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SBLOCA TeR Questions for KHNP for the Wednesday, November 18, 2015 Telecom

(1) APR1400 Loop Seal Clearing

The computer code CEFLASH-4AS is used to calculate the blowdown hydraulics in the APR1400 reactor coolant loops during blowdown. Blowdown is defined in the methodology as the period between transient initiation and initiation of SIT (Safety Injection Tank) flow. Of particular interest is the CEFLASH-4AS treatment of loop seal clearing. Since the liquid cleared from a loop seal ends up in the core, a lack of loop seal clearing can have a strong influence on the calculated peak cladding temperature (PCT).

SRP Section 15.0.2 specifies that an evaluation model must be able to predict all important physical phenomena necessary for the accident under consideration reasonably well from both qualitative and quantitative points of view, or should treat the phenomena conservatively. However, it is not clear that the applicant's SBLOCA evaluation model is meeting this guidance with respect to loop seal clearing, and the staff is concerned that the modeling of the loop seal clearing phenomena may not be conservative, either. Since the original approval of the ABB-CE SBLOCA methodology, best estimate calculations conducted using RELAP5 have shown that only one or two of the four loop seals may clear for smaller break sizes and only partial clearing of loop seals may occur for some breaks, when all four loop seals are explicitly modeled. However, a description of the loop seal clearing in CENPD-137P Report ("Calculative Methods for the CE Small Break LOCA Evaluation Model," August 1974, page 47 and 48) indicates that all of the liquid is removed from the loop seals regardless of break size. The staff seeks clarification of that indication. The staff would also like to understand the justification for the CEFLASH-4AS model nodalization that combines the two intact loop cold legs into a single equivalent cold leg, as illustrated in Fig. 3.1-1 of the Technical Report (TeR) APR1400-F-A-NR-14001-P, "Small Break LOCA Evaluation Model." How would this combined cold leg arrangement lead to a conservative prediction of the loop seal clearance for the individual loops?

The applicant is requested to discuss how loop seal clearing is being treated conservatively in the SBLOCA analyses. Staff would like to understand the number of loop seals clearing as a function of break size for the SBLOCA simulations, as asked in RAI 8337. Also staff would like to discuss a comparison between the CEFLASH-4AS and a RELAP5/MOD3.3 of the 18.6 cm^2 and the 372 cm^2 DVI line breaks. Following this discussion, staff may craft a RAI to have a docketed response that we can rely upon to make our safety finding.

[Response]
According to the CENPD-137P, the suction legs or loop seal are modeled with two vertical control volumes to preserve height and volume. Two volumes are connected to one flow path between the bottoms of each volume. This configuration delays the loop seal clearing until the level reaches the bottom of loop seal volume. The delayed loop seal clearing produces a conservative peak cladding temperature (PCT).

The CE SBLOCA methodology has adopted a method to predict the PCT conservatively instead of using the loop seal model. That is by combining the CEFLASH-4AS and COMPER-II reflood two-phase levels. When the safety injection tank (SIT) flow is taken into account, the COMPERC-II code calculates the two-phase levels instead of CEFLASH-4AS, which can be seen in Figure (1)-1. The COMPERC-II code calculates the collapsed two-phase level and the results of the level are transferred to the PARCH code. For this reason, the most conservative PCT occurs mainly for the large break size when SIT flow is injected.

The results of the comparison between the CEFLASH-4AS and a RELAP5/MOD3.3 of the 18.6 cm^2 and the 372 cm^2 DVI line breaks are shown in the Figures (1)-2&3.

As you can see in Figure (1)-2, both the RELAP5 and the CENPD methodology show only one loop seal clearing for the case of 18.6 cm^2 DVI line break. On the other hand, both of them show the all loop seals clearing for the case of 372 cm^2 DVI line break. This is shows that the number of loop seals clearing depends on the break size instead of the methodology.

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(2) RAI 8337: SBLOCA Break Spectrum Analysis & Core Two-Phase Level

The staff would like to take this opportunity to make any clarifications about RAI 8337 that the applicant may need. RAI 8337 was issued to address the SRP Section 15.6.5 related specific concerns for the loop seal clearing.

[Response]
According to the RAI 8337(1), the staff requests to run total 37 cases including 17 cases for DVI line break and 20 cases for Cold Leg break. As described in the response (6), the CE SBLOCA methodology code consists of 4 codes (CEFLASH-4AS, STRIKIN, COMPERC, PARCH) and then the interfacial data transferring is conducted manually.

As describe in the response (1), run of COMPERC and re-run of PARCH codes are necessary if SIT actuated. In that case, total four stage of interfacial data transferring conducted manually. Therefore, a lot of effort and time is required. The CEFLASH-4AS code calculates thermal-hydraulic during total transient period. After that, the COMPERC codes re-calculates thermal-hydraulic transient when the SIT flow is taken into account. STRIKIN, PARCH codes calculates fuel rod heat up for the separated phases.

Generally, it can be confirmed whether results are sort of limiting PCT cases or unlimited PCT cases using the only results of the CEFLASH-4AS. The RAI 8337(1) requests for running all 37 cases and updating to the DCD and TeR. However, the unlimited cases such as uncovering core or non-SIT actuation are not necessary to run all four codes to determine the limiting cases. Therefore, KNF, in order to prepare the answers for the RAI 8337(1) quickly, would like to propose as follow four steps instead of full calculations.

1. For the CEFLASH-4AS codes, KNF will perform the calculation for all 37 cases (17 cases for DVI line break, 20 cases for Cold Leg break).
2. With the results of 37 cases, KNF will summarize the thermal-hydraulic transient results and classify the limiting case and non-limiting cases.
3. KNF will proceed running STRIKIN, PARCH, COMPERC, and final PARCH codes for the candidate limiting cases.
4. KNF will update in DCD and TeR with the results of limiting cases if it is necessary.

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(3) Differences in the APR1400 & CE SBLOCA Evaluation Models

The TeR describes the APR1400 SBLOCA evaluation model in broad terms. In Section 1 of the TeR, "Introduction", it is stated that the SBLOCA methodology used for APR1400 is very similar to the conventional CE SBLOCA methodology used for currently operating US CE-fleet PWRs. However, the report did not provide a discussion of the differences between the CE methodology and the KHNP methodology. SRP Section 15.0.2 suggests review of any changes to the approved evaluation models. The applicant is requested to discuss any differences between the KHNP SBLOCA methodology and the CE SBLOCA methodology upon which it is based. Staff would seek to understand all changes made in the mathematical modeling, computer codes (CEFLASH-4AS, COMPERC-II, STRIKIN-II, and PARCH) used to analyze the APR1400 SBLOCA, as well as any differences in data transfer between the codes since they were last reviewed and accepted. The staff needs to understand the changes in the methodology and codes that have been made to the approved SBLOCA methodology in order to ascertain that there is nothing new that could invalidate the previous approval, including the range of applicability for the analysis method. Following this discussion, staff may craft a RAI to have a docketed response that we can rely upon to make our safety finding.

[Response]
There are no differences between the CE methodology and the KHNP methodology. We currently use the CE SBLOCA methodology without any changes to the approved evaluation models approved by US-NRC.

(4) DVI Line and Cold Leg Elevations in the Node Diagram

SRP Section 15.0.2 specifies that an evaluation model must involve all phenomena and components that have been determined to be important or necessary to simulate the accident under consideration. It must be able to predict the important physical phenomena reasonably well from both qualitative and quantitative points of view.

CE-FLASH-4AS node diagram in Figure 3.1-1 of the SBLOCA Technical Report (APR1400-F-A-NR-14001-P) indicates that the SIT and SIP flows are injected into the downcomer below the node where the cold legs are connected to the downcomer. The TeR description of Figure 3.1-1 also mentions that the ECCS is modeled by flow paths connected to the lower annulus of the RPV downcomer. However, the DVI nozzles are actually located in the upper annulus of the APR1400 design, 2.1 m above the cold leg nozzles. Therefore, this simulated arrangement could lead to a non-conservative retention of ECCS water in the downcomer. The approved CE-ABB SBLOCA methodology specifies that CEFLASH-4AS is to be used until the SITs are activated. Thus, for smaller breaks in the cold leg, there is ample opportunity for the pumped safety injection to be bypassed to the break, an effect which is precluded with the nodalization being employed in the CEFLASH-4AS model. It appears that the applicant's methodology provides no mechanism for the ECCS injection water to be ejected out of the break, and thus, may be non-conservative in this regard. Please explain how placing the DVI nozzles in the lower annulus instead of the upper annulus, where they are actually located results in a conservative or realistic treatment of ECCS injection in the CEFLASH-4AS simulations. Also explain where the DVI line break node is located in the CEFLASH-4AS model. This information is needed by the staff to complete its review of the KHNP SBLOCA methodology.

[Response]

According to the CENPD-137(page 119), the sensitivity study for the three injection locations(upper annulus, lower annulus, and cold leg) were performed in order to determine the influence of injection location in CEFLASH-4AS on the calculated annulus pressure transient. The sensitivity study shows that the pressure transient used for reflood calculations is insensitive to the CEFLASH-4AS ECC injection model (See figure (4)-1).

When it comes to the CEFLASH-4AS code, if the ECC injection is connected to the upper annulus, a code calculation instability occurs after the ECC is injected into the steam region during calculation. The DVI line break node located in the CEFLASH-4AS model is shown Figure (4)-2.

During SBLOCA, the effect of ECC bypass is very small because the thermal hydraulic transient is very slow in comparison with LBLOCA. For the case of DVI line break, the effect of ECC bypass is negligible, because the break height is the same as ECC injection location. For a cold leg break the ECC bypass may have an effect, however the impact is expected to be minimal.

In order to evaluate the effect of ECC bypass, the sensitivity studies were performed for the three cases of HPSI flowrate. As you can see in Figures (4)-3 thru 6, even if the HPSI flowrate reduces to 25% considering the effect of ECCS bypass, there was no impact on the analysis result.

Therefore, it is determined that the CEFLASH-4AS model has sufficient conservatism for the ECC injection location.

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(5) Assumption of the Loss of Offsite Power upon Reactor Trip

In Section 4, "SBLOCA Analysis", of the TeR, it is stated that it is conservatively assumed that the offsite power is lost upon reactor trip. The staff would like to understand the basis as to why this is a conservative assumption. If offsite power is not lost, the reactor coolant pumps (RCPs) would continue to run for an extended period resulting in more liquid lost out the break. The applicant is requested to justify that the loss of offsite power upon reactor trip is a conservative assumption vis-à-vis an SBLOCA and provide a supporting analysis.

[Response]

According to the CEN-268, Rev.1(Justification of Trip Two/Leave Two RCP Trip Strategy during transient), the RCP trip strategy for the case of 0.1 ft^2 SBLOCA results in no significant core uncovering and virtually no clad temperature heatup.

According to the WCAP-10054-P-A, the scenarios included are: continued pump operation throughout the entire transient and tripping the pump at 10 minutes. The continued pump operation case showed that pump operation results in greater mass depletion than if the pumps tripped case, while maintaining a cooled core. For the 10-minute trip case, NOTRUMP showed that a delayed pump trip could result in a deeper core uncovering than an FSAR trip case. However, the delayed pump trip also caused the accumulator injection setpoint to be reached earlier.

The representative of RCP on/off experiment is the LOFT L3-5/6 test series. According to the results of L3-5/6 experiment and evaluation, the results of RCP-on(L3-6) show greater mass depletion than RCP-off(L3-5). However, the operation of RCP does have a role to provide coolant continuously and keep the core maintained in a saturation state even if the core level is lower than RCP-off and also there is no clad temperature heatup.

Below are results of the supporting analysis using RELAP5. One is the case of RCP-off upon reactor trip and the other one is tripping the pump at 5 minutes. The comparison results of the two cases are shown in Figures (5)-1 thru 4. As you can see the case of RCP-on shows lower core level and earlier Loop Seal Clearing than RCP-off. Especially, the core void fraction for the case of RCP-on shows no core uncovering other than RCP-off.

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(6) Computer Codes Usage & Data Transfer

Section 2 of the TeR gives a brief discussion of the computer codes (CEFLASH-4AS, STRIKIN-II, COMPERC-II, and PARCH) used in the SBLOCA methodology and an overview of the data transferred between the codes. However, no explanation is given about exactly what information is transferred between the codes and how it is transferred, automatically or otherwise. The staff therefore requests the applicant to demonstrate the methodology for a typical SBLOCA calculation in which all four codes are exercised. It could be handled through an ERR audit.

According to Section 3.2, "Reflood Hydraulics", of the TeR, the reflood period of a SBLOCA is defined as the period of time following ECC injection from the SITs. It is the staff's understanding that the COMPERC-II code is used only for the reflood phase. It is unclear why a computer code different from CEFLASH-4AS is needed during this phase of the transient. Clarification of this issue could be made as a part of the audit question proposed above.

[Response]

Figure (6)-1 shows the CENPD SBLOCA codes with interface data. The detail transferred data lists from each code are shown below in Table (6)-1 to Table (6)-6. The transferred data from CEFLASH to STRIKIN are generated automatically by CEFLASH-4AS. The PARCH input data in Table (6)-2 were found in the STRIKIN output at the end of calculation time. In the case of Table (6)-3, the input data were select properly to reflect transient characteristics in limited input space. COMPERC and PARCH input data in Table (6)-4 and Table (6)-6 were found in previous calculations of each PARCH and COMPERC results at SIT injection time. Figure (6)-2 to Figure (6)-7 shows the sample information from code output for transferring. Specifically, the selecting method of interface data between CEFLASH-4AS and PARCH for pressure, 2-phase level, liquid mass use as shown in Figure (6)-9 because the PARCH input space for the interface data is limited as 20. For the interface data between CEFLASH-4AS and COMPERC, the example of selecting data is shown in Figure (6)-8.

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(7) Discussion Item for Next Public Meeting Teleconference, November 25, 2015

The staff appreciates that KHNP has made available the original C-E topical report (CENPD-170), which provides greater detailed description of the Core Protection Calculator System. The staff is looking at this document and seeking to understand how this topical is referenced in the DCD. The staff is now working to recover from our archive the original staff review and approval to assess any conditions and limitations. The present reviewers have questions regarding the sensitivity of the method to fuel burnup, CEA position, and cycle to cycle variation in loading pattern. Additionally, the procedure for development and implementation of the addressable constants is not fully understood. The staff should benefit from a discussion of the entire process, from initial cycle testing to development of the shape annealing and rod shadowing factors, to normal operational experience with the system. However, the staff would like to take an additional week to digest the new information provided prior to engaging in a discussion with KHNP so we would like to defer this topic to the next regularly scheduled meeting on 11/25/2015.

[Response]

a. The staff is looking at this document and seeking to understand how this topical is referenced in the DCD.

   The C-E topical report (CENPD-170) describes the methods used in CPCS to process sensor information and initiate the high LPD and low DNBR trips. Also, a detailed examination of the uncertainties associated with the synthesis of the 3D peaking factor (Fq) and the ability with which the CPCS accommodate CEA misalignments are presented. This document was just provided to give additional information for CPCS power distribution. The CPCS functional design requirements (APR1400-F-C-NR-14003-P) that provides the design bases and the detailed algorithm for CPCS is basically referred to DCD.

b. The present reviewers have questions regarding the sensitivity of the method to fuel burnup, CEA position, and cycle to cycle variation in loading pattern

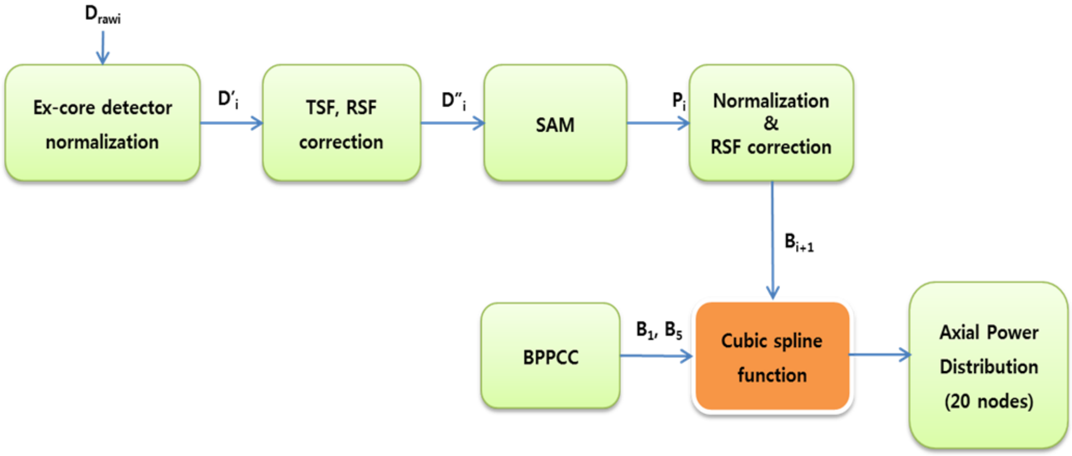
   Nuclear design group generates the nuclear design data based on the fuel burnup, CEA position and loading pattern for every reload cycle. COLSS/CPCS design group generates 1200 cases axial power shapes using these nuclear design data. Then, these power shapes will be used to generate the uncertainty factors for DNBR and LPD calculation through CPCS Overall Uncertainty Analysis (OUA). CPCS OUA is performed at four burnup point; BOC, IOC, MOC and EOC. Among the four CPCS OUA results, the biggest DNBR and LPD penalties are determined and used in CPCS.

c. Additionally, the procedure for development and implementation of the addressable constants is not fully understood.

   There are three kinds of database constants in CPCS; Database (Non-RDB) constants, RDB (Reload Data Block) constants, and Addressable constants. Database constants can’t be changed during plant life. RDB constants are the constants can be changed every cycle. Addressable constants can be changed during plant operation by operator. Some addressable constants can be determined by designers, but some addressable constants (Shape Annealing Matrix, Rod Shadowing Factors, Temperature Shadowing Factors, …) will be measured during startup test.

d. The staff should benefit from a discussion of the entire process, from initial cycle testing to development of the shape annealing and rod shadowing factors, to normal operational experience with the system.

CPCS uses excore detector signals to generate axial power distributions. The CPCS axial power distribution is synthesized from response of the three element excore detector string. Following figure shows the calculation flow of CPCS axial power distribution. Shape Annealing Matrix (SAM) and Rod Shadowing Factor (RSF) will be measured and installed to CPCS database during every reload startup test.



Where, Drawi : Raw excore detector signals
TSF : Temperature Shadowing Factor
RSF : Rod Shadowing Factor
SAM : Shape Annealing Matrix
BPPCC : Boundary Point Power Correlation Coefficient

CPCS provides two digital trip functions; low DNBR trip and high LPD trip. Also CPCS has several auxiliary trip functions. CPCS has provided a proper trip action during transients.

[KEPCO-E&C SD's response in relation to SAF]

Shape Annealing Function (SAF) is defined as the fractional ex-core detector response per percent of core height for a three-subchannel system. Shape annealing functions are determined utilizing a fixed-source adjoint MCNP calculation. DCD subsection 4.3.3.1.1.4 describes the MCNP model and method to develop the SAF in more detail.