Audit Issues for Discussion Related to
Realistic Large Break LOCA Evaluation Model

The list of questions, ordered according to the specific sections of the topical report is as follows:

Preface Material

1. The abstract for the topical report states that the methodology does not cover the long-term performance of the emergency core cooling system (ECCS). All best-estimate ECCS methods are expected by the NRC to also include the long-term core cooling (LTCC) phase as is stated in the criteria provided by Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50.46 (b). That requirement applies to the approved ECCS and evaluation models. The guidance of Regulatory Guide (RG) 1.157 also addresses this issue. The Applicant needs to be prepared to address and/or present the following:

   a. The KHNP plans for revising all applicable statements in the topical report in order for the proposed KHNP methodology to fully address the LTCC in the topical report. This also applies to the revision in the topical report to fully describe the approach to modeling the LTCC functionally to meet the corresponding regulatory requirements.

   b. Results of calculations to demonstrate LTCC phase of ECCS performance. The Applicant is requested to include details of the assumptions, input decks (for all relevant codes), and the methodology/computer codes used in arriving at the results.

2. Based on project drawing 1-190-H-184-001C (“primary piping interfaces”) provided in the document “KHNP Responses to Request for Additional Information No. 1-7425” it appears that the loop seal elevation for the APR1400 design is [ ]. During the long-term period of a LOCA (i.e., small break (SB) LOCA) the loop seal in the cold leg can be covered, and the steam pressure in the reactor coolant system (RCS) may have to increase before it can overcome the static head associated with the loop seal, in order to enable steam venting into the containment through the break. There is a possibility that the buildup of the steam pressure can cause the water level in the reactor core to depress thereby uncovering the fuel. Since ECCS must provide long term core cooling for a period of up to 30 days:

   a. Demonstrate that the peak cladding temperature remains within acceptable limits at all times under the stated conditions for a range of break sizes (including a 1 percent SBLOCA) in the cold leg.

   b. Assess the impact of having [ ] of safety injection pump (SIP) as being available during the long term reflood period, on the long term cooling performance under the stated conditions.

3. The guidance in RG 1.157, Section 3.1 establishes acceptable controls for the establishment of acceptable break sizes and types. The topical report Section 1 states that the report describes the methodology “...for large-break loss-of-coolant accidents (LBLOCA) for APR1400.” The Applicant needs to clearly specify the range of break sizes, locations and types of breaks for which the methodology in the topical report will be used for licensing applications.

4. Comparing Figure 1-1 in the topical report with Figure 1 of NUREG/CR-5249 it is noted that the step that determines whether a noding change is necessary is different in the two approaches. According to Figure 1-1 of the topical report, the determination of whether a noding change is required occurs after all the uncertainties and biases have been determined. It is unclear how this is accomplished and what metric will be used to determine if a nodalization change is warranted. It appears that decision of 'noding change' should be a part of the 'covering ok' decision in Figure 1-1 of the topical report, and it should follow more closely the NUREG/CR-5249 guidance. The Applicant will need to explain and provide additional rationale including the technical bases related to the process used to assess any changes to the noding in the evaluation model.

5. The guidance in RG 1.157, Section 4.3.1 establishes acceptable controls for the utilization of conservative parameters in best estimate analysis. The topical report states that the methodology is best-estimate. However, the actual implementation of the methodology incorporates a mixture of best-estimate and conservative assumptions. The reason for the conservative treatment is provided for only certain parameters. The Applicant will need to provide the basis and justifications for the selecting the parameters to be treated conservatively instead of a best-estimate manner, involving the quantification and propagation of uncertainties.

Section 3

6. RG 1.157 specifies that breaks should be evaluated to include the range from "full double-ended" to small breaks. This range would include single and double-ended breaks. Furthermore, the guidance specifies that longitudinal split breaks should be considered as well. RG 1.157 also states that actual peaking factors and fuel conditions should be used. Section 3.1 (and its subsections) of the topical report discuss the limiting scenario that is used to determine the processes that must be addressed in the evaluation model. However, the criteria specified therein include break location and size only. Furthermore, Section 5.2.1.1 of the topical report describes the spectrum of cases evaluated as being [ ]. A reference to [ ] is also provided without further discussion. The Applicant needs to:

   a. Fully describe the spectrum of breaks that are applicable to analysis of APR1400 using the proposed methodology for licensing submittals. This includes a description of the break type (e.g., guillotine, double or single-ended, and longitudinal split), size, and location. Ensure that the size parameters are either quoted in measured units, or if in percentage, clearly describe that it is with respect to what dimension or pipe size.

   b. Describe the peaking factors and fuel conditions used in such determinations.

   c. Explain the modeling approach used (i.e., nodalization, discharge coefficient, etc.) for representing longitudinal split breaks.

   d. Clarify whether any sensitivity calculations were performed to arrive [ ]. If such sensitivity calculations have been performed, describe the results and highlight any differences. If such calculations have not been performed, justify the basis for their exclusion.

e. Describe whether the limiting break analysis included consideration for loop sensitivity (e.g., loops with and without the pressurizer). If such sensitivity calculations have been performed, describe the results and highlight any differences. If such calculations have not been performed, justify the basis for their exclusion.

f. Describe whether the limiting break analysis included consideration of the location of the available safety injection pump (SIP) trains with respect to the broken cold leg. (Previous tests (e.g., UPTF) with downcomer injection have shown that nearly all water injected through the nozzle located near the broken leg is lost through bypass.)

g. The topical report Section 3.1.2.1 states that the reactor coolant pumps (RCPs) are assumed to be tripped upon loss of offsite power (LOOP). Operational RCPs may impact the peak cladding temperature as well as the coolant inventory, because the flow from the intact loops can bypass the downcomer and eject coolant out of the break. Provide justification, using results of sensitivity calculations, for the assumption that the LOOP coincident with the break is limiting.

h. Provide information for all the activation signals used in the representative LBLOCA simulation and corresponding delay times. Justify the delay times used and provide results from sensitivity studies that consider the uncertainty in the delay times for reactor trip, RCP trip, SIP activation, etc.

7. NUREG/CR-5429, Section 2.1 establishes an acceptable approach for the documentation of the event sequence. Provide a table with the sequence of events and their timing for the limiting LBLOCA scenario described in Section 3.1.2 of the topical report.

8. NUREG/CR-5429, Appendix B establishes an acceptable approach for the documentation of the timing of events. Section 3.1.2.1 of the topical report states that the blowdown period ends when a safety injection tank fluidic device (SIT-FD) injection is initiated at approximately 15 seconds after the break. Figure 5-12 of the topical report appears to illustrate this behavior. However, the SIT-FDs are connected via check valves to the downcomer. Due to the nature of a double-ended guillotine break, it is likely that the downcomer pressure decreases faster than the pressurizer pressure causing earlier initiation of SIT-FD injection. Such a sequence may affect the calculated peak cladding temperature (PCT). Demonstrate that such a situation does not exist, or if it does, characterize the impact on the behavior of the blowdown, reflood, and the resulting PCT.

9. NUREG/CR-5429, Appendix B establishes an acceptable approach for the documentation of the timing of events. Section 3.1.2 of the topical report states that the refill period ends when the mixture level reaches the bottom of active core. However, Section 3.1.2.2 of the topical report uses the terminology “water level” and “liquid level” to describe the end of the refill period. In addition, topical report Section 3.1.2.3 states that the early reflood period begins when the lower plenum is “completely filled with water.” Clarify the definition of the end of refill period, and plans to revise of the topical report to use consistent terminology throughout.

10. NUREG/CR-5429, Section 2.1 establishes an acceptable approach for the documentation of the event sequence. The Section 3.1.2.1 of the topical report describes the major phenomena occurring during the blowdown period. The end of the blowdown period is

defined as the initiation of SIT-FD injection. However, the last paragraph of Section 3.1.2.1 of the topical report describes the phenomena that occurs when the four SIT-FD begin to inject water. If this is part of the refill period then the discussion is incorrectly located. Discuss plans to make appropriate changes to the description in Section 3.1.2.1 to ensure consistency with the definition of the accident period.

11. NUREG/CR-5429, Appendix B establishes an acceptable approach for the documentation of the timing of events. Section 3.1.2.3 of the topical report describes the early reflood period as starting from ~38 s and ending at ~192 s. However, the text in the third paragraph of Section 3.1.2.3 states that "the maximum SIT-FD injection is reached during this period at around 30 s" which is inconsistent. Clarifications are needed.

12. NUREG/CR-5429, Appendix B establishes an acceptable approach for the documentation of the timing of events. The liquid and void fractions in various RCS components at key times in the accident progression are depicted in Figures 3-3 through 3-8 of the topical report. According to the phenomena description in Sections 3.1.2.1 through 3.1.2.3 of the topical report, the SIT-FD water injection begins from ~15 seconds and ends at ~192 seconds. However, Figures 3-5 through 3-8 of the topical report indicate that the SIT-FD is fully filled with water during this period. This is an inconsistency that needs to be addressed by making appropriate changes to Figures 3-5 to 3-8 to be consistent with the scenario description.

13. RG 1.157 outlines guidance in many places that the results for best estimate calculations are to be considered acceptable provided their technical bases are demonstrated with appropriate data and analyses. However, some of the results provided in the topical report are unclear. Figure 3-2 of the topical report shows the normalized collapsed water level in the downcomer and the reactor core. It is essential to confirm that the following interpretations of Figure 3-2 are correct:

    a. At the end of blowdown, approximately 25 percent of the initial core liquid volume remains in the core.

    b. At the end of refill, approximately 5 percent of the initial core liquid volume remains in the core.

    c. At the end of blowdown, approximately 30 percent of the initial lower plenum liquid volume remains in the lower plenum.

    d. At the end of refill, approximately 20 percent of the initial lower plenum liquid volume is in the lower plenum.

    e. In the late reflood period, approximately 35 percent of the initial core liquid volume is maintained in the core. Also, define what constitutes the lower downcomer relative to Figure 3-2 of the topical report.

14. NUREG/CR-5429, Section 2.1 establishes an acceptable approach for the documentation of the phenomena identification and ranking table (PIRT). A large number (i.e., 83 parameters) of phenomena or processes are ranked 4 or higher in the APR1400 PIRT. However, the application of CAREM actually uses only 30 uncertainty parameters as shown in topical report Table 5-1.

a. A description of the process followed to determine the 30 uncertainty parameters that are actually ranged for the simple random sampling (SRS) calculations from the entire possible set (i.e., 83 parameters) based on the PIRT is needed.

b. An explanation and justification of the approach used (i.e., conservative or best estimate values) for the remaining parameters not included in the uncertainty analysis is needed.

15. It appears that what is being termed the APR1400 PIRT in Table 3-2 and Table 5 of Appendix A of the topical report is actually a subset of the Korea Next Generation Reactor (KNGR) PIRT, shown in Table 3 in Appendix A, that includes only those phenomena from the KNGR PIRT (with modifications for APR1400) that are ranked 4 or higher during at least one of the accident periods. A complete PIRT, as described in NUREG/CR-5249 includes all the phenomena and their corresponding ranking. Both the KNGR and the APR1400 PIRTs lack a state-of-knowledge ranking for each phenomenon. In addition, according to RG 1.203, the PIRT generated to guide the evaluation model (EM) development process must be adequately documented. A complete documentation of the PIRT for APR1400 that includes the rationale for the assigned ranks and state-of-knowledge is needed.

16. Section 3.12.1 of RG 1.157 states that "the containment pressure used for evaluating cooling effectiveness during the post-blowdown phase of a LOCA should be calculated in a best-estimate manner and should include the effects of containment heat sinks." According to Section 3.4 of the topical report, the APR1400 LBLOCA methodology calls for the coupling of RELAP5/MOD3.3/K with CONTEMPT4/MOD5 for the LBLOCA. As a result, the adequacy of CONTEMPT4/MOD5 also needs to be determined. Table 3-2 of the topical report (also Table 3 in Appendix A from which Table 3-2 is derived) contain and rank the generic processes such as [ ] for the containment component. However, the ranking of such generic processes is insufficient for adequacy determination. Individual phenomena that impact these general processes (e.g., "condensation heat transfer," "impact of non-condensable gases," "droplet heat and mass transfer," etc.) need to be included and ranked in the PIRT to determine the code adequacy and uncertainty following the SRP Section 15.0.2, Revision 0, and NUREG/CR-5249 guidance. A complete PIRT for the containment phenomena is required. Also, provide an explanation of how the containment is treated statistically.

17. NUREG/CR-5429, Section 2.1 establishes an acceptable approach for the documentation of the PIRT. The following concerns are related to Table 3-2 of the topical report:

a. A more detailed explanation of the phenomena [ ] along with a justification for their respective importance rankings is needed. This needs to include a discussion of how these phenomena (ranked 4 or higher) are modeled and how the uncertainty in these parameters is determined and included in the analysis.

b. According to the Table 3-1 of the topical report, the end of blowdown period is defined as the initiation of SIT-FD injection. As a result, the process or phenomena associated with SIT-FD are not present during the blowdown period. However, some of phenomena for the SIT-FD are ranked during the blowdown period in

Table 3-2 of the topical report. The basis for the importance rankings assigned to the SIT-FD phenomena during the blowdown period is needed.

c. Section 3.1.2.3 of the topical report provides the phenomena descriptions during the early reflood period. [

]. Based on the accident period definition, the gas discharge should be initiated after the SIT-FD water has depleted at the end of the early reflood period. The same comment also holds for the ranking of the [ ]. The basis for the stated importance rankings is needed.

d. [

]. According to the accident period definition, SIT-FD do not inject until the beginning of period 2. Therefore, provide the rationale for the rank of 3 for period 2 and the rank of 5 for period 1, for both the above mentioned phenomena. The ranking for these phenomena is important because they are treated with a bias during the accident.

e. [
].

f. Provide an explanation for not considering downcomer boiling during the refill period.

g. [

].

h. According to Table 3-2 of the topical report, non-condensable gas is only expected to be influential in the reactor vessel downcomer component during the early reflood period. However, a relatively large amount of non-condensable gas is transferred from SIT to the downcomer after the depletion of SIT water inventory, the late reflood period. Provide an explanation of the current ranking for the cited phenomenon.

i. [

]. Table 5-1 the topical report shows that this parameter is part of the uncertainty analysis. Provide the rationale for not including the form loss through the RCPs.

18. The guidance in RG 1.157, Section 3.12.2 establishes acceptable controls for the calculation of mixture level in best estimate analysis. Table 3-2 of the topical report ranks [

]. Since the RELAP5 fluid nodes are basically homogenous, a description of the approach (i.e., fine nodalization, level tracking, etc.) used to determine the mixture level in the APR1400 RELAP5/MOD3.3/K model is needed to better understand the PIRT and the reported results.

19. NUREG/CR-5429, Section 2.1 establishes an acceptable approach for the documentation of the computer codes and associated interfaces. Table 3-5 of the topical report does not provide the entire picture of the presence of models and correlations in RELAP5/MOD3.3/K and CONTEMPT4/MOD5. Therefore:

    a. A clear statement of all the phenomena that are treated by biases in Section 3.6.1 is needed.

    b. Table 3-5 of the topical report needs to include a column providing the status of the existence of model ("yes/no") in RELAP5/MOD3.3/K and CONTEMPT4/MOD5 for each of the listed phenomenon.

20. The guidance in RG 1.157, Section 2.1.2 establishes acceptable controls for the calculation of the effects of noncondensible gases in best estimate analysis. In addition, NUREG/CR-5249 (pg. 68) explicitly addresses the bias due to dissolved nitrogen. The RELAP5/MOD3.3 code does not model dissolved nitrogen in the liquid and therefore, the predicted reflood peak cladding temperature does not reflect its effect. An assessment and documentation of the effect of dissolved nitrogen on the PCT is needed.

21. NUREG/CR-5429, Section 2.1 establishes an acceptable approach for the documentation of the computer codes and associated interfaces. Address the following concerns related to Section 3.4 and Appendix B of the topical report:

    a. Section 3.4 and Appendix B give the impression that all the changes made to the original RELAP5/MOD3.3 code are described in Appendix B. However, in response to prior requests for additional information (RAIs), documented in APR1400-F-A-RA-14001-P, it appears that additional changes have been made to RELAP5/MOD3.3, including the ability to input uncertainty variables. A complete characterization of all changes made to RELAP5/MOD3.3 for inclusion in Appendix B is needed.

    b. A list of all changes that have been made to the original CONTEMPT5/MOD4 source code for the present application is needed.

22. RG 1.157 outlines in many places that the results from best estimate calculations are to be considered acceptable provided their technical basis is demonstrated with appropriate data and analyses. Section 3.4 and Appendix B of the topical report discuss [

    ]. Appendix C provides a list of the FLECHT-SEASET tests for comparison to RELAP5/MOD3.3/K calculations, most of which have flooding rates larger than 25 cm/s. Address the following:

    a. Provide results from the examination of the [ ] against data from low flooding rate tests such as test 31805 and/or test 34006.

    b. Figure 5-16 of the topical report shows the liquid velocity at the core inlet for the base case calculation. Provide the transient history (from 50 seconds onwards) for the liquid velocity at the core inlet for the base case calculation in sufficient detail to enable assessing the general flooding rate.

23. The guidance in RG 1.157, Section 2.1.2 establishes acceptable controls regarding the accuracy of computational models in best estimate analysis. Section 3.4 and Appendix B of the topical report discuss the modification [ ]. Figures 11 and 12 of Appendix B provide comparisons of the cladding temperature calculated with the modified code against the data for FLECHT-SEASET tests 31108 and 31504, respectively. The high flooding rate test (31108) shows an excellent comparison to the quench time at the PCT location. The low flooding rate test (31504) shows an under-prediction of the cladding temperature at the peak location and a delay in the quench time. Figure 14 of Appendix B provides a comparison of the calculated heat transfer coefficient against the data for test 31504. However, Figure 14 of Appendix B only shows the comparison beyond 200 seconds. Address the following:

a. Provide the heat transfer coefficient comparison for the time period of 50 to 200 seconds against the data for test 31504.

b. Provide the RELAP5/MOD3.3K calculated mass flow rates (liquid/vapor) for the elevation at which the peak temperature occurs for tests 31108 and 31504.

c. Provide results from the examination of the final combined heat transfer coefficient compared with data for FLECHT-SEASET test 31805 and/or test 34006.

d. The code modification [ ] based on Figure 5 of Appendix B. Assuming the flow rate is accurately predicted, the underprediction of heat transfer should translate into an over-prediction of the cladding temperature. However, the cladding temperature is under-predicted for the low reflood rate test (Figure 12 of Appendix B) implying that another mechanism may be responsible. This is also true for test 34006 as shown in Appendix C. If the APR1400 calculated flooding rate is low, the calculated cladding temperature will be lower than that calculated if a better or more realistic heat transfer coefficient is utilized. A justification for the code modification that enables a best-estimate representation is needed.

e. The caption for Figure 12 in Appendix B is incorrect. It refers to FLECHT-SEASET Test 31504 instead of 31108.

24. The guidance in RG 1.157, Section 2.1.2 establishes acceptable controls regarding the accuracy of computational models in best estimate analysis. Appendix B of the topical report states that the [ ]. Provide the basis for performing the modification [ ] to that of the earlier version. Include discussion of the accuracy of the models.

25. NUREG/CR-5429, Section 2.1.4 discusses controls over code versions and changes that could affect best estimate calculations. The effects of the modifications to RELAP5/MOD/3.3 have been demonstrated using either SET data (from the FLETCH-SEASET tests) or APR1400 plant simulations in Appendix B. The APR1400 simulations show the comparison of results before and after a particular modification [ ] is made. However, a comparison of results for either the APR1400 plant or an integral test using RELAP5/MOD3.3 and RELAP5/MOD3.3/K (with all changes present in the frozen code version) is missing. Provide such a comparison.

26. SRP 15.0.2 Section 2.5 requires that the EM be placed under a quality assurance program that meets the requirements of 10 CFR 50 Appendix B. Confirm that the RELAP5/MOD3.3/K EM for LBLOCA is controlled in this manner. Also provide details of the code modification quality assurance program in place to confirm that the changes to RELAP5/MOD3.3 are correctly implemented and that the remainder of the source code is not altered. Furthermore, explain the use of the term "frozen" and how this affects the current submittal and future use in various licensing calculations.

Section 4

27. NUREG/CR-5429, Section 2.2.2 discusses issues related to model nodalization. Address the following issues regarding nodalization of the APR1400:

    a. Section 4.2.1 of the topical report states that the APR1400 nodalization of the reactor vessel "...follows the typical pressurized water reactor nodalization..." Provide additional details to support this assertion. Furthermore, as specified by RG 1.157, provide a reference for the documentation related to the nodalization sensitivity studies that were performed in order to determine the final APR1400 RELAP5 nodalization that will be used for licensing calculations.

    b. [ ] have been chosen to represent the downcomer based on [ ]. However, no information is provided as to what phenomena were investigated. Moreover, the ECCS bypass is introduced [ ] and is not dependent on the nodalization of the downcomer. List the applicable phenomena considered.

    c. No evidence is provided to support the assertion that the selected nodalization for the downcomer [ ] requested in part (b) as asserted in the topical report. Address this concern.

    d. RG 1.157 states that "…one-dimensional approximations to three-dimensional phenomena will be considered if those approximations are properly justified." [ ]. The lower power peripheral fuel assemblies are also not represented separately. It is unclear how this nodalization was selected over other options and how it can model multidimensional phenomena (e.g., "upper plenum to core counter-current flows (CCF)" in topical report Table 3-2). Provide the basis for the selected nodalization with respect to capturing the multidimensional phenomena occurring in the core.

    e. Section 4.3.1.1 of NUREG/CR-5249 discusses the use of different nodalizations in the core to evaluate the hot channel bias. The topical report does not document or discuss such sensitivity studies. The selected nodalization may also overestimate the cross-flow into the hot assembly from the surrounding assemblies which is non-conservative for PCT calculation. Provide the basis for the selected radial nodalization of the core and upper plenum.

f. Cross-flow through the junctions in the core depends on the associated flow areas and loss coefficients. Provide an explanation of the calculation approach used to determine these parameters and how their uncertainties are represented.

g. The froth level is typically important in determining the quench front progression. This requires accurate calculations of the fluid quality and heat release in a control volume and the mass flow rate and steam flow rate through a control volume. Provide an explanation of the basis for the core axial nodalization and the uncertainty associated with it. Also provide an assessment of the Courant limits on the nodalization.

h. According to NUREG/CR-5249 (see Figure 18 in NUREG/CR-5249), analysis results from the simulation of a pressurized-water reactor (PWR) LBLOCA showed that at least two nodes are required in the lower plenum below the downcomer skirt to adequately model the sweep-out effect which is [ ]. It appears that the APR1400 nodalization models the region below the downcomer skirt [ ]. Provide justification for the selected nodalization.

i. According to RG 1.157 Section 3.5 the break location and ECCS injection point are areas of high fluid velocity and complex fluid flow and contain phenomena that are often difficult to calculate. The results of these calculations are often highly dependent on noding. Justify the nodalization selected for the APR1400 broken cold leg and provide results from relevant sensitivity studies to assess the impact of nodalization changes in the break discharge region (i.e., based on the Marviken data).

j. RG 1.157 Section 3.5 discusses nodalization near the ECCS injection point and states that "…sufficient sensitivity studies should be performed on the noding and other important parameters to ensure that the calculations provided realistic results." Appendix E of the topical report discusses tests performed in the ATLAS facility to study direct vessel injection (DVI) performance relative to emergency core cooling water bypass and downcomer boiling. Describe or refer to the sensitivity studies performed to assess the selected nodalization near the ECCS injection point using the ATLAS test results.

k. In order to adequately simulate the depletion time of the pressurizer and liquid drainage during the blowdown period, the nodalization of the pressurizer surge line should be consistent with the actual plant geometry. However, the description for the pressurizer surge line nodalization is not provided in Section 4.2.1 of the topical report. According to the RELAP5 base model input deck, the surge line is modeled using a single inclined hydraulic component. Additionally, the loss coefficient through surge line pipe is set to be computed by the code which neglects the turns and orientation changes in the line. Justify the selected nodalization and loss coefficients including any references to nodalization sensitivity studies comparing the pressurizer flow into upper plenum against the available special effects tests and/or integral effects tests data.

l. Discuss the differences in the nodalization of the upper guide support structure region between the RELAP5 nodalizations shown in Figure 4-1 of the topical report, and Figure 17 in Appendix B. Identify, with justification, the nodalization that will be used for licensing calculations.

m. Differences are noted in the nodalization of the vessel between the APR1400 plant shown in Figure 4-1 of the topical report and the ATLAS facility shown in Figure 3-3 of Appendix E. These differences include the nodalization of the downcomer, lower plenum, upper plenum and the upper plenum to dome connection. Explain the reasons for the noted differences.

28. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of calculational uncertainty. Section 4.2.2.1.1 of the topical report states that the uncertainty of fuel thermal conductivity is based on the information from MATPRO (Version 11, Rev. 1, 1980). However, Section 2.3 of NUREG/CR-7024 provides the latest comparison of fuel thermal conductivity models against available experimental data. Section 2.3.2 of NUREG/CR-7024 provides a higher uncertainty for the MATPRO fuel thermal conductivity correlation for both un-irradiated and irradiated fuel as compared to that in Section 4.2.2.1.1 of the topical report. Section 2.3.2 of NUREG/CR-7024 states that the MATPRO fuel thermal conductivity correlation has a bias in the prediction of data from un-irradiated and irradiated uranium oxide fuel. Address the discrepancy between the uncertainty cited in the topical report and the assessment in NUREG/CR-7024, and justify the value used in the topical report.

29. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of calculational uncertainty. The guidance in RG 1.157, Section 3.3.1 establishes acceptable controls regarding the calculation of clad swelling and rupture. Section 4.2.2.1.1 of the topical report states that the uncertainty in [ ]. According to Section 9.3 of Volume 4 of the RELAP5/MOD3.3 manual, [ ] in the code, derived from FRAP-T6, considers "...elastic deformation of cladding under the differential pressure..." A few lines later the manual states that "...clad ballooning is not included in the [ ]." Address the following issues:

a. Describe the methods used by RELAP5/MOD3.3 to calculate clad ballooning, fuel pellet fragmentation, and relocation.

b. Describe how ballooned cladding affects long term core coolability.

c. Describe how the ballooning model alters the calculated [ ].

d. Provide the rationale for not utilizing the uncertainty in the existing [ ].

e. Provide evidence that the selected uncertainty in the cladding rupture model bounds the uncertainty in [ ].

f. Manufacturing tolerance for gas composition, initial backfill pressure, and the uncertainty associated with fission gas production, will also affect the potential ranges of cladding temperature independent of the swelling and rupture, particularly if rupture is not calculated to occur. Describe how the chosen approach treats the gap gas uncertainty component of [ ].

30. The guidance in RG 1.157, Section 3.3.1 establishes acceptable controls regarding the calculation of clad oxidation. Section 4.2.2.1.1 of the topical report describes the uncertainty in the cladding oxidation. The document “KHNP Responses to Request for Additional Information No. 1-7425” (page 4 of 23) describes the input for the uncertainty in the cladding oxidation reaction. Address the following issues:

    a. The description implies that the uncertainty will be [ ]. The rationale provided is that [ ]. However, the acceptance criterion applies to core-wide cladding oxidation, and in addition, RG 1.157 does not distinguish between oxidation in different rods for best-estimate analysis. Therefore, justify the basis for [ ].

    b. According to Section 3.2.5 of RG 1.157, “For rods calculated to rupture their cladding during the loss-of-coolant accident, the oxidation of the inside of the cladding should be calculated in a best-estimate manner.” A discussion of how this requirement is met in CAREM is needed.

31. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of calculational uncertainty. Section 4.2.2.1.1 of the topical report provides the uncertainty for the Dittus-Boelter correlation for the liquid-phase forced convection heat transfer by citing “various references.” Provide the references used to determine the uncertainty as well as the results used to determine the standard deviation for this parameter.

32. The guidance in RG 1.157, Section 3.8 establishes acceptable controls for the calculation of critical heat flux. Section 4.2.2.1.2 of the topical report states that the nucleate boiling heat transfer coefficient is calculated in RELAP5/MOD3.3 based on the Chen correlation, and it goes on to cite the RELAP5/MOD3.3 code manual for the average error of 21.1 percent for saturated nucleate boiling and ± 40 percent for subcooled nucleate boiling. However, the reviewers find that the maximum average error using the Chen correlation for saturated nucleate boiling is 15.7 percent according to Table 4.2-4 of Volume 4 of the RELAP5/MOD3.3 manual. Furthermore, the range of errors using the Chen correlation for subcooled nucleate boiling is given as +180 percent to -60 percent in the Section 4.2.3.2.3 of Volume 4 of the RELAP5/MOD3.3 manual. Provide the basis and details of the source(s) used to determine the values listed in Section 4.2.2.1.2 of the topical report for the uncertainty in the Chen correlation.

33. The guidance in RG 1.157, Section 3.8 establishes acceptable controls for the calculation of critical heat flux. Section 4.2.2.1.2 of the topical report discusses the comparison of the performance of the Groeneveld lookup table, shown in Figure 4-2 for the “high-pressure and high-flow critical heat flux” phenomenon. Demonstrate that the system conditions encountered during the limiting LBLOCA are covered by the 1993 data points that were used for comparison. In addition, clarify whether the 1993 data points represent data from steady-state tests or include transient critical heat flux (CHF) tests as well.

34. The guidance in RG 1.157, Section 3.8 establishes acceptable controls for the calculation of critical heat flux. Address the following regarding the two CHF correlations when the RELAP5/MOD3.3 reflood model is activated:

a. Provide the mass flux limits and transition criterion for the CHF calculated from the lookup table and from the modified Zuber correlation when the reflood model is activated.

b. Indicate whether the conditions in the representative LBLOCA during the early reflood period fall in the transition region. Furthermore, explain how separate uncertainties in the high- and low-flow CHF calculations can capture the uncertainty in the transition region where interpolation is used.

35. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of calculational uncertainty. Section 4.2.2.1.2 of the topical report discusses the uncertainty for the “film boiling heat transfer” phenomenon. Address the following regarding the corresponding uncertainty determination:

a. The assessments presented in Appendix C of the topical report compare the prediction of the overall film boiling heat transfer correlation in RELAP5/MOD3.3/K against experimental data, so that the resulting uncertainty in the prediction can be determined. Explain the reason for the current approach of using uncertainties for the individual correlations (e.g., Bromley and Forslund-Rohsenow (F-R)) instead of the uncertainty range based on the overall film boiling heat transfer prediction by RELAP5/MOD3.3/K. Justify use of the Forslund-Rohsenow correlation and any modifications made in its application.

b. Section 4.2.2.1.2 of the topical report cites NUREG/CR-5249 as the basis for determining the uncertainty range for the F-R heat transfer correlation. However, Section 4.1 of NUREG/CR-5249 (pg. 82, second paragraph), the range of multipliers (0.75 – 1.5) used in NUREG/CR-5249 is for the total film boiling heat transfer. The impact of only the F-R correlation is captured via a bias as noted in Section 4.1 of NUREG/CR-5249 (pg. 82, second paragraph) and described in Section 4.3.1.2 and Table 37 of NUREG/CR-5249. Justify the range for the F-R correlation in Section 4.2.2.1.2 of the topical report [ ].

c. Section 4.2.2.1.2 of the topical report states that the study documented in the topical report Reference [16] showed that the experimental data was [ ]. As described in Appendix B of the topical report, [ ]. Explain how the performance of only the Bromley correlation was determined from the RELAP5/MOD3.3 comparisons for use in the uncertainty analysis.

d. Section 4.2.2.1.2 of the topical report states that the study documented in the topical report Reference [16] showed that [ ].” The topical report proceeds to assign, without any explanation, the standard deviation for the Bromley correlation based on the lower end of this prediction range. Provide the corresponding justification.

36. NUREG/CR-5429, Section 2.1 establishes an acceptable process for the documentation of PIRT. Section 4.2.2.1.2 of the topical report discusses the phenomenon of spacer grid

heat transfer which carries a rank of [ ] in the APR1400 PIRT (topical report Table 3-2). It is stated that "RELAP5/MOD3.3/K does not have a model to address these heat transfer enhancement effects of the spacer grids. The deficiency of the spacer grid model would result in a conservative prediction of the cladding temperatures." The FLECHT-SEASET test bundle incorporates spacer grids. It would be expected therefore that the RELAP5/MOD3.3/K simulations would over-predict the cladding temperature test data. However, Figure 8 of Appendix B shows that for the low flooding rate test 31504 the cladding temperature at the 78-inch elevation is under-predicted. Appendix C provides a comparison of RELAP5/MOD3.3/K simulations of 17 FLECHT-SEASET tests. Most of those tests were at high flooding rates. At the 72-inch and 96-inch elevation, several cases were under-predicted. In addition, three of the four low flooding rate cases (less than 30 cm/sec) tended to be under-predicted. Furthermore, most of the RELAP5/MOD3.3/K calculated results show unusual behavior for rod quenching at the various elevations – the rod cladding temperature rapidly drops followed by a declining plateau and then a final temperature drop to quenching. The above discussion indicates that even though the RELAP5/MOD3.3/K calculations do not include the effects of modeling the spacer grids, the cladding temperature calculation is non-conservative for several cases. Therefore, describe the code calculated physical phenomena providing the cladding cooling in the noted results.

37. The guidance in RG 1.157, Section 3.9.1 establishes acceptable controls regarding the calculation of radiation heat transfer. Section 4.2.2.1.2 of the topical report states that [

].” Address the following concerns about this statement:

a. As mentioned in Appendix B, the prediction by RELAP5/MOD3.3/K using [ ] is added to the convective vapor and radiation heat transfer to determine the total heat transfer. In addition, Appendix C makes no mention of [ ] in the comparison of RELAP5/MOD3.3/K predictions against experimental data. Clarify whether [ ] as part of CAREM and therefore, [ ] the film boiling heat transfer calculation.

b. Clarify whether the code used for the assessments documented in Appendices B and C of the topical report includes radiation heat transfer, especially for the film boiling heat transfer calculation.

c. [ ] in Section 4.2.2.1.2 of the topical report is called "conservative." [ ] may actually be non-conservative. Justify [ ].

d. The APR1400 PIRT assigns a rank of [ ] or lower for the "radiation heat transfer to the surfaces, vapor and liquid" phenomenon. Based on the definition of the importance rankings, it is implied that the phenomenon is calculated in the code. [ ].

38. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties. Section 4.2.2.1.2 of the topical report states that the uncertainty in the

interfacial drag and heat transfer models is captured via [ ]. Address the following concerns about [ ]:

a. It is unclear what is being achieved by the uncertainty on [ ] because the impact on entrainment from the upper plenum resulting in steam binding is captured via a separate assessment that does not include [ ]. In addition, results showing the actual impact of [ ] have not been provided. Therefore, it is difficult to determine the purpose of the selected uncertainty and whether the selection and the ranges are appropriate. Justify the selection of [ ].

b. The purpose of the ranging of parameters is to capture the uncertainty in the code prediction by comparisons against relevant experimental data. Such an approach has not been followed to determine the uncertainty in the interfacial drag and heat transfer models. The range of uncertainty selected for [ ] is based on code manuals rather than on the comparison against interfacial drag or heat transfer data (i.e., tests listed in the Table 4-4 of the topical report). Furthermore, comparisons against data also reveal the impact of code features such as level tracking. These code features can potentially impact the predicted entrainment and therefore, the uncertainty in the predictions. Justify the values used for the uncertainty in the interfacial drag and heat transfer in the topical report.

c. Section 6.1.3.1 of Volume 4 of RELAP5/MOD3.3 manual states that [ ] is 3.0 and that for post-CHF droplets is 12.0. These values are also stated on page 46 in Volume 4 of RELAP5/MOD3.3 manual. These [ ] values appear to represent a range. Provide details of the source(s) for [ ] that is documented in Section 4.2.2.1.2 of the topical report.

39. The guidance in RG 1.157, Section 3.11 establishes acceptable controls regarding the calculation of flow distribution. Provide the reason for flashing in the downcomer to be treated using a different approach (i.e., ECCS bypass bias) in Section 4.2.2.2 of the topical report as compared to flashing elsewhere in the RCS (e.g., uncertainty in break flow and system pressure).

40. The guidance in RG 1.157, Section 3.11 establishes acceptable controls regarding the calculation of flow distribution. [ ]. Explain these phenomena are sampled in the calculations.

41. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties. Address the following questions about the uncertainty determination for critical flow described in Section 4.2.2.7.1 of the topical report:

a. NUREG/CR-5249 proposes that the nodalization for the plant should follow that used to establish the uncertainty ranges. Explain whether the final nodalization of the break discharge location in the Marviken facility used for the break flow uncertainty determination was identical to that for the plant deck.

b. Based on Figure 4-6 of the topical report, it appears that RELAP5 shows underprediction for two-phase break flow in excess of 4500 kg/s even with the adjusted discharge coefficient. Provide the range of two-phase discharge flow for the APR1400 design based on integral tests and plant calculations.

42. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties. Section 4.2.2.7.1 of the topical report states that [ ]. Instead of sampling the break mass flow rate, in Section 5.2.1.1 of the topical report the limiting break is determined. Section 5.2.1.1 and Table 5-1 of the topical report do not mention whether the loss coefficients in the break flow paths (on both sides of the break) were varied during sensitivity studies. [ ]. Clarify the uncertainty evaluation.

43. The guidance in RG 1.157, Section 3.12.1 establishes acceptable controls for the calculation of containment pressure. Section 4.2.2.7.2 of the topical report states that [ ]. However, there is no description of the CONTEMPT inputs (i.e., for heat transfer surface area, the wall condensation model, etc.), including results of sensitivity calculations that demonstrate [ ]. Provide justification for [ ].

44. The guidance in RG 1.157, Section 3.12.1 establishes acceptable controls for the calculation of containment pressure. According to "KHNP Responses to Request for Additional Information No. 1-7425" (pg. 7 of 23) for the APR1400 LBLOCA analysis, "...TPEAK is set to 0 (zero) and CONTEMPT4/MOD5 dynamic-link library (contl.dll) is loaded when RELAP5/MOD3.3 starts reflood calculation (reflood heat structures enter to reflood mode). The coupled code sets TPEAK to the time reflood calculation starts." The explanation implies that the coupling between the codes does not commence till the early reflood period. Explain how the containment backpressure is determined and supplied to RELAP5 for the accident period before early reflood.

45. The guidance in RG 1.157, Section 3.4.2 establishes acceptable controls for the calculation of bypass flow. Address the following concerns about [ ] determination discussed in Section 4.2.3.1 of the topical report:

a. The actual implementation of [ ] in the code calculations is unclear. It cannot be determined whether [ ]. A clarification is needed about the approach used to incorporate [ ] in the code during the blowdown, early and late reflood periods.

b. Provide the assessment results of [ ] is appropriate, should be provided.

c. The selected test, [ ] during the refill period initiates from a system pressure of 1200 kPa (i.e., 1.2 MPa). The refill period in APR1400 begins, based on the results in Figure 5-12 of the topical report, when the system pressure is approximately 6 MPa. Therefore, [ ] may not capture a large portion of the depressurization transient and the resulting [ ] during the APR1400 refill period. Discuss the applicability of [ ].

d. UPTF-21A and -21B involve downcomer injection of ECCS. Justify the selection of UPTF-4A with cold leg injection for determination of the ECCS bypass bias over the tests with a configuration similar to that in APR1400.

e. NUREG/CR-5249 recommends that the nodalization selected for the nuclear plant be consistent with that used for selected test facilities. The UPTF nodalization shown in Appendix F of the topical report is different (i.e., the downcomer axial and azimuthal nodalization) as compared to that selected for APR1400. Discuss the differences between the nodalizations and its impact on the conclusions from the UPTF simulations.

f. ATLAS Tests 9, 11 and 15 are included to determine the ECCS bypass bias during the reflood period. However, the figures for Tests 9 and 11 in Appendix E are provided only from 200 seconds after the beginning of the accident. The results from the period before 200 seconds were adjusted to match the measured conditions. The results for ATLAS Test 15 shown in Figures 3-19 and 3-20 in Appendix E of the topical report reveal that RELAP5/MOD3.3/K over-predicts the downcomer and core collapsed water levels for the period from 38 seconds to 150 seconds (early reflood). Provide justification for the neglect of this non-conservatism in the ECCS bypass prediction during the early reflood period.

g. None of the descriptions of the models for APR1400, MIDAS or UPTF that are used to determine [ ] mention the use of a counter-current flow limitation (CCFL) correlation in the downcomer. Clarify whether any such correlation was used and if so, describe the resulting impact on [ ].

46. The guidance in RG 1.157, Section 3.4.2 establishes acceptable controls for the calculation of bypass flow. The expression for the bypass fraction shown in Section 2.1 of Appendix F appears to be incorrect. M_water_out is defined as the liquid flow rate discharged through the lower plenum which would be indicative of the amount that has not been bypassed in the test. Confirm and if necessary, provide the correct the expression. Also confirm that the bypass fractions shown in Figures 2-3, 2-7 and 2-8 in Appendix E are correctly calculated and compared.

47. The guidance in RG 1.157, Section 3.11 establishes acceptable controls regarding the calculation of core flow distribution. Section 4.2.2.1.2 of the topical report states that the uncertainty in the high importance phenomenon of [ ] is not determined because it is included in the steam binding bias. Flow through the top nozzles is a complex multidimensional process with liquid down flow through the lower power outer assemblies and steam and entrained liquid up flow through the central higher power assemblies. Bias in the steam binding process is not directly related to the uncertainty in the countercurrent flow at the top nozzles. Demonstrate how the bias in the

steam binding process bounds the uncertainty in countercurrent flow at the top nozzles or provide the bases for neglecting the relevant uncertainty.

48. The guidance in RG 1.157, Section 3.11 establishes acceptable controls regarding the calculation of steam or two-phase fluid interaction with injection flow. Address the following concerns about [ ] determination discussed in Section 4.2.3.2 of the topical report:

    a. Results from a past assessment using RELAP5/MOD3.1 have been cited. However, that is not the code version being utilized for the KHNP analyses. Indicate whether RELAP5/MOD3.3/K has been used to confirm that the results cited are applicable.

    b. It is expected that the predicted entrainment from the upper plenum will be a strong function of nodalization in the core and the upper plenum regions. Describe the nodalization of these components for the comparison against [ ]. In case the nodalization for the core and upper plenum for comparison against [ ] is different from that for APR1400, justify the applicability of the nodalization used for APR1400 calculations.

    c. The implementation of [ ] in RELAP5/MOD3.3/K is shown in Slide 18 of 29 of APR1400-F-A-RA-14001-P. Use of inconsistent activation times for [ ] may lead to different results and render the assessment inapplicable. Clarify whether the activation time implemented in RELAP5/MOD3.3/K is consistent with that used for the [ ]. If the activation times are different, a justification needs to be provided.

    d. The implementation of [ ] in RELAP5/MOD3.3/K is shown in Slide 19 of 29 of APR1400-F-A-RA-14001-P which states that this feature is activated at [ ]. This selection of the activation time for this portion of [ ]. According to Table 3-5 of the topical report, the PIRT assigns a rank of [ ] is expected to be more important during the early reflood period due to the higher rates of flow and entrainment. Justify the selected activation timing for [ ].

49. The guidance in RG 1.157, Section 3.16.1 establishes acceptable controls regarding the calculation of acceptance criteria. In Section 4.3.1.1 of the topical report, the one-sided 95 percent limit of blowdown PCT is specified as [ ] and it is calculated using [ ]. However, the one-sided 95 percent limit of reflood PCT is calculated as [ ]. Moreover, the calculation for the blowdown period is inconsistent with the expression in Section 4.3.1 of the topical report. Provide the reason for the discrepancy in the approaches used for blowdown and reflood PCT calculations in Section 4.3.1.1.

50. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation

and propagation of uncertainties. Address the following concerns about the “coverage check” discussed in Section 4.3.2 of the topical report:

a. Explain how the limited number of parameters for uncertainty variation in the blowdown and reflood “coverage check”’ was chosen from the list of all phenomena with [ ] during these periods.

b. The “coverage check” uses a small subset of parameters for uncertainty variation. However, a larger set of parameters is actually used in the best-estimate plant calculations. Explain how it is ensured that inclusion of the additional uncertainty parameters does not change the results and alter the conclusions of the “coverage check.” Further, if such a demonstration has been accomplished, describe the change in the limiting PCT.

c. Clarify whether [ ] was included in the performance of the “coverage checks” for reflood period when compared to integral test data.

51. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties. The following issues are related to the distribution-free statistics method described in Section 4.3.2 of the topical report:

a. It appears that the method described in Section 4.3.2 is similar to the formulation of Guba, Makai and Pál based on order statistics (Reliability Engineering and System Safety, Vol. 80, Issue 3, pp.217-232, June 2003). Confirm or provide a reference for the method used in the topical report.

b. Section 4.3.2 states that the third highest result of 124 random calculations provides the 95/95 limit. In case the method in the topical report uses order statistics (see part (a) of this issue), it is unclear whether the approach employed in the topical report is the single parameter uncertainty evaluation with the third estimator grade or the multiple parameter uncertainty evaluation with three parameters. Both approaches require 124 random calculations. Clarify the method used in CAREM.

c. In case the distribution-free statistics method is based on the single parameter uncertainty evaluation for the PCT, the approach used to determine the limiting values of local cladding oxidation and hydrogen generation is not clear. It is not possible to determine whether the limiting values of local cladding oxidation and hydrogen generation are those that correspond to the calculations resulting in the limiting PCT or are derived from separate 124 random calculations for each of those two parameters. Explain and justify the approach used.

d. In case the distribution-free statistics method is based on the multiple parameter uncertainty evaluation with three parameters, such a method assumes that the parameters are continuous and independent. During LBLOCA calculations bursting of cladding may be predicted to occur resulting in a discontinuous increase in the cladding temperature. In addition, the local and the core-wide cladding oxidation and hydrogen generation values are dependent on the corresponding cladding temperature. Clarify whether the methodology described in the topical report is limited to pre-burst conditions or justify the applicability of the assumption of the continuity of the parameters in the event of cladding burst. Further, justify the assumption of the independence of the three parameters (e.g., PCT, cladding oxidation and hydrogen generation).

Section 5

52. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties. In addition, NUREG/CR-5249 describes the process for formulation of uncertainty distributions. Address the following questions about the statistical treatment of uncertainties in CAREM:

    a. RG 1.157 states that “the methodology used to obtain an estimate of the overall calculation uncertainty at the 95 percent probability limit should be provided and justified.” Provide the justification for the use of the distribution free statistical approach.

    b. The example of the process shown in NUREG/CR-5249 indicates that mean value of the effect for each of the uncertainties on the blowdown and reflood portions is calculated. The sum of all the 95^{th} percentiles relative to the mean are added to obtain the summed biases. The summed biases are then added to 95^{th} percentile of the response surface produced from the calculation of the mean peak cladding temperatures from the uncertainty of high influence parameters. Tables 5-4 through 5-7 of the topical report provide the determination of the biases for application in the CAREM process. Describe how the CAREM process provides the 95^{th} percentile for the bias determination.

    c. RG 1.157 indicates that the uncertainty can vary over time during the transient, and states that “In evaluating the code uncertainty, it will be necessary to evaluate the code's predictive ability over several time intervals, since different processes and phenomena occur at different intervals. For example, in large-break loss-of-coolant accident evaluations, separate code uncertainties may be required for the peak cladding temperature during the blowdown and post-blowdown periods. Justification for treating these uncertainties individually or methods for combining them should be provided.” It is not clear how the temporal differences in the bias and uncertainty are treated in the CAREM methodology. Provide the basis and the process for determination and application of the bias and uncertainty during the blowdown and reflood (early and late) periods.

53. The guidance in RG 1.157, Section 4.3.1 establishes acceptable controls for the utilization of conservative parameters in best estimate analysis. Provide the following details:

    a. Explain the determination of the radial peaking factor (Fr) for [ ] in the LBLOCA analysis.

    b. Describe how the power shape and peaking factor (Fq) were determined for the base case calculation.

54. The guidance in RG 1.157, Section 4.3.1 establishes acceptable controls for the utilization of conservative parameters in best estimate analysis. [ ].” Explain how this will be applied for operational cycles to ensure adequate conservatism.

55. The guidance in RG 1.157, Section 4.3.1 establishes acceptable controls for the utilization of conservative parameters in best estimate analysis. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of calculational uncertainty. Section 5.1.2 of the topical report discusses the reactivity feedback related parameters and the corresponding uncertainty. There is no discussion of the fuel temperature reactivity and its uncertainty. Explain whether the Doppler reactivity contribution is considered in the model input. If so, provide and justify the values used and the corresponding uncertainty.

56. The guidance in RG 1.157, Section 3.3 establishes acceptable controls for the determination of thermal/physical parameters. Section 5.1.3 of the topical report provides details of [ ]. Address the following:

   a. Section 5.1.3 states that “...variations of gap conductance with linear power can be simulated via [ ].” Although this is technically reasonable, justification has not been provided for the selected range of [ ]. Demonstrate the selected range of [ ] is either related to gap temperatures of interest based on burn-up and operational cycle or to available data.

   b. The mean value and the [ ] are determined using a fuel performance code that is not referenced. The fuel performance analysis code may have its own effect on the uncertainty in [ ]. Provide details of the uncertainty in the calculation of [ ] in the fuel performance analysis code, and describe how any such uncertainty is accounted for.

   c. Provide the actual values of the [ ] that are determined and are used in the analysis.

   d. The current [ ] in Section 5.1.3 is inconsistent with the current [ ] in Table 5-1. Address this inconsistency.

57. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties. Address the following regarding the pump degradation multiplier uncertainty in Section 5.1.4:

   a. Explain and justify the pump degradation multiplier uncertainty.

   b. The minimum (and therefore, the mean) value of the head and torque degradation multiplier provided in Section 5.1.4 is different from that listed in Table 5-1. In addition, the range of pump resistance in Table 5-1 and Appendix J (page J-2) is also inconsistent. Address these inconsistencies.

   c. [

]. Explain:

i. The inconsistency between the mean of zero and the lower and upper bounds of the uniform distribution.

ii. The application of the distribution provided in the topical report for the pump degradation multiplier.

58. The guidance in RG 1.157, Section 3.8 establishes acceptable controls for the calculation of critical heat flux. [

]." It is unclear what the minimum value means since it is expected that the "dial" implies a multiplier. The distribution encompasses a value of 0.0 and the implication of that value is also unclear. [

].

59. The guidance in RG 1.157, Section 4.3.1 establishes acceptable controls for the utilization of conservative parameters in best estimate analysis. Table 5-2 lists some of the containment parameters used in the APR1400 RELAP5/MOD3.3/K calculation. Provide the basis for the containment parameters and any other assumptions used in the analysis regarding the passive heat sinks and the activation and operation of containment sprays.

60. RG 1.157 guidance expresses in many places that results from best estimate calculations will be considered acceptable provided their technical basis is demonstrated with appropriate data and analyses. However, some of the results provided in the topical report are unclear. Figures 5-12 to 5-25 provide some transient information for the base case calculation. In order to understand the details of the base case transient, provide the following additional transient information:

a. Break mass flow rate from 25 to 125 seconds

b. Downcomer void fractions for the control volumes in [ ]

c. [ ] inlet liquid mass flow rate from 30 to 130 seconds

d. [ ] inlet vapor mass flow rate from 30 to 130 seconds

e. [ ] inlet liquid mass flow rate from 175 to 225 seconds

f. [ ] inlet vapor mass flow rate from 175 to 225 seconds

g. [ ] inlet liquid mass flow rate from 30 to 130 seconds

h. [ ] inlet vapor mass flow rate from 30 to 130 seconds

i. [ ] inlet liquid mass flow rate from 175 to 225 seconds

j. [ ] inlet vapor mass flow rate from 175 to 225 seconds

k. [ ] outlet liquid and vapor flow

l. [ ] outlet liquid and vapor flow

m. Downcomer flow below the cold leg [ ]

n. Void fraction in the upper plenum

61. The guidance in RG 1.157, Section 3.1 establishes acceptable controls for the establishment of acceptable break sizes and types. Section 5.2.1.1 of the topical report provides information regarding the selection of the limiting break. Address the following concerns:

a. Provide the calculated PCT and corresponding elevation during the blowdown period and the reflood period for the 100 percent and 80 percent guillotine break cases.

b. Since the reflood PCT for [ ] provide the basis for NOT examining the 90 percent and 70 percent guillotine break cases.

c. Since the rod quenching for [ ] describe the phenomena resulting in [ ].

d. Based on the information on Figure 5-10 of the topical report, [ ]. Provide information to justify that the 180 percent, 160 percent, 140 percent, etc., CLS break PCT will be bounded by the guillotine break.

e. Based on Figure 5-9, the 100 percent guillotine break is selected as the limiting case because its blowdown PCT is the maximum as compared to [ ]. However, the reflood PCT for [ ]. If various uncertainties and biases are factored in, it is likely that the reflood PCT for the 80 percent guillotine break resulting from the application of distribution free statistics may be limiting. Provide evidence that such a situation does not exist.

f. The CAREM methodology permits the determination of the limiting break type, location and size with a 95th percentile tolerance at a 95 percent confidence level using the simple random sampling process to sample across break locations (cold leg or pump suction leg), break types (DECLG or split) and break sizes/areas. This is the only method that provides a 95/95 basis that the limiting break type, location, and area are determined. To justify that the calculations performed are representative of the spectrum of break sizes and locations, provide the results of a calculation using the simple random sampling method considering the variation in the break type, location, and area. Also provide confirmation that split breaks continue to remain bounded when a random selection of break areas for the split break and the DECLG are used.

62. RG 1.157 guidance expresses in many places that results from best estimate calculations will be considered acceptable provided their technical basis is demonstrated with appropriate data and analyses. However, some of the results provided in the topical report are unclear. The base case calculation of the APR1400 plant applying the best-estimate operating conditions is shown in Figures 5-12 through 5-28. The water level in the reactor vessel is mainly determined by the balance of inlet (ECCS) and outlet mass flow (break flow). During late reflood period, ECCS water is supplied by SIPs with constant flow rate (see Figure 5-14), while the break flow in Figure 5-13 decreases to almost zero beyond 250 seconds. Based on these results, the mass balance is expected to cause continuous water level recovery in the reactor core region after 250 seconds. However, the water levels in the core and downcomer region, shown in Figure 5-15, are constant and gradually decreasing, respectively, beyond 250 seconds. Provide an explanation for the observed behavior.

63. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of calculational uncertainty. Section 5.2.2 of the topical report discusses the use of simple random sampling approach to perform 124 calculations using the distributions of the uncertainty parameters listed in Table 5-1. Describe the model or method that is utilized to perform the random selection of samples and provide justification that the sampling process is unbiased.

64. RG 1.157 guidance expresses in many places that results from best estimate calculations will be considered acceptable provided their technical basis is demonstrated with appropriate data and analyses. However, some of the results provided in the topical report are unclear. Provide the values and plots for the three highest PCTs predicted via the plant SRS calculations documented in Section 5.2.2.

65. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties, including the determination of biases. The selection of the cases for evaluation of scale bias in Section 5.2.3 of the topical report is "...based on previous experiences..." Provide details of the referenced "experiences" and the basis for the selection of the cases. Also confirm that the case with the highest second peak is captured in the set that is used for the evaluation of the scale bias.

66. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties and determination of biases. Elaborate and provide reason(s) for Cases 9 and 105 in Tables 5-5 and 5-6 that show no influence from any of the biases.

Appendix A

67. The guidance in NUREG/CR-5429, Section 2.1 establishes acceptable controls for the ranking and documentation of the PIRT. Appendix A of the topical report provides the modification to the PIRT ranking of the in-containment refueling water storage tank (IRWST). [ ].
Address the following:

a. The end of the late reflood period is not clearly specified. Provide the definition for the end of the late reflood period and therefore, the beginning of the long term cooling period, in the analysis.

b. To confirm sufficiency, provide the volume of the IRWST and indicate the amount of water that was depleted at the end of the late reflood period.

c. Explain how suction is provided to the SIPs when the IRWST inventory is exhausted.

68. The guidance in NUREG/CR-5429, Section 2.1 establishes acceptable controls for the documentation of the ranking rationale for the PIRT. Page A-5 of Appendix A provides the rationale for the change to PIRT ranking of the stored energy release from pressurizer. However, it is unclear whether the stored energy release is actually modeled or simply lumped into the pressure uncertainty. The rationale for the ranking change states, [ ]. In such a case, no stored heat transfer is expected. Explain the modeling of pressurizer wall heat structures and clarify whether the pressurizer vessel stored energy release is explicitly represented in the calculation through transient heat transfer to the fluid.

69. NUREG/CR-5429, Section 2.1 discusses the process for the documentation of the PIRT. Page A-6 of Appendix A provides the modification to PIRT ranking of [ ]. The rationale for the change states [ ]. Explain what is meant by the phrase [ ] with respect to this issue.

70. NUREG/CR-5429, Section 2.1 discusses the process for the documentation of the PIRT. Appendix A provides the modification to the ranking for the phenomenon [ ]. Fluid in the upper head and the flashing behavior in the upper head may have a significant effect on the LBLOCA transient response. To understand the bases for the change of the influence rank discussed above, provide the temperature of the upper head fluid and describe the flow process to and from the upper head during the LBLOCA.

71. NUREG/CR-5429, Section 2.1 discusses the process for the documentation of the PIRT. Appendix A provides the modification to the ranking for the phenomenon of [ ]. In the early reflood period the safety injection flow is higher and the amount of liquid entrainment is likely higher than in the late reflood period. Therefore, the steam binding effect is expected to be more important during the early reflood period. Provide the transient results for the steam flow, entrained liquid through the top nozzles, and the vapor and liquid flow into the steam generator inverted U-tubes. These are intended to confirm the Applicant's conclusions on the influence of the phenomenon.

72. NUREG/CR-5429, Section 2.1 discusses the process for the documentation of the PIRT and associated ranking of various phenomena. [

]. Section 3.3.1 of RG 1.157 states that the calculation of the swelling and cladding rupture should be included in the analysis and performed in a best-estimate manner. The blockage may reduce the cladding temperature but that would not appear to decrease the importance of the effect of blockage on the physical response. The calculated cladding temperature transient should reflect the cooling effects of cladding swelling. Confirm that RELAP5/MOD3.3/K can calculate fuel cladding swelling and rupture. Further, confirm that the calculated effect of swelling and rupture on fluid flow and cladding temperature calculations reflects that effect into the fuel channel blockage.

73. NUREG/CR-5429, Section 2.1 discusses the process for the documentation of the PIRT and associated ranking of various phenomena. Appendix A provides the modification to the ranking for the phenomenon "stored energy release" for the lower plenum and downcomer components. In order to concur with the modified influence ranking, provide the following information:

   a. Transient results for the energy release from the lower plenum metal structures as a function of time, the enthalpy (or fluid temperature and void fraction, if saturated) as a function of time, and the stored energy of the lower plenum metal structures as a function of time for the base case calculation discussed in Section 5.2.1.3.

   b. Transient results for the energy release from the reactor vessel downcomer metal structures, core barrel and thermal shield metal structures as a function of time, the enthalpy of the fluid (or temperature) as a function of time, and the stored energy of the downcomer, core barrel and thermal shield metal structures as a function of time for the base case calculation discussed in Section 5.2.1.3.

   c. The outside boundary conditions used for the heat structures representing the vessel wall in the downcomer region and the lower head are not specified in the topical report. The RELAP5 base model uses an insulated boundary condition for these regions. The selection of the boundary condition affects the stored energy release to the fluid in the downcomer and the lower head. Justify the outer surface boundary conditions used for the lower head and vessel wall in the downcomer region in the APR1400 RELAP5/MOD3.3/K model, and if external cooling of the reactor pressure vessel (RPV) lower head can impact this boundary condition.

74. NUREG/CR-5429, Section 2.1 discusses the process for the documentation of the PIRT and associated ranking of various phenomena. Provide the rationale for [ ] to the coast down phenomenon in the RCP component for the blowdown period in Table 3 of Appendix A.

Appendix B

75. The guidance in NUREG/CR-5429, Section 2.1.4 establishes acceptable controls over code versions and changes that could affect best estimate calculations. The RELAP5/MOD3.3/K source code has been provided in response to a previous NRC RAI. Address the following concerns:

   a. The file "gapcon.f" for the RELAP5/MOD3.3/K code (in the folder Question-2\(1)

Source code\relap5\kREM from the response CD) contains several changes that are in addition to the single line mentioned in Section 1.4 of Appendix B. Examples of such changes include lines 51-53, lines 73-81 and line 233 in the file “gapcon.f.” Explain the purpose and function of these additional changes.

b. The RELAP5/MOD3.3/K source code has been provided in response to a previous NRC RAI. The source code in the files “fidisv.f” and “fidis2.f” for RELAP5/MOD3.3/K (in the folder Question-2\(1) Source code\relap5\kREM from the response CD) does not contain the changes listed in lines (f) and (h) of Section 1.3 of Appendix B. The source code in the two files still shows the old logic with “dcon(2)” thereby restricting the droplet diameter to 1.5 mm. Address this discrepancy and its implication on the discussion and the results in the topical report.

76. The guidance in NUREG/CR-5249, Section 2.0, discusses issues related to model nodalization. Figure 17 of Appendix B shows the RELAP-5 nodalization of the primary system. [

]. Provide justifications regarding this core radial nodalization. If a different nodalization is to be used, justify why it will provide conservative or realistic predictions of the core heat transfer behavior.

Appendix C

77. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties. Table 2-2 in Appendix C shows the parameters and distribution functions used for SRS calculations for FLECHT-SEASET tests. Explain how the uncertainty range and distribution for flooding rate and power were determined. Explain the implication of negative power and flooding rate and how these are handled in the calculations.

78. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties. Clarify the uncertainty limits (e.g., 2 times standard deviation) used for the parameters with normal distribution during the SRS sampling in Appendix C.

79. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties. Section 4.5 of Appendix C states that “...the selected code parameters and distribution functions for the NEPTUN test are the same as those used in the SRS calculations against FLECHT-SEASET tests.” However, Table 4-5 of Appendix C lists only 8 parameters compared with the 12 parameters used for the FLECHT-SEASET tests. Confirm this apparent inconsistency.

80. The guidance in RG 1.157, Section 3.16.2 establishes acceptable controls for the data comparisons necessary to justify best estimate models. RG 1.157 states that “…best estimate code calculations should be compared with applicable experimental data (e.g., separate effects tests…”. Appendix C presents the results of comparisons against FLECHT- SEASET tests. These selected tests utilize a cosine power distribution. [

]. Provide the results or a reference for the calculations performed for the FLECHT-SEASET tests that utilize skewed power distributions or provide the bases justifying the applicability of the selected tests.

Appendix E

81. NUREG-0800, Section 15.0.2 establishes review guidance related to the documentation of the evaluation model. Provide the input decks used for the RELAP5/MOD3.3/K assessments against the ATLAS tests 9, 11, and 15 described in Section 3 of Appendix E.

82. NUREG-0800, Section 15.0.2 establishes review guidance related to the documentation of the evaluation model. The scaling of the ATLAS facility is briefly discussed in Section 2.1 of Appendix E. Describe how the metal mass to fluid volume ratio was scaled in order to correctly capture the stored energy release and the downcomer boiling phenomena.

83. The guidance in RG 1.157, Section 3.16.2 establishes acceptable controls for the data comparisons necessary to justify best estimate models. Section 2.2 of Appendix E states that the conditions at the start of the reflood period of the APR1400 LBLOCA were given as the initial and boundary conditions. Presumably, these conditions are determined based on code calculations. Confirm this understanding and clarify whether RELAP5/MOD3.3/K is used to determine the initial conditions. If so, describe the assessments used to validate the code's prediction of the phenomena during the blowdown period. Include details about the accuracy of code prediction of depressurization, levels and break flow discharge during the blowdown period against corresponding data.

84. The guidance in RG 1.157, Section 3.16.2 establishes acceptable controls for the data comparisons necessary to justify best estimate models. Figures 2-9 and 2-15 of Appendix E show the SIT-FD injection rate (high- and low-flow) for the ATLAS tests 9 and 11. The tests start from the reflood period and therefore, as shown in Figure 2-6 of Appendix E, a portion of the SIT-FD flow is not considered. Explain how the time at which SIT-FD injection occur and therefore, the injection rate in the tests is determined. Also explain the reason for the difference in the injection rate between the four SITs as seen in Figure 2-9 and especially, for Figure 2-15.

85. The guidance in RG 1.157, Section 3.16.2 establishes acceptable controls for the data comparisons necessary to justify best estimate models. The Applicant asserts in Section 3.1 of the topical report Appendix E that the abnormalities observed in Tests 9, 11, and 15 are not expected to occur in the APR1400 plant. However, the purpose of integral tests is to demonstrate the expected behavior of the plant. Therefore, stating that certain phenomena observed in the tests are not expected in the plant, defeats the purpose of the tests. In addition, the Applicant's rationale for not expecting the anomalous behavior in the plant is unconvincing. As an example, it is stated that the difference between the lower and upper downcomer wall temperatures is not expected to exist in the plant "...because of the existence of continuous flow in the downcomer..." but such flow will also exist in the test facility which does exhibit the temperature difference. Please justify the representativeness of the selected ATLAS tests and their use for assessment purposes.

Appendix G

86. The guidance in RG 1.157, Section 3.16.2 establishes acceptable controls for the data comparisons necessary to justify the applicability of the best estimate models. Table 1 of Appendix G provides the downcomer boiling test conditions. Describe how these test conditions correspond to those that would exist in the APR1400 during the late reflood period. Include the transient time at which the test wall heat fluxes correspond to the downcomer/core barrel heat fluxes, expected temperature/pressure of the downcomer coolant, and the expected scaled high pressure safety injection flow at these times.

87. The guidance in RG 1.157, Section 3.16.2 establishes acceptable controls for the data comparisons necessary to justify the applicability of the best estimate models. Provide the fluid volume temperatures and the void fractions for each of the control volumes in both stacks of the dual stack RELAP5 model (i.e., two channel modeling) for the downcomer boiling test.

Appendix H

88. The guidance in RG 1.157, Section 3.16.2 establishes acceptable controls for the data comparisons necessary to justify the applicability of the best estimate models. Differences are noted in the details of the total, liquid and therefore, gas volume for each SIT- FD between the RELAP5 base input model and the VAPER facility. [

].

   a. Provide the technical specification values for the total volume, the initial volume of liquid and the liquid volume below the standpipe and the gas volume of a single SIT-FD.

   b. Justify the use of the volumes cited in the VAPER facility and the applicability of the corresponding data to the APR1400 plant.

89. The guidance in RG 1.157, Section 3.16.2 establishes acceptable controls for the data comparisons necessary to justify the applicability of the best estimate models. Appendix H Section 1.3.1 briefly discusses the air release behavior for Cases 01-01 through 01-03 referring to Figure 1-7 of Appendix H. That figure shows two peaks in the air release behavior. Section 1.3.2 of Appendix H discusses the air release behavior for Case 01-04 referring to Figure 1-11 of the same Appendix.

   a. Provide the physical reason(s) for the double-peaked behavior of air release for Cases 01-01 through 01-03.

   b. Provide a discussion of the noncondensible transport, the impact on the flow pattern, and the effect on the heat transfer.

90. The guidance in RG 1.157, Section 3.16.2 establishes acceptable controls for the data comparisons necessary to justify the applicability of the best estimate models. Address

the following concerns regarding the SIT-FD tests and K-factor determination discussed in Appendix H:

a. The Section 5.1.5 of the topical report states that [ ]. The range selected for the sensitivities, as documented in Section 3 of Appendix H, is narrow as compared to the scatter in the experimental results shown in Figure 1-2 of Appendix H for the high and low-injection period. The scatter in the low-flow K-factor for the experimental results is [ ]. These K-factors are much higher than the design values which are supposed to bound the K-factor for the SIT-FD. Explain the rationale and basis for the selection of the SIT-FD K-factors.

b. Figure 1-2 in Appendix H shows the selected SIT-FD K-factor values based on the sensitivity calculations. [ ] is lower than that shown in Figure 1-2 of Appendix H. Justify the use of the lower K factor for the APR1400 plant calculations.

c. Table 3-1 of Appendix H defined the "K" sensitivity study range and also the fluidic device high flow and low flow loss coefficient design requirements. Demonstrate that either the manufacturing tolerance of the device will result in loss coefficients within the defined range, or, the bounding K values based on LOCA analyses can greatly cover the K value uncertainties due to the manufacturing tolerance.

d. Figure 1-2 in Appendix H shows a large number of data points and large variations in the K-factor determination. However, Figure 1-5 of Appendix H does not show a similar number of data points and variation for the SIT-FD level. Explain the reason for these differences.

e. The initial SIT-FD water temperature for the VAPER tests listed in Table 1-3 of Appendix H is 5°C to 6°C which is lower than the operating temperature range of 10°C to 50°C according to Table 6.3.2-1 of the APR1400 DCD. Provide the justification for such a low initial SIT-FD water temperature. Also discuss the impact of the initial water temperature on the non-condensable gas release behavior near the end of SIT injection in the test.

f. According to Table 1-2 of Appendix H, the exit pressure for the SIT-FD in the VAPER tests (e.g., the stock tank pressure) is atmospheric for all tests. The RPV pressure during a LBLOCA is higher than atmospheric pressure at the time of SIT injection. This is also demonstrated by the results of the Applicant's simulation studies (see Figure 5-12 of the topical report). Therefore, the exit pressure boundary condition in the VAPER tests (especially Cases 01-01 through 01-03) results in a higher pressure difference between the SIT tank and the exit as compared to that during a LBLOCA. Provide the rationale for the selected boundary pressures in the tests as compared to the prototypical pressure boundary conditions, and the impact of the low pressure in the test on the SIT-FD high and low-flow delivery and K-factor determination in Appendix H Figure 1-2.

g. Figure 3-1 of Appendix H shows noticeable variation of the maximum SIT-FD flow which is not reflected in the PCT prediction shown in Figure 3-5 in Appendix H.

However, the ECCS bypass bias does not appear to be factored into the sensitivity in Section 3 of Appendix H. Clarify whether the ECCS bypass bias was included in the SIT-FD K-factor sensitivities.

h. Describe the type and number of valves in the line connecting the SIT-FD to the RPV in the actual APR1400 plant. Furthermore, explain whether all the valves have been represented in the VAPER tests. If not, justify the exclusion of the valves and their corresponding loss coefficients in determining the SIT-FD K-factor and injection rate.

91. The guidance in RG 1.157, Section 3.16.2 establishes acceptable controls for the data comparisons necessary to justify the applicability of the best estimate models. Appendix H describes the assessment of RELAP5/MOD3.3/K for the performance of the safety injection tank with the fluidic device installed. Address the following concerns:

a. Figure 1-6 of Appendix H shows the experimental data for the water level (as well as three RELAP5/MOD3.3/K models) as a function of time for three tests in the VAPER test facility. Based on the stand pipe height in Table 1-1 in Appendix H, the water level falls below the top of the standpipe at approximately 50 seconds. However, the rate of water level decrease is seen to change at approximately 35 seconds. Explain this change.

b. Figure 1-7 of Appendix H shows that gas is released beginning at about 105 seconds while the SIT-FD tank level is approximately 1.9 m. Provide a description of the fluid and gas flow patterns in the SIT-FD tank from approximately 100 seconds to 225 seconds.

c. It is difficult to discern between the actual data and the analysis calculations in Figures 1-6 through 1-13 of Appendix H. Provide a comparison of the prediction of each model against the experimental data separately to confirm the Applicant's conclusions.

92. The guidance in RG 1.157, Section 2.1.2 establishes acceptable controls for the calculation of the effects of noncondensible gases on the results of best estimate analysis. The sensitivity of PCT to non-condensable gas injection is documented in Section 2.1 of Appendix H. As part of Case 2 sensitivity studies, the non-condensable gas release from Model D is input to the calculation as a table. Describe how the temperature of the injected gas is represented in the calculations for the Case 2 sensitivities. Further, describe the local pressure and condensation effects of the injected gas and whether these translate into a decrease in the collapsed water level in the lower downcomer and a corresponding increase in the core collapsed water level (Figures 2-4 and 2-5 of Appendix H).

Appendix J

93. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties. The uncertainty ranges for various parameters used in the actual demonstration calculations used to determine the limiting PCT for a LBLOCA are shown in Appendix J (page J-2). The ranges for the pressurizer pressure, fuel thermal conductivity, and the power peaking factor (Fq) provided in Appendix J are inconsistent

with the corresponding ranges listed in Table 5-1 of the topical report. Address these inconsistencies and their impact on the demonstration calculations.

General

94. The guidance in NUREG-0800, Section 15.0.2 establishes acceptable controls for the documentation of the evaluation model. Provide the following documents cited in the topical report and in APR1400-F-A-EC-13012-P:

   a. "Performance Verification Test for APR1400 Fluidic Device," A03NJ02, KAERI, February 2005.

   b. "Phenomena Identification and Ranking Tabulation Korean Next Generation Reactor Large Break Loss of Coolant Accident," KINS/INEEL, 2001.

   c. "The Best Evaluation Methodology for the Emergency Core Cooling System," TR-KHNP-002, KEPRI/KHNP, December 2002.

   d. "Development of PCT Uncertainty Quantification Methodology, Assessment of Separate Models and Construction of Thermal-Hydraulic Data Banks for Establishment of the Korean ECCS Evaluation Model," KINS/GR-011, December 1990.

   e. Nuclear Technology, V.148, 3, 2004.

   f. Nuclear Technology, V.158, 2007.

   g. Annals of Nuclear Energy, Vol. 38 (2011), p.1053-1064.

   h. "Fluidic Device Design for the APR1400," APR1400-Z-M -TR-12003-P Rev.0, 2012.

Accompanying Technical Report (APR1400-F-C-NR-12001-P)

95. The guidance in RG 1.157, Section 3.8 establishes acceptable controls for the calculation of critical heat flux. Section 4 of the technical report (APR1400-F-C-NR-12001-P) discusses the development of the CHF correlation for the 16x16 PLUS7 fuel assemblies that is to be used for APR1400 analysis. RG 1.157 states "Research has shown that CHF is highly dependent on the fuel rod geometry, local heat flux, and fluid conditions." [

].

96. The guidance in RG 1.157, Section 4 establishes acceptable controls for the estimation of uncertainties. The "inlet flow factor" or form loss coefficient for the limiting channel is identified as one of the uncertainty parameters for minimum departure from nucleate boiling ratio determination in Section 5.2 of the technical report (APR1400-F-C-NR-12001-P, Rev. 0). The uncertainty in the inlet form loss coefficient for the hot channel is expected to be important in the calculation of the reflood PCT. Justify the reasons for not including this parameter in the APR1400 LBLOCA uncertainty analysis and the PIRT described in the topical report (APR1400-F-A-TR-12004- P, Rev. 0).

Other Documentation Issues

Preface Material

97. The list of acronyms in the topical report does not contain all the acronyms used in the topical report (e.g., EDG, SI, etc. are missing). An updated list of all acronyms or abbreviations needs to be supplied.

Section 3

98. There is a typographical error in the second paragraphs of Section 3.3 of the topical report and Section 1 of Appendix A. The current text incorrectly states “ARP1400” instead of “APR1400.” Also the second paragraph of Section 3.6.2 of the topical report, “CONTEPT4” should read “CONTEMPT4” and in Section 3.6.3 where “CONTEPM4” should read “CONTEMPT4.”

Section 4

99. The topical report Table 4-4 lists “RELAP5 document” as the entry in the second column “’Tests (SET)’” for a couple of phenomena. List the full document reference and to the actual tests used for the assessment.