NRC RAI Letter Nos. ML18341A004 and ML18341A005 Dated January 15, 2019

3. Concrete, GALL AMR XI.S6

RAI 3.5.2.2.2.6-10

Background:

SRP-SLR Section 3.5.2.2.2.6 states that data related to the effects and significance of neutron radiation on concrete mechanical and physical properties is limited, especially for conditions (dose, temperature, etc.) representative of light-water reactor (LWR) plants. The SRP-SLR also states that based on literature review of existing research, a fluence limit of 1×10^{19} neutrons/cm^2 radiation is considered a conservative radiation exposure level beyond which concrete material properties may begin to degrade markedly.

Turkey Point Units 3 and 4 (Turkey Point) SLRA Section 3.5.2.2.2.6, as supplemented by letter dated October 5, 2018, states that the reduction in concrete strength due to neutron fluence would be 10 percent up to a depth of 2.6 inches into the primary shield wall (PSW) based on Turkey Point's calculated neutron fluence of 3.57×10^{19} n/cm^2 at the inner face PSW concrete. The Turkey Point SLRA also relies on research work performed by Murayama (2017) citing Figure 54 "Comparison of observed strength ratio (F_c/F_{co}) and total neutron fluence in preceding research and the present study." The SLRA also states that "[d]ue to the [radiation induced volumetric expansion] RIVE effect, the excessive compressive stress was calculated and the inner side of the concrete (up to 3.14 inches) is considered as yielded (cracked)."

With regard to prior studies made on the effects of radiation in concrete strength, the SLRA states that data presented in studies made by Hilsdorf (1978) and Field, et al. (2015) contained results of specimens tested at varying neutron energy levels (fluence) and temperatures and concluded that "compressive strength appears to begin to decrease at a fluence of approximately 1×10^{19} neutrons/cm^2."

The staff noted that Maruyama's (2017) paper stated that the main reason for degradation due to neutron irradiation is the metamictization of rock-forming minerals in aggregates that leads into aggregate expansion and then cracking of the surrounding concrete. A comparable observation was made by Hilsdorf (1978) which stated that "neutron radiation with a fluence of more than 1×10^{19} n/cm^2 causes a marked volume increase of the concrete [that] can be tracked back to microstructural changes in the crystalline aggregates of the concrete and is with all likelihood responsible for the concrete deterioration." Field et al. (2015) also concluded that indications show that the mechanism of RIVE (i.e., aggregate expansion) "is a first-order mechanism for loss of mechanical properties [of quartz aggregates] under neutron irradiation" and could affect limestone aggregates containing minor amounts of quartz or feldspar embedded in the calcite matrix as well.

In addition, the staff noted that the studies referenced in the SLRA regarding compressive strength loss indicate that operational temperature is a factor that must be considered in the degradation of concrete due to neutron irradiation. The staff noted that with regard to neutron irradiation of concrete, Maruyama's (2017) paper further stated that "there is no data of aggregate expansion for neutron flux in commercial reactors;" and that "the variety and rates of expansion behavior of rock-forming minerals, and their respective roles in thermal healing roles, are key factors to incorporate into soundness assessment;" and "[m]ore extensive data should be obtained for long-term operation of nuclear power plants."

NUREG/CR-7171 is an informational research document that was published by the NRC in 2013. It provides a summary of the effects of neutron and gamma radiation on the mechanical and physical properties of concrete through 2012.

Issue:

The staff notes that there are several bodies of research associated with irradiation of concrete, as noted above. In addition, in research performed for the NRC in NUREG/CR-7171 (2013), an assessment of the results of several past studies related to the degradation of concrete due to irradiation was performed. The staff notes that the reduction of strength in concrete due to radiation is complex and depends on many variables such as type of cement, aggregates, water/cement (w/c) ratio, and temperature to which the concrete is exposed. In order for the staff to assess the reasonableness of the applicant's evaluation approach and assumptions, the applicant should provide a justification for the applicability of the cited study assessing the extent of degradation and reduction in strength for the PSW concrete.

The staff noted that the SLRA did not provide a plant-specific comparison of its concrete constituents (w/c ratio, aggregate type) and its environment (operating temperature) with those of applicable specimens used in the applicant's referenced studies, nor did it appear to present a basis to bound the Turkey Point concrete. Without plant-specific concrete considerations, it is not clear how the applicant reached the conclusion that the Maruyama studies are applicable to Turkey Point. The staff noted that the Figure 54 in Maruyama's (2017) paper (referenced in the SLRA) shows data from a variety of concretes with different cement, aggregates, w/c ratios, and test temperatures that were bounded by a "lower boundary curve." In order to assess the acceptability of the applicant's use of the Maruyama (2017) study in development of the SLRA, the staff needs an explanation and justification for how the following constituents/variables used in assessing Turkey Point's concrete relate to those used in Maruyama's study. In its review of Maruyama's study, the staff noted the following:

- **type of cement and w/c ratio**: Maruyama's (2017) study used a high early-strength ordinary Portland cement with a w/c ratio of 0.5. Turkey Point's uses an ASTM C-150-64 Florida Type II cement with a w/c ratio of 0.59.
- **aggregates**: Maruyama's (2017) study used a combination of fine aggregates (land sand and sandstone) and coarse aggregates (altered tuff crushed and sandstone

gravel) and confirmed findings of previous studies by stating that "the degree to which an aggregate expands depends of its mineral composition, and accordingly, that concretes containing different aggregates incur different levels of damage even following exposure to identical neutron fluence." Turkey Point's concrete fine and coarse aggregates (Miami Oolite (limestone) with some quartz sand) conformed to ASTM C-33-64.

- **temperature**: The staff noted that the test temperature of the Maruyama study specimens was lower (10 to 46 degrees Celsius) than the operating temperature for the concrete at Turkey Point's PSW (approximately 49 degrees Celsius). The staff also noted that in relation to Figure 54 of Maruyama's (2017) paper there is a statement that "it is necessary to include the caveat that no corrections have been made for temperature in this figure." The staff notes that the temperature of the environment can affect the amount of degradation of concrete exposed to neutron radiation due to expansion of the aggregate, in particular for siliceous aggregates (e.g., quartzite).

Considering the variability in the data of Figure 54 in Maruyama (2017) and considering how the varying factors (cement type, aggregate, w/c ratio, and environment temperature) of the concrete at Turkey Point PSW compare to the data in Figure 54, the applicant should clarify or provide a justification of its basis for selecting a value for F_c/F_{c0} of 0.9 (i.e., a 10 percent reduction in concrete compressive strength as a measure of concrete degradation). The applicant should discuss why it chose a value that is less conservative than the "lower boundary curve" value of approximately 0.8 (i.e., a 20 percent reduction in concrete compressive strength) for a neutron fluence of $3.57x10^{19}$ n/cm^2 as seen in Figure 54 of Maruyama's (2017) paper referenced in the SLRA. In addition, the applicant should provide a discussion on how it considered the results of other studies referenced in the SLRA such as those by Hilsdorf (1978) and Field et al (2015) that show a greater loss of strength due to neutron radiation as shown in the lower bound curve value of approximately .75 (25 percent loss of strength) shown in Figure 2 of Hilsdorf (1978) and 0.5 (50 percent loss of strength) shown in Figure 3 of the SLRA (from Field et al. (2015)) for a neutron fluence of $3.57x10^{19}$ n/cm^2.

Request:

1. Justify the plant specific evaluation approach and specific assumptions associated with cement, aggregate, w/c ratio, and operating temperature of the concrete at Turkey Point PSW compared to those cited in applicable tests of referenced studies (Figure 54 of Maruyama's 2017 paper, Figure 2 of Hilsdorf (1978) and Figure 3 of Field, et al. (2015)) for determining the reduction in strength and of other mechanical properties of concrete due to neutron fluence at the PSW. If they are not comparable, or if the SLRA credits a bounding case, provide justification that such consideration is unnecessary.

2. Provide a basis for selecting a 10% reduction in strength and mechanical properties of concrete due to neutron fluence at Turkey Point PSW. Clarify whether the selected value is solely based on Figure 54 of Maruyama's (2017) paper. If so, clarify and justify why the more conservative values in Figure 2 of Hilsdorf (1978) and Figure 3 of Field, et al. (2015) are not applicable or are less representative of the concrete at Turkey Point's PSW of the multiple radiation aging effects articulated above.

FPL Response:

The following numbered items respond to the comparable numbered requests above:

1. A plant-specific evaluation of the PTN Primary Shield Wall (PSW) was performed (including comparison to referenced studies) to estimate the reduction in concrete strength and other mechanical properties due to neutron fluence. The same tendency of reduced strength ratios due to neutron fluences are shown in studies by Hilsdorf (1978), Field, et al. (2015) and Maruyama (2017), as well as the related NUREG/CR-7171 (Reference 1).

   The evaluation, summarized in SLRA 3.5.2.2.2.6, Rev. 1 (attachment to Reference 2), relies on material and section properties, Current Licensing Basis (CLB) loading and estimated neutron fluence for the PTN PSW. This PTN-specific information is used with industry standard equations (Reference 3) to evaluate the radiation effects (i.e., swelling strain, compressive & tensile strengths, and elastic modulus) as well as Radiation Induced Volumetric Expansion (RIVE) on the reinforced concrete of the PTN PSW. The specific considerations associated with type of cement and w/c ratio, aggregates, and temperature for this evaluation in relation to the (more recent) Maruyama paper (2017, Reference 4) are discussed as follows:

   Type of cement

   As provided in the PTN SLRA, PTN uses Type II cement, which is for general purpose with moderate sulfate resistance. The cement used in the Maruyama paper (2017) is Type III (high-early-strength cement). Per ASTM C-150 (Reference 5), both Type II and III are identified as Ordinary Portland Cement (OPC) having similar chemical and physical requirements. The required compressive strengths for Type II (at 28 days) and for Type III (at 3 days) are 4,000 psi and 3,500 psi, respectively, and are considered the typical range for compressive strength. Although Type II cement is required to gain a targeted compressive strength at 28 days, and Type III cement is required to gain the targeted compressive strength at 3 days as shown in ASTM C-150, Tables 3 and 4 (Reference 5), the concrete composition is similar. Thus, the concrete used by Maruyama is comparable to the concrete used for PTN.

Water cement (w/c) ratio

Water-to-cement (w/c) ratio is related to concrete compressive strength. Per ACI 211.1, Table 6.3.4(a) (Reference 6), typical concrete compressive strength corresponding to the w/c ratio of 0.59 is 3,000 psi, while it is 4,000 psi for a w/c ratio of 0.48. Per the attachment of Reference 2, the estimated w/c ratio of the PTN PSW is between 0.54 and 0.56. The corresponding concrete strength is estimated somewhere between 3,000 psi and 4,000 psi. In the Maruyama paper (2017), a w/c ratio of 0.50 is used. The corresponding compressive strength is also estimated between 3,000 and 4,000 psi, which is bounded by the compressive strength range of 3,000 to 7,500 psi (i.e., achieved at 28 days and 90 days, respectively) for the PTN primary shield wall (PSW) concrete.

Maruyama (2017) selected the high-early-strength cement with the w/c ratio of 0.50 to stabilize hydration as much as possible over a preparation period of one year for the test specimens, with the aim of avoiding hydration-induced strength development appearing in the irradiation tests (see Section 2.2.4 of the paper for details). The w/c ratio used in the Maruyama paper (2017) represents typical concrete compressive strength and are comparable to the w/c ratio used for PTN.

Aggregates

Maruyama (2017) tested different types of aggregates (including limestone, as shown in Table 11 of the paper) and concluded in Section 2.5 of the paper that *"For aggregates, it was confirmed that quartz, with its high covalent bond content, has poor neutron resistance and expanded, while limestone, which contains ionically bonded calcite, did not expand for fast neutron fluences of up to* 8.09×10^{19} *n/cm*^{2}*."* In the same section, the paper also stated that *"It was confirmed that the cement paste did not reduce in strength when exposed to fast-neutron (> 0.1 MeV) fluences of up to* 8.09×10^{19} *n/cm*^{2}*."*

Per UFSAR, Section 5.1.6.2, the aggregates used for the PTN PSW are ASTM C-33-64 (fine and coarse aggregate, Miami Oolite). Miami Oolite is now referred to as Miami Limestone. In the Maruyama paper (2017), neutron radiation tests were performed on specimens (Con-A and Con-B) which included high contents of tuffaceous sediments and the origin of quartz (silica) as provided in Tables 10 and 11 of the paper. Based on the aggregate expansion results shown in Figure 42 for different types of aggregates, the limestone aggregates (GF) are less sensitive than the others and bounded by quartz aggregates (GA). Therefore, the PTN aggregates (limestone) are less sensitive and bounded by the Maruyama test results performed with specimens including quartz.

Temperature

The temperature range of 10 to 46 degrees Celsius (°C) in the issue above is for the Heating Test (HT) to reproduce the heating and drying experienced by specimens exposed to gamma radiation as provided in Figure 59(a) of the Maruyama paper (2017). For the neutron radiation experiments, the temperature of concrete specimens was measured and provided in Table 23 of the paper where the measured average temperature ranged from 58.9 to 72°C. This temperature range bounds expected operating temperatures of 49 to 65.6°C (i.e., 120 to 150°F) in the reactor cavity and at the RPV supports, respectively. Thus, the measured temperature in the Maruyama paper (2017) bounds the one for PTN.

Based on the above description of concrete properties (i.e., cement type, aggregate, w/c ratio) and operating temperature, the concrete of the PTN PSW is comparable to corresponding information in applicable tests of the referenced studies. Therefore, there is reasonable assurance that the referenced studies are suitable for determining the reduction in strength and of other mechanical properties of concrete due to neutron fluence at the PSW.

2. Based on the neutron fluence limit of 1.0 x 10^{19} n/cm^2 and the calculated PTN neutron fluence of 3.57 x 10^{19} n/cm^2 incident on the primary shield wall at the end of the SPEO, the irradiation effect (i.e., about 10% reduction in concrete strength up to a depth of 2.6 inches) was not selected from Figure 54 of Reference 4, but calculated by using Equations 5-1 to 5-5 in EPRI report number 3002011710. PTN neutron fluence attenuation is calculated for different depths into the concrete, and the reduced strength in concrete is calculated for the corresponding fluence attenuation. The maximum strength reduction in the concrete is calculated at the inner surface of the concrete and it is about 10% as indicated on page 10 of 19 in the attachment to Reference 2. However, due to the RIVE effect (excessive swelling strain), the inner side of the concrete is yielded (cracked). The strength of concrete up to a depth of 3.14 inches is reduced by 100%, which is considered in the PTN PSW evaluation. This is conservative and bounds the concrete strength reduction ratios (due to neutron fluence) presented in Maruyama (2017), Hilsdorf (1978) and Field, et al. (2015).

References:

1. NUREG/CR-7171, “A Review of the Effects of Radiation on Microstructure and Properties of Concretes Used in Nuclear Power Plants”, Nuclear Regulatory Research, Washington D.C., November 2013.

2. FPL Letter L-2018-187 to NRC dated October 5, 2018, Turkey Point Units 3 and 4 Subsequent License Renewal Application Revision to SLRA Section 3.5.2.2.2.6,

Reduction of Strength and Mechanical Properties of Concrete Due to Irradiation (ADAMS Accession No. ML18283A308)

3. EPRI Report No. 3002011710, “Irradiation Damage of the Concrete Biological Shield – Basis for Evaluation of the Concrete Biological Shield Wall for Aging Management”, Electric Power Research Institute, Charlotte, NC, May 2018.

4. Maruyama, I., Kontani, O., Takizawa, M., Sawada, S., Ishikawa, S., Yasukouchi, J., Sato, O., Etoh, J., and Igari, T., “Development of Soundness Assessment Procedure for Concrete Members Affected by Neutron and Gamma-Ray Irradiation”, Journal of Advanced Concrete Technology, Vol. 15, pp 440-523, 2017 (https://www.jstage.jst.go.jp/article/jact/15/9/15_440/_article)

5. ASTM C-150-07, “Standard Specification for Portland Cement”

6. ACI 211.1-91, “Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete”, Reapproved 2002.

Associated SLRA Revisions:

None

Associated Enclosures:

None

NRC RAI Letter Nos. ML18341A004 and ML18341A005 Dated January 15, 2019

RAI 3.5.2.2.2.6-12

Background:

The SRP-SLR Section 3.5.2.2.2.6 states the following:

> Higher fluence or dose levels may be allowed in the concrete if tests and/or calculations are provided to evaluate the reduction in strength and/or loss of mechanical properties of concrete from those fluence levels, at or above the operating temperature experienced by the concrete, and the effects are applied to the design calculations. Supporting calculations/analyses, test data, and other technical basis are provided to estimate and evaluate fluence levels and the plant-specific program.

The PTN SLRA Section 3.5.2.2.2.6 states:

> Radiation effects such as neutron fluence and Radiation-Induced-Volumetric-Expansion (RIVE) effects were determined. The existing primary shield wall was evaluated for the CLB loading with the radiation effects by using the same design/analysis approach as the recently updated CLB calculation. Due to the RIVE effect, the excessive compressive stress was calculated and the inner side of the concrete (up to 3.14 inches) is considered as yielded (cracked). The design stresses were then re-calculated for the reduced concrete section under the CLB loading in which the reduced strengths and modulus of the irradiated concrete were also considered. Comparing with the un-irradiated concrete (where the maximum interaction ratio (IR) is calculated as 0.74), the maximum IR for the irradiated concrete (including the cracking discussed above) was calculated as 0.82, which is increased but is still less than 1.0. Therefore, the existing primary shield wall including the radiation effects is qualified for the CLB loading based on the evaluation results.
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> [...]
>
> Upon NRC approval, the loads on the reactor vessel supports and Primary Shield Wall [PSW] concrete will be significantly reduced. For the [PSW], the implementation of auxiliary line LBB will result in the IR being reduced to 0.41 (tension). The governing load case would be Normal (IR = 0.41 for tension) and Emergency (IR = 0.32 for compression). Considering the IR increasing ratios (i.e., 10.8% for tension and 10.2% for the maximum compression), the maximum IRs are approximated as 0.45 (=0.41 x 1.108) for tension and 0.35 (= 0.32 x 1.102) for the maximum compression.

Issue:

The SLRA does not provide a clear description of the CLB design basis with load combinations, governing load case(s), and their respective maximum IRs and their locations for all stress conditions (tension, compression, and shear stresses) of the Turkey Point PSW concrete structure, or a justified bounding case. The staff needs this information to assess margins in available capacities considering the effects of concrete degradation due to irradiation (i.e., cumulative effects of neutron fluence, gamma dose, and RIVE effects) for the PSW concrete structure during the SPEO.

Request:

Taking into consideration the loss of strength and change in mechanical properties of irradiated concrete due to cumulative effects of neutron fluence, gamma dose, and RIVE effects, describe all affected design basis load combinations, identify the governing load case(s), provide the respective maximum horizontal, vertical loads, and bending moments on the PSW surface and at the point of termination of concrete loss of strength. For the governing load case(s) provide the resulting maximum IRs and their location under all stress conditions (tension, compression, shear) for the Turkey Point PSW concrete structure. Alternatively, provide a justified bounding case.

FPL Response:

Per FSAR, Section 5.1.8.2(c), the PSW has been designed to withstand the proper load combinations of dead, live, thermal, seismic, and accidental loads. For the CLB design loads that include the new reactor vessel head weights and new LOCA, its functionality has been examined by using the same analysis approach and considerations used in the original PSW design. The considered load combinations are as follows:

- Normal operating: D + L + T
- Emergency (with seismic): D + L + T + E
- Faulted (with original LOCA): D + L + T + original LOCA
- Faulted (with new LOCA): D + L + T + new LOCA

where D = dead load, L = live load, T = thermal load due to radiation, E = seismic load, and LOCA = Loss-Of-Coolant-Accident (refer to the design basis calculation for loading of the PSW for more detail).

The structural responses of the existing PSW have been examined in its radial, tangential, and longitudinal directions under the above load combinations. Based on the examination, it was observed that the stress and displacement in the radial direction are insignificant as shown in the design basis calculation for loading of the PSW (for instance, the radial displacement for the thermal gradient is 0.027 inches). The maximum IRs were calculated for the normal, emergency (seismic) and faulted load cases (with the original and new LOCA) and summarized in the calculation. Based on the calculated IRs, the faulted load case (with new LOCA) is governing where the maximum IR for the longitudinal reinforcement is 2 times larger than the other load cases (normal, seismic and original LOCA). The design basis calculation for loading of the PSW contains a summary of the IRs for different load cases.

The radiation effect on the PSW is representatively examined for this governing load case in the evaluation report of the effect of radiation on the PSW and supports. This report is available on the ePortal. In addition, the existing PSW was evaluated for the radiation effects (i.e., neutron, gamma, and RIVE) by EPRI for the governing load case which is faulted loading with new LOCA. Due to the RIVE effect, the excessive compressive stress is calculated, and the inner side of the concrete (up to 3.14 inches) is considered as yielded (cracked). The corresponding axial force and bending moment for the reduced concrete section under the governing external loads (i.e., dead, live, and new LOCA loads) are calculated as 215 kip and 558.4 kip-ft, respectively. The total stresses including thermal stresses are then re-distributed to the reduced concrete section under the governing CLB loading considering the radiation effects (reduced strengths and modulus of the irradiated concrete). The maximum stresses in the reinforcement and in concrete are calculated and compared with the un-irradiated concrete in the evaluation report.

For horizontal seismic loads, its shear capacity was examined at the base by using the concrete shear capacity alone. The shear capacity is 8,333.6 kip, which is much greater than the 3,119 kip seismic base shear demand. Thus, the existing PSW has sufficient capacity for the horizontal seismic loads.

The maximum IR for the un-irradiated concrete is 0.74 for tension, while the maximum IR for the irradiated concrete is 0.82. The maximum IR has increased by 10.8% (= [0.82-0.74] / 0.74) but is still less than 1.0. Therefore, the existing PSW including the radiation effects is qualified for the CLB loading based on the evaluation results. The maximum IR for tension is calculated at the outer side longitudinal reinforcement, while the maximum IR for compression is calculated at the inner side of the concrete, which is between 10 and 15 inches from the inner surface.

It should be noted that the Leak-Before-Break (LBB) analysis of reactor coolant system auxiliary lines has been submitted as part of the SLRA (Section 4.7.4 and Enclosure 4, Attachment 12). Upon NRC approval of the LBB analysis, the loads on the reactor vessel supports and PSW concrete may be significantly reduced and more design margin is expected.

References:

1. FPL Letter L-2018-187 to NRC dated October 5, 2018, Turkey Point Units 3 and 4 Subsequent License Renewal Application Revision to SLRA Section 3.5.2.2.2.6, Reduction of Strength and Mechanical Properties of Concrete Due to Irradiation (ADAMS Accession No. ML18283A308).

Associated SLRA Revisions:

SLRA Section 3.5.2.2.2.6, Rev. 1, is amended as indicated by the following text deletion (strikethrough) and text addition (red underlined font) revisions.

Revise SLRA Section 3.5.2.2.2.6, Rev. 1, Page 14 of 19 (2nd paragraph) of Reference 1 as follows:

Due to the RIVE effect, the excessive compressive stress was calculated and the inner side of the concrete (up to 3.14 inches) is considered as yielded (cracked). The design stresses were then re-calculated for the reduced concrete section under the **governing** CLB loading **case (i.e., faulted with new LOCA)** in which the reduced strengths and modulus of the irradiated concrete were also considered.

Associated Enclosures:

None

NRC RAI Letter Nos. ML18341A004 and ML18341A005 Dated January 15, 2019

RAI 3.5.2.2.2.6-13

Background:

The SRP-SLR Section 3.5.2.2.2.6 states the following (in part):

> Higher fluence or dose levels may be allowed in the concrete if tests and/or calculations are provided to evaluate the reduction in strength and/or loss of mechanical properties of concrete from those fluence levels, at or above the operating temperature experienced by the concrete, and the effects are applied to the design calculations. Supporting calculations/analyses, test data, and other technical basis are provided to estimate and evaluate fluence levels and the plant-specific program.

The SLRA states in part the following:

> The [RPV] support structure for each PTN [Turkey Point] Unit consists of six (6) individual supports, one of which is placed under each of the three hot leg and three cold leg Reactor Coolant System pipe nozzles at elevation (EL) 25'-7 ½". A majority of each [RPV] support is embedded in the primary shield wall. […] The [RPV] support structure includes vertical columns, cantilever beams, horizontal (cross) beams and roller assembly. The columns and portion of the cantilever beams are located inside the primary shield wall, with the centerline of the cantilever beams at a height approximately equal to the top of the active fuel, and the inboard edge of the innermost column ~ 5 inches from the inside surface of the primary shield wall.

The SLRA provides an evaluation of the RPV steel supports for the aging effect of reduction in fracture toughness due to irradiation embrittlement.

Issue:

The staff noted that the RPV steel support assemblies are partially embedded into the concrete of the PSW. As stated in the SLRA, this concrete is expected to have a loss of strength and change in mechanical properties due to the aging effects of radiation. The SLRA provides an evaluation of the RPV structural steel support assemblies for the aging effect of reduction in fracture toughness due to irradiation embrittlement. The staff noted, however, that the SLRA does not include a consideration of how the degradation of the PSW concrete due to irradiation would affect the CLB structural performance/integrity and intended function of the RPV supports – particularly their embedded portion into the concrete (e.g., degree of fixity of steel beams) – and the state of the local concrete (e.g., local crushing of concrete).

The staff notes that a loss of strength and change in mechanical properties of concrete in which the RPV steel support structure is embedded would result in partial fixity of the steel beam supports into the PSW, thus potentially changing behavior of the composite concrete steel RPV support system which could affect the intended function of RPV support, including limits of its displacement.

The staff needs additional information to assess, with regard to the CLB design loads and intended function, the margin in structural capacity available under critical stress conditions for the RPV support structure and the ability of the steel support structure to prevent excessive movement (per CLB design) of the RPV during the SPEO. The staff needs this information regarding assessments of the degree of fixity and load transfer of the RPV steel supports into the degraded PSW concrete in order to evaluate the impact such degradation could potentially have on the CLB intended functions of the reactor vessel supports during SPEO. Specifically, the staff needs information regarding (1) the governing CLB (or credited LBB) design basis load combination(s), consideration of possible redistribution of maximum stresses (e.g., tension, compression, and shear) or change in maximum IRs (e.g., tension, compression, and shear) and their location, consideration of potential pull-out or slippage of the concrete/steel support system, and any potential settlement of the RPV supports due to the expected degradation of the surrounding concrete caused by the combined effect of neutron fluence, gamma dose, and RIVE; or (2) a justified bounding case.

Request:

1. Discuss whether and how the loss of strength and change in mechanical properties of concrete due to irradiation has a local effect on the degree of fixity and load transfer of the RPV steel supports into the degraded PSW concrete, or provide justification for not needing to consider these local effects.

2. Taking into consideration the values provided by the SLRA for loss of strength and change in mechanical properties of concrete due to irradiation discussed in the SLRA, and variation in the degree of fixity of the steel beams, if any, provide an analysis that includes the governing design basis load combinations (identified in RAI 3.5.2.2.2.6-12) with their respective maximum horizontal, vertical loads, and bending moments under all stress conditions (e.g., tension, compression, shear) including IRs, for the supports, and any potential settlement for the RPV steel support structure; or provide a justified bounding case.

FPL Response:

The following numbered responses correspond to the numbered requests above:

1. Due to the radiation effects (i.e., loss of strength, change in mechanical properties, and swelling strain), the inner side of the concrete (up to 3.14 inches) in the PTN Primary Shield Wall (PSW) is calculated to be yielded (cracked). Considering the overall wall thickness of 7 ft, the crack is limited and localized to the inner surface of

the PSW. The Reactor Pressure Vessel (RPV) steel supports are integrated into the concrete over the full cross section of the wall. The majority portions of the horizontal cantilever beams and the vertical columns which are the main structural members transferring RPV support loading are embedded into the concrete.

Per the plant drawings, approximately 4.5 ft out of 6 ft of the horizontal cantilever beams are embedded into the concrete. Based on the span-depth ratio, compact section, and 1” thick stiffener plates, the horizontal cantilever beam 14WF342 is considered as a deep beam, which is governed by shear as shown in the Westinghouse RPV support calculation. The effective length of the cantilevered portion of the beam may be increased by 3.14 inches due to the crack. However, the span-depth ratio is less than two. Thus, the horizontal cantilever beam is still considered a deep beam. The governing structural response (shear demand of the beam) will not change due to this localized cracking depth. Per the PSW liner plate drawing, the inner surface of the PSW is covered by ¼” thick liner plates with angles and channels that are welded to the liner plates from the top to the bottom of the PSW. Considering the resistance from the liner plates and the remaining concrete in compression, the effect to the fixity will be reduced. Therefore, it is considered that the horizontal cantilever beam, its fixity, and load transfer to the concrete are not significantly affected by this local effect in the concrete.

The vertical columns of the RPV steel supports are fully embedded into the concrete with forty-eight (48) 7/8” dia. by 3 ½” long headed studs for each column. Among these studs, the outer row of studs is located at about 5 inches away from the inner surface of the concrete wall. Therefore, the interface between the RPV steel support and concrete will not be affected by the cracking of the concrete (up to of 3.14 inches) due to the radiation effects. Even if the outer row of studs is affected, it will be limited and localized in a small area. A significant number of studs is still remaining effective.

2. The Westinghouse RPV support calculation provides the related analysis and evaluation details on the existing RPV steel supports for the CLB design loads (i.e., normal operating, seismic, and old and new LOCA loads). Among the considered CLB loading cases, the faulted load case with new LOCA is determined as the governing load case. The governing structural behavior of the cantilever beam is shear (not bending). The maximum IR is calculated for the shear in the faulted load case (with new LOCA), and it is four times larger than the other IRs for the upset (seismic) load case. The increased span length due to the cracking depth will not provide any appreciable impact on the structural demand.

   With respect to the loss of strength and degree of fixity in the concrete up to the cracking depth, the corresponding displacement at the end of cantilever beam is calculated by using the minimum vertical stiffness of the RPV support provided in the Westinghouse RPV support stiffness calculation. From Figure 5-9 of the calculation, the average length of the cantilever beam is calculated, and the span length of the cantilever beam is increased by about 21% considering the cracking depth of 3.14 inches. Vertical stiffness of the cantilever beam is inversely proportional to (span length)^3, so the displacement corresponding to the maximum RPV support reaction for the faulted load case (with new LOCA) can be calculated by using the vertical stiffness considering the radiation effect in the concrete. The corresponding maximum displacement is calculated to be less than 0.1 inches. Therefore, the local effect (including associated settlement) is considered as miscellaneous and not needed to be considered with respect to the degree of fixity, related displacement, and load transfer. The Westinghouse calculations and the PSW evaluation report are available on the ePortal.

References:

None

Associated SLRA Revisions:

None

Associated Enclosures:

None