## KHNPTopRptsRAIsPEm Resource

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**Sent:** Thursday, June 18, 2015 7:28 AM
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**Subject:** APR1400 Topical Report RAI 5-7954 (PLUS7 Fuel Design for the APR140 [APR1400-F-M-TR-13001-P])
**Attachments:** APR1400 TR RAI 5 SRSB 7954.pdf; image001.jpg

KHNP,

The attachment contains the subject Request for Additional Information (RAI). This RAI was sent to you in draft form. Your licensing review schedule assumes technically correct and complete responses within 30 days of receipt of RAIs. KHNP will provide RAI responses in 30 days. However, KHNP will provide the response cycle for questions TR PLUS7 Fuel Design for the APR1400-16 and TR PLUS7 Fuel Design for the APR1400-23 after having discussion with the NRC on June 23, 2015.

Please submit your RAI response to the NRC Document Control Desk.

Thank you,

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# Request for Additional Information 5-7954

Issue Date: 06/18/2015
Application Title: APR1400 Topical Reports
Operating Company: Korea Hydro & Nuclear Power Co. Ltd.
Docket No. PROJ 0782
Review Section: TR PLUS7 Fuel Design for the APR1400
Application Section: PLUS7 Fuel Design for the APR140 (APR1400-F-M-TR-13001-P)

QUESTIONS

TR PLUS7 Fuel Design for the APR1400-11

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SRP Section 4.2 (II)(1)(B)(v) provides guidance stating that the fuel failure criteria should address excessive fuel enthalpy.

This fuel failure criterion is addressed on Page 3-9 of APR1400-F-M-TR-13001-P for the PLUS7 fuel design. Section 3.4.4 of the topical report states that the code used to analyze this fuel failure mechanism (FATES3B) over predicts fuel thermal conductivity at high burnup. Therefore, it will also under predict fuel enthalpy. The staff notes that Section 3.4.4 provides a qualitative argument to state that the effects of burnup dependence of TCD are bounded by the reduced power capabilities at higher burnups. This raises concerns from the staff on the ability of the excessive fuel enthalpy analysis to demonstrate compliance with the excessive fuel enthalpy SAFDL given all core loading options available.

Please include a discussion, supported by analysis, within Section 3.2.10 and/or 3.4.4 of APR1400-F-M-TR-13001-P regarding the impacts of the fuel enthalpy under prediction and how excessive fuel enthalpy is precluded.

TR PLUS7 Fuel Design for the APR1400-12

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SRP Section 4.2 (II)(1)(B)(iv) provides guidance in regards to GDC 10 by stating that overheating of fuel pellets should be avoided by preventing centerline melting. This analysis should be performed for the maximum linear heat generation rate anywhere in the core, including all hot spots and should account for the effects of burnup and composition on the melting point.

Sections 3.4.4 of the PLUS7 fuel design topical report (APR1400-F-M-TR-13001-P) and 2.2.2 of the thermal conductivity degradation (TCD) technical report (APR1400-F-A-NR-13002-P) discuss overheating of the fuel pellets. The PLUS7 fuel design includes $UO_2$-$Gd_2O_3$ pellets. The impact of the $UO_2$-$Gd_2O_3$ pellet composition on the overheating of fuel pellets analysis is not discussed in either Section 3.4.4 of APR1400-F-M-TR-13001-P or Section 2.2.2 of APR1400-F-A-NR-13002-P. $UO_2$-$Gd_2O_3$ has a lower melting temperature and lower thermal conductivity than $UO_2$ which has caused the staff to question the ability of the fuel centerline melting analysis provided to demonstrate compliance with GDC 10.

Update the topical report, as applicable, to address fuel pellet overheating considering $UO_2$-$Gd_2O_3$ to ensure that no fuel centerline melting occurs for all fuel compositions and normal operation/AOO conditions.

# Request for Additional Information 5-7954

TR PLUS7 Fuel Design for the APR1400-13

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SRP Section 4.2 (II)(1)(B)(iv) provides guidance in regards to GDC 10 by stating that overheating of fuel pellets should be avoided by preventing centerline melting. This analysis should be performed for the maximum linear heat generation rate anywhere in the core, including all hot spots and should account for the effects of burnup and composition on the melting point.

Section 2.2.2 of APR1400-F-A-NR-13002-P provides a scoping analysis using FRAPCON3.4 to investigate the impacts of burnup dependent TCD on the fuel centerline temperature analysis. The staff has concerns regarding the methodology and results presented in that the methodology is different than what is presented in APR1400-F-M-13001-P and the results do not support the stated conclusions. This in turn has caused the staff to question the ability of the fuel centerline melting analysis provided to demonstrate compliance with GDC 10.

Address the following concerns, as appropriate, to demonstrate compliance with GDC 10:

a) Provide a basis for the assumed uncertainty of 9.7% on best estimate fuel centerline temperature used to calculate the conservative power to melt results.

b) Section 2.2.2 of APR1400-F-A-NR-13002-P provides a SAFDL of 20 kW/ft. Figure 2-10 shows that the fuel would melt above 30 GWd/MTU assuming a conservative analysis. Update the topical report, as applicable, to ensure that the linear heat rate SAFDL is conservatively met.

c) Provide a description and update the topical report, as necessary, to explain how the melt analysis will be performed on a cycle specific basis since FRAPCON-3.4 was used to perform the scoping analysis, or update the topical report methodology to not require FRAPCON-3.4 to confirm compliance with GDC 10.

TR PLUS7 Fuel Design for the APR1400-14

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SRP Section 4.2 (II)(1)(B)(iv) provides guidance in regards to GDC 10 by stating that overheating of fuel pellets should be avoided by preventing centerline melting. This analysis should be performed for the maximum linear heat generation rate anywhere in the core, including all hot spots and should account for the effects of burnup and composition on the melting point.

Section 3.2.9 of the PLUS7 fuel design topical report, APR1400-F-M-TR-13001-P, provides the overheating of fuel pellets analysis for the APR1400 design. On Page 3-9, it is stated that the linear heat rate corresponding to the centerline melt of $Gd_2O_3$-$UO_2$ burnable absorber fuel rods is always less than that of the $UO_2$ fuel rods. The lower thermal conductivity of $Gd_2O_3$-$UO_2$ burnable absorber fuel rods causes the staff to question the claimed bounding nature.

Provide linear heat generation rate limits for $UO_2$ and $Gd_2O_3$-$UO_2$ to support the position presented in APR1400-F-M-13001-P, or revise the topical report as necessary.

TR PLUS7 Fuel Design for the APR1400-15

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SRP Section 4.2 (II)(1)(B)(vi) provides guidance in regards to GDC 10 by stating that rod internal gas pressures should be limited in order to (1) prevent cladding liftoff during normal operation, (2) prevent radial reorientation of hydrides in the cladding and (3) account for additional failures resulting from departure of nucleate boiling (DNB) caused by fuel rod overpressure during transients and postulated accidents. This analysis should be performed for the maximum linear heat generation rate anywhere in the core, including all hot spots and should account for the effects of burnup and composition on the melting point.

Section 3.2.5 of APR1400-F-M-TR-13001-P provides the APR1400 fuel rod internal pressure analysis. Page 3-17 of APR1400-F-M-TR-13001-P qualitatively discusses the impact of TCD on fuel rod internal pressure, stating that the impact of TCD on fuel rod internal pressure is negligible. While the stated overall calculated rod internal pressure is less than system pressure, the actual limit proposed by KHNP is not clear. This has caused the staff to question the specific rod internal pressure limit proposed by KHNP.

In order to assist the staff to perform confirmatory calculations to investigate the statements that TCD has a negligible effect on the rod internal pressure safety analyses, provide the rod internal pressure limit used for the PLUS7 fuel rod internal pressure safety analysis. If the limit is greater than system pressure, provide a basis and update the topical report, as applicable.

TR PLUS7 Fuel Design for the APR1400-16

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SRP Section 4.2 (II)(1)(A)(ii) provides guidance in regards to GDC 10 by stating that the cumulative number of strain fatigue cycles on the structural members should be significantly less than the design fatigue lifetime, which is based on appropriate data and includes a safety factor.

Pages 3-17 and 2-5 of the TCD report (APR1400-F-A-NR-13002-P) discuss cladding strain and fatigue. Section 3.4.2 states that the increased thermal expansion can be offset with available design margin in the cladding strain and fatigue limits. Sample calculations provided in the TCD report show that the fatigue damage factor will increase from 0.28 to 0.77 when TCD is considered. This has caused the staff to question the claim that increased thermal expansion can be offset with available design margin in the cladding strain and fatigue limits.

a) Discuss how the fatigue analysis will be performed on a cycle specific basis given this demonstration that FATES3B alone is inadequate to assess the fatigue damage fraction. Update the topical report, if necessary, to include the clarification.

b) The fatigue damage factors (FDF) presented in topical report APR1400-F-M-TR-13001-P and technical report APR1400-F-A-NR-13002-P (for the operating condition “without TCD”) do not appear to match. Update the report(s) as necessary to reflect the correct FDF.

TR PLUS7 Fuel Design for the APR1400-17

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SRP Section 4.2 (II)(3)(A)(i) provides review guidance related to the assessment of fuel system damage related to dimensional changes (including hydrogen uptake induced swelling) that should be presented and reviewed.

It is stated on Page 4-7 of APR1400-F-M-13001-P that a 13% hydrogen pickup fraction will be used for ZIRLO. This pickup fraction is lower than the staff expected based on previous experience and has caused the staff to question the basis for this hydrogen pickup fraction.

Please justify the use of a 13% hydrogen pickup fraction. Provide a figure based on Figure 4-44 with an overlay of calculated hydrogen pickup assuming 13%, 15%, and 17.5% pickup fractions. Also include the data shown in Figure 10-1 of the response to RAI 4-7542 on this figure.

TR PLUS7 Fuel Design for the APR1400-18

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs).

To perform accurate confirmatory calculations to evaluate the application's conformance with GDC 10, NRC must use the correct input information for the APR1400 design, including rod geometry, reactor conditions, power history, and axial power profile.

Please provide the following sample calculations using FATES3B. For each case, include all appropriate input information including rod geometry, reactor conditions, power history, and axial power profile:

a. Provide sample calculations of cladding strain under AOOs for a typical AOO overpower event. Provide calculations at rod average burnup of 0 GWd/MTU, 20 GWd/MTU, 40 GWd/MTU, and 60 GWd/MTU.
b. Provide a sample calculation of rod internal pressure for a bounding power history up to a rod average burnup of 62 GWd/MTU. Provide pressure calculations as a function of time.
c. Provide a sample calculation of power to melt at the following rod average burnup levels; 0 GWd/MTU, 10 GWd/MTU, 20 GWd/MTU, 30 GWd/MTU, 40 GWd/MTU, 50 GWd/MTU, 60 GWd/MTU.
d. Provide a sample calculation of fuel stored energy for a bounding power history up to a rod average burnup of 62 GWd/MTU. Provide stored energy calculations as a function of time.

TR PLUS7 Fuel Design for the APR1400-19

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SRP Section 4.2 (II)(3)(C)(i) provides guidance in regards to GDC 10 and the phenomenological models important to fuel temperature (stored energy) calculations. This fuel temperature calculation is important to the pellet swelling and clad creep models.

Table 4-8 on Page 4-12 of APR1400-F-M-TR-13001-P shows predicted and measured results from the puncture analysis. The staff notes that FGR is overpredicted but rod internal pressure is underpredicted. This has caused to the staff to question the validity of the void volume calculations and the potential subsequent impacts on the pellet swelling and clad creep models.

Provide a discussion to explain why FGR is overpredicted but rod internal pressure is underpredicted, and update the topical report if applicable. If the pellet swelling or clad creep models are non-conservative, also address all other impacted analyses and update the topical report, if applicable.

TR PLUS7 Fuel Design for the APR1400-20

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SRP Section 4.2 (II)(1)(B)(iv) provides guidance in regards to GDC 10 by stating that overheating of fuel pellets should be avoided by preventing centerline melting. This analysis should be performed for the maximum linear heat generation rate anywhere in the core, including all hot spots and should account for the effects of burnup and composition on the melting point.

Table 3-10 on Page 3-24 of APR1400-F-M-TR-13001-P lists various core inlet and outlet temperatures for plants. The staff notes that APR1400 is listed as having a higher core average linear heat rate while having essentially the same $\Delta T$ and core average mass flow as the other examples. This has caused the staff to question the accuracy of the core average linear heat rate calculations presented in Table 3-10.

Please describe the core average linear heat rate calculations in sufficient detail to explain how APR1400 calculates a higher linear heat rate and make the supporting calculations available for staff audit or submit them on the docket.

TR PLUS7 Fuel Design for the APR1400-21

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SRP Section 4.2 provides review guidance related to the development of acceptance criteria based on test data, in part or in whole, for various phenomena (e.g. fretting wear, oxidation/hydriding/crud buildup, dimensional changes, PCI, cladding embrittlement, etc.).

Appendix A of APR1400-F-M-TR-13001-P provides a summary of PLUS7 fuel assembly tests. During the review, the staff noted that the test conditions were listed but not compared with the APR1400 operational ranges for all of the tests. This has made it difficult for the staff to complete the review of the adequacy of the testing.

Provide a table that compares the test condition ranges to the APR1400 condition ranges for the liftoff tests, assembly vibration tests, and buckling strength discussed in Appendix A so it can be determined that the test conditions bound the expected reactor conditions. Update the topical report as necessary.

TR PLUS7 Fuel Design for the APR1400-22

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SRP Section 4.2 (II)(3)(A)(i) provides review guidance related to the assessment of fuel system damage by stating that stress limits must be presented and reviewed.

Section 2.2.2 of APR1400-F-M-TR-13001-P provides the structural integrity design basis, criteria, and evaluation. Within this section, it is stated that the evaluation of fuel assembly for seismic and LOCA loads will be addressed in the APR1400 DCD Section 4.2. The staff notes that APR1400 DCD Section 4.2 in turn points back to APR1400-F-M-TR-13001-P. Therefore, the staff is unable to ascertain if the proposed stress limits are violated by the analysis.

Provide the stress analysis results for the PLUS7 fuel design, and update the topical report as necessary.

TR PLUS7 Fuel Design for the APR1400-23

GDC 10 requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences (AOOs). SRP Section 4.2 (II)(1)(B)(viii) and Appendix A provides review guidance related to mechanical fracturing based on seismic and LOCA applied loads. It is also stated specifically that control rod insertability must be maintained.

This topic is addressed in Section 2.2.2 of APR1400-F-M-TR-13001-P and also in the response to Question 2 of RAI 4-7542 (ML14177A220). The staff notes that for postulated accidents, the limits proposed in the topical report are based on ASME Section III Service Level D requirements. This service level could result in “faulted” conditions for the guide tubes. A faulted guide tube could affect the ability to insert RCCAs, and therefore challenge GDC 27.

Provide a discussion that covers the proposed stress-strain limits and what level of damage could occur to the components based on those limits. If damage could occur to the guide tubes, include a description of the tests and results that demonstrate control rod insertability. Update the topical report, as necessary, to capture these points.

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