry percent nickel database. The format of the database summary is consistent with how the % Cu information was previously transmitted to the Energy Northwest and NRC.

GEH SA-508-CL-1 Chemistry Percent Nickel Database Summary

SA 508-CL-1 %Ni
[[

]]

[[ ]] = Mean

[[ ]] = Standard Deviation

[[ ]] = Mean + One Standard Deviation

EVIB RAI 3.2-3 Circumferential and Axial Weld Parameters

Background:

Enclosure 9, "General Electric-Hitachi Nuclear Energy Report, NEDO-33853, Revision 0, Safety Analysis Report for Columbia Generating Station Thermal Power Optimization," of the LAR contains information related to the effects of irradiation on the RPV circumferential weld properties and axial weld properties. This information is provided in MUR LAR Table 3-6, "CGS 51.56 EFPY Effects of Irradiation on [reactor pressure vessel] RPV Circumferential Weld Properties."

The information in the LAR, Enclosure 9, tables include:

> A mean [reference nil-ductility temperature caused by irradiation] RT_{NDT} value of -5.6 degrees Fahrenheit [°F] based on limiting circumferential weld wire of 3P4955 in Table 3.6.

The staff's approval of the limiting circumferential and axial weld information for the current 60-year operating license is based partially on its review of LRA Table 4.2-6, "Circumferential Weld Parameters at 54 EFPY" as revised by the applicable RAI responses.

The information in the licensee's LRA includes a "mean ART" value of -6.0 degrees Fahrenheit based on a limiting circumferential weld wire of 5P6756 in Table 4.2.6.

FSAR Supplement Section A.1.3.1.6 provides a summary description for the RPV axial weld failure probability evaluation described in LRA Section 4.2.6. The TLAA evaluation performed in LRA Section 4.2.6 and described in FSAR Supplement Section A.1.3.1.6 is for 54 EFPY and a 60-year operating license. The staff's evaluation of the TLAA is documented in Section 4.2.6 of NUREG-2123.

Issue:

A justification has not been provided for establishing that circumferential weld wire 3P4955 is more limiting than 5P6756, with regard to the probability of failure. The limiting weld wire (3P4955) identified in LAR Table 3-6 appears to be less conservative then weld wire 5P6756. Weld wire 5P6756 has a larger ART value in LAR Table 3-4.

Request:

Justify the use of weld wire 3P4955, with a lower ART value than 5P6756, to evaluate the probability of failure of the circumferential welds. Substantiate that the evaluation for weld wire 3P4955 is bounding.

ENERGY NORTHWEST RESPONSE TO EVIB RAI 3.2-3:

The TPO T0301 evaluation considered both weld heat numbers (3P4955 and 5P6756) in the probability of failure evaluation for the circumferential welds.

Circumferential Weld Parameters at 51.56 EFPY

Parameter	NRC Limiting Specific Analysis (Circ Welds)[1] 64 EFPY (CB&I RPV)	CGS Best Estimate Chemistry Weld Wire (5P6756) 51.56 EFPY (CB&I RPV)	CGS Best Estimate Chemistry Weld Wire (3P4955) 51.56 EFPY (CB&I RPV)	CGS Overall Limiting Weld Wire (3P4955) 51.56 EFPY (CB&I RPV)
Cu%	0.10	[5]	[5]	[5]
N1%	0.99	[5]	[5]	[5]
CF	134.9	[6]	37	37
End of License Inside Diameter Fluence, (10^{19} n/cm^2)	1.02	0.0467	0.0467	0.047
$RT_{NDT(U)}$ (°F)	-65	-50	-16	-16
ΔRT_{NDT} w/o margin (°F) [2]	135.6	43.4	10.4	10.4
Mean RT_{NDT} (°F)	70.6	-6.6	-5.6	-5.6
P (F|E) NRC [3]	1.78E-05	[4]	[4]	[4]

Notes:

[1] Chemistry information reported in BWRVIP-05.

[2] $\Delta RT_{NDT} = CF * f^{(0.28 - 0.10 \log f)}$

[3] P (F/E) stands for "Probability of a failure event"

[4] Although a conditional failure probability has not been calculated, the fact that the Columbia values at the end of license are less than the 64 EFPY value provided by the NRC leads to the conclusion that the Columbia RPV conditional failure probability is bounded by the NRC analysis, consistent with the requirements defined in Generic Letter (GL) 98-05.

[5] See Enclosure 7, Table 3-4, CGS Adjusted Reference Temperatures 60-Year License (51.56 EFPY) of the LAR dated June 28, 2016, for chemistry values.

[6] See Enclosure 7, Table 3-4, CGS Adjusted Reference Temperatures 60-Year License (51.56 EFPY) of the LAR dated June 28, 2016, for chemistry factors.

As shown in the table above, the evaluation inputs and results between Heats 3P4955 and 5P6756, show that:

a.) Heat 5P6756 has a higher chemistry factor (CF) value than Heat 3P4955 (~154 °F (adjusted for ISP data) vs. 37 °F).

b.) Both heats have the same end of life fluence.

c.) Heat 5P6756 has a lower RT_{NDT} value than Heat 3P4955 (-50 °F vs. -16 °F).

d.) Heat 5P6756 has a lower calculated Mean RT_{NDT} than Heat 3P4955 (-6.6 °F vs. -5.6 °F).

Therefore, Heat 3P4955 is the Overall Limiting Weld Wire Heat material because it has a higher Mean RT_{NDT} and is reported as such in the Safety Analysis Report (SAR).

EVIB RAI 3.2-4 Pressure-Temperature (PT) Limits

Background:

Enclosure 9, "General Electric-Hitachi Nuclear Energy Report, NEDO-33853, Revision 0, Safety Analysis Report for Columbia Generating Station Thermal Power Optimization" of the LAR contains data concerning the current licensed PT curves and the ART values for the RPV beltline materials.

Specifically, LAR Enclosure 9, Section 3.2.1, "Fracture Toughness," states:

> "The [Thermal Power Optimization] TPO end of cycle 27 cumulative energy in less than the [Current Licensed Thermal Power] CLTP cumulative energy, therefore the CLTP curves remain bounding for TPO, limited to the currently approved fluence/EFPY (33.10 at OLTP). The current Adjusted Reference Temperature (ART) values for the beltline plates and welds from the PT curve report increase slightly for TPO conditions. However they remain bounded for TPO when compared to the TLAA evaluation (considers an EFPY and resulting higher fluence level)".

The information in the current licensing basis and LRA include:

> License Amendment No. 193, dated May 12, 2005 (ADAMS Accession No. ML051160277). The staff confirmed in Section 4.2.4 of NUREG-2123 that the PT limit curves are valid for the current licensed core thermal power level of 3486 MWt and 33.1 EFPY of facility operation, and bounding, for operation of the reactor coolant system through the end of the 40-year operating period.
>
> The ART TLAA for 54 EFPY in LRA Section 4.2.3, as evaluated in NUREG-2123.

FSAR Supplement Section A.1.3.1.4 provides a summary description for the PT limits evaluation described in LRA Section 4.2.4, as revised by letter dated November 23, 2010 (ADAMS Accession No. ML103280370). The TLAA evaluation performed in LRA Section 4.2.4 and described in FSAR Supplement Section A.1.3.1.4 is for 3486 MWt and 33.1 EFPY. The staff's evaluation of the TLAA is documented in Section 4.2.4 of NUREG-2123.

Issue:

The LAR states that the beltline plate and weld ART values from the PT curve report have increased but data has not been provided to conclude that the CLTP (3486 MWt) PT curves remain bounding for the MUR increased thermal power level of 3544 MWt. Additionally, it is not clear to staff that the how the ART TLAA evaluation for 3486 MWt and 54 EFPY support the continued use of PT curves for 3486 MWt and 33.1 EFPY at the proposed MUR thermal power level of 3544 MWt.

Request:

1. Provide the ART values for the limiting beltline plate, limiting beltline weld, limiting beltline nozzle, N6 nozzle, and plate surrounding the N12 nozzle at the thermal power optimization (TPO) conditions. Justify that the CLTP PT curves for 3486 MWt remain bounding for the MUR increased thermal power level and ART values related to 3544Mwt.

2. Clarify how the ART TLAA evaluations support that the current PT limit curves remain bounding for the increased thermal power level and increased ART values.

ENERGY NORTHWEST RESPONSE TO EVIB RAI 3.2-4:

1. The LRA evaluation conservatively considered the end of the 60-year license to occur at 54 EFPY. Table 4.2-5 in the LRA provides ART values, considering CLTP (3,486 MWt) conditions for the plates, welds, and applicable nozzles. For TPO, the end of the 60-year license was considered to occur at 51.56 EFPY. The fluence was adjusted to account for this reduction in time. It was then also increased to account for the increase in power from 3,486 MWt to 3,544 MWt due to TPO.

   The overall result of the fluence adjustment resulted in a lower ¼T fluence value for TPO conditions, due to the decrease in EFPY, compared to the CLTP value, because the small increase in fluence due to the increase in power level due to TPO was less than the reduction in fluence due to the decrease in the EFPY.

   The adjusted ¼T fluence was used in the ART calculation for TPO conditions. Table 3-4 in the TPO SAR (TSAR) provides the calculated ART values considering TPO conditions for the plates, welds, and applicable nozzles (N6 and N12).

   Because the ¼T fluence in the TPO 51.56 EFPY ART evaluation is less than the ¼T fluence used in the LRA 54 EFPY ART evaluation for all the evaluated plate, weld, and nozzle components, the resulting ART values are less than those reported in the 54 EFPY LRA. Therefore, the CLTP 54 EFPY ART evaluation remains bounding for the end of the 60-year license for TPO conditions. See the response to EVIB RAI 3.2-4 Item 2 for additional details regarding the applicability of the CLTP 33.1 EFPY PT curves for TPO conditions.

2. The PT curves were prepared for Power Uprate (PU) at the end of the original 40-year license considering 33.1 EFPY and the plant-specific fluence.

   The TLAA did not change the PT curve report, inputs or its evaluations / conclusions. The TLAA extends the operating license. It does not change the power level. Therefore, for TLAA, the PT curve report still remains applicable for the calculated EFPY based on the fluence used in the curve development. Simply put, for TLAA operation, new curves are needed to go past 33.1 EFPY, for which the PT curves were calculated.

   As part of the TPO evaluation, the cumulative energy and EFPY for the Original Licensed Thermal Power (OLTP) were re-calculated considering CLTP and TPO conditions. It was determined that the PT curve evaluation considered incremental energy estimates for Cycles 22-23 that bounded the actual incremental energy for Cycles 22-23.

   In the TPO evaluation, the incremental energy for Cycles 22-23 was reduced based on actual calculated values, and the incremental energy for Cycles 24-27 and 28-37 were calculated for TPO operating conditions.

Summary of Incremental Energy Calculation performed as part of TPO T0301 – Supporting evaluation to show current PT curves remain applicable for TPO conditions.

	Incremental Energy		
Cycle	**Used in PT curve evaluation (GWD)[1]**	**Used in TPO Evaluation (GWD)[1]**	**Delta (PT curve to TPO (GWD)[1])**
1-10 (OLTP)	7966 (OLTP)	7966 (OLTP)	0
11-17 (PU)	9806 (PU)	9806 (PU)	0
18-21 (PU)	8952 (PU)	8952 (PU)	0
22-23 (PU)	4476 (PU)	4208 (PU)	-268
24-27 (PU/TPO)	8952 (PU)	9104 (PU/TPO)	+152
28-37 (PU/TPO)	22380 (PU)	22760 (PU/TPO)	+380
Cumulative Total Cycle 1-27	40152	40036	-116

Note [1]: GWD = Gigawatt Days

While TPO increased the incremental energy for Cycles 24-27, the delta (increase) is offset by the delta (decrease) for Cycles 22-23 when the actual incremental energy is taken into consideration for Cycles 22-23. The cumulative energy and cumulative EFPY at OLTP for the end of Cycle 27 (33.1 EFPY) considering TPO conditions are bounded by (less than) the calculated values for CLTP in the reference calculation. Therefore, the CLTP PT curves remain bounding for TPO, limited to the currently approved fluence associated with 33.1 EFPY at OLTP.

In addition, it is noted that the fluence calculation was not revised to incorporate the reduction in incremental energy for Cycles 22-23. Therefore, the fluence calculation used in the TPO evaluation is conservative.

References:

1. US NRC, "Safety Evaluation report – Related to the License Renewal of Columbia Generating Station," US NRC, NUREG-2123 (Volume 2), Docket # 50-397, May 2017.
2. US NRC, "Regulatory Guide 1.99 – Radiation Embrittlement of Reactor Vessel Materials," US NRC, RG 1.99, Revision 2, May 1988.