Continuation of the 11-18-2015 SBLOCA TeR Question Responses for the 12-09-2015 Teleconference

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

(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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Figure (1)-1. Combining CEFLASH-4AS and COMPERC-II reflood two-phase levels

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Figure (1)-2a Loop Seal Steam Flow Rate – RELAP5 for 18.6 cm^2 DVI line break

Figure (1)-2b Loop Seal Mixture Level – CENPD for 18.6 cm^2 DVI line break

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Figure (1)-3a. Loop Seal Steam Flow Rate – RELAP5 for 372 cm^2 DVI line break

Figure (1)-3b. Loop Seal Mixture Level – CENPD for 372 cm^2 DVI line break

Here is the method how to determine the two-phase level in the CENPD SBLOCA methodology. According to the CENPD-137(page 30~42), the total node mixture height is determined using phase separation model (See Figure (1)-4) and bubble rise model as follow. Typical calculation equations related to the core level are as follows:

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Tests conducted in the Westinghouse ECCS Verification Test Facility to measure the height of two-phase fluid as a function of water inventory. Comparison of the test results with predictions obtained using the CEFLASH-4AS inner vessel bubble rise model are shown in Figure (1)-5. The good agreement between data sets verifies the applicability of the model.

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Figure (1)-4 CEFLASH-4AS Inner Vessel Phase Separation Model.

Figure (1)-5 Comparison of CEFLASH-4AS bubble rise model with WESTINGHOUSE boil-off tests Two-phase level

(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 response (1), run of COMPERC and re-run of PARCH codes are necessary if SIT is actuated. In that case, a total of four stages for interfacial data transferring is conducted manually. Therefore, a lot of effort and time is required. The CEFLASH-4AS codes calculates thermal-hydraulic throughout the 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 unlimiting 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, for the unlimiting cases such as uncovering core or non-SIT actuation, it is 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 DCD and TeR with the results of limiting cases if it is necessary.

Screen Criteria for determining limiting break size of CENPD SBLOCA analysis is as follow.

As you can see Figure (2)-1, the results of DVI line break spectrum analysis are shown. The first step is to exclude any cases that the core is not uncovered during SBLOCA. For the DVI line break, the core uncovery were not observed in the break sizes lower than the 0.0341 ft^2. The lower graph of Figure (2)-1 shows only the cases with the core uncovery occurrence.

The second step is to determine relevant case to show the maximum core uncover. According to the lower graph of Figure (2)-1, the 0.1364 ft^2 break size demonstrates the maximum core uncovery. Generally, the core uncovery occurs two times during SBLOCA. One occurs before loop seal clearing and the other one occurs before injecting of SIT. The first core uncovery occurs during the short period in comparison with the second core uncovery. The peak cladding temperature mainly occurs in the second core uncovery because the second core uncovery maintains during the long period as compared to the first core uncovery even if the depth of the first core uncovery is greater than the second core uncovery.

The third step is to determine the limiting case. During the SBLOCA, the core uncover mainly occurs in the upper part of active core and the limiting case can be determined by the core uncovery duration and depth. As seen in the lower graph of figure (2)-1, considering the duration and depth of the core uncovery, the limiting case is the 0.1364 ft^2 break size. Therefore, the candidate group of the break spectrum sizes are 0.1104 ft^2, 0.1364 ft^2 and 0.1650 ft^2 to perform full SBLOCA analysis to describe the DCD and then the procedure of screen criteria and break spectrum results of Figure(2)-1 will be described in the TeR.

According to the results of break spectrum(Figure (2)-1,2), the boil-off PCT by the core uncovery does not occur in less than 0.1 ft^2 break size regardless of break location during SBLOCA. But the DNB PCT can occur by reducing the core inlet flow rate during short period between starting of RCP costdown and initiating drop of CEA after reactor trip. However, the DNB PCT is generally lower than the boil-off PCT. Therefore, the DNB PCT will not be considered to determine the candidate groups.

When it comes to the cold leg break, two SIPs flow rate are available during SBLOCA. The second core uncovery doesn't appear substantially because the SIP flow rate is greater than the case of DVI line break. For this reason, the results of cold leg break do not show the core uncovery after the loop seal clearing other than the cases of DVI line break. Thereby, the boil-off PCT by the first core uncover before loop seal clearing becomes the limiting PCT. And also, as the break size decrease, the core uncovery does not occur by the effect of doubled SIP flow rate in comparison with the DVI line break. Therefore, the limiting PCT for the cold leg break mainly occurs in a large break size.

The method for determining limiting break size for the cold leg break is same as the case of DVI line break. The results of spectrum analysis for the cold leg break are illustrated in Figure (2)-2. For the cold leg break, the core uncover were not observed in lower than 0.3068 ft^2 break size. The lower graph of Figure (2)-2 shows only the cases that the core uncovery occurs.

As seen in the lower graph of figure (2)-2, considering the duration and depth of the core uncovery, the limiting case is the 0.4418 ft^2 break size. Therefore, the candidate group of the break spectrum sizes are 0.4006 ft^2, 0.4418 ft^2 and 0.4922 ft^2 to perform full SBLOCA analysis to describe the DCD and then the procedure of screen criteria and break spectrum results of Figure(2)-2 will be described in the TeR.

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Figure (2)-1. Results of DVI line break spectrum

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Figure (2)-2. Results of Cold Leg break spectrum

(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.

As shown in Table (3)-1, the initial conditions used in the SBLOCA analysis of two plants are similar except for the core power. However, when it comes to the SIP flow rate, there are large differences between System80+ and APR1400 as shown in Table (3)-2. Depending on the pressure range, the SIP flow rate of System80+ is smaller than about 10~30% in comparison that of APR1400. During the SBLOCA, SIP flow rate does have a role to mitigate the phenomena of SBLOCA. If the SIP flow rate changes, the behavior of thermal hydraulic differs. Therefore, the differences of SBLOCA PCT between System80+ and APR1400 are mainly caused by the differences of SIP flow rate.

Table (3)-1 Comparison of General System Parameters and Initial Conditions, Small Break LOCA Analysis for SYSTEM80+ and APR1400

Parameters	System 80 +	APR1400	Units
Core Power Level	3,992	4,063	MWt
Average Linear Heat Generation Rate	5.6	5.715	kw/ft
Peak Linear Heat Generation Rate (PLHGR)	15.0	15.0	kw/ft
Gap Conductance at PLHGR	2,123	2,107	Btu/hr-ft^2-°F
Fuel Centerline Temperature at PLGHR	3,638	3,568	°F
Fuel Average Temperature at PLHGR	2,239	2,192	°F
Hot Rod Gas Pressure	1,061	740	psia
Moderator Temperature Coefficient	0.0×10^{-4}	0.0×10^{-4}	$\Delta\rho$/°F
Initial RCS Flow Rate	165.8×10^{6}	166.6×10^{6}	lbs/hr
Initial Core Flow Rate	160.8×10^{6}	161.6×10^{6}	lbs/hr
Initial RCS Pressure	2250	2250	psia
Initial Reactor Vessel Inlet Temperature	555.8	555.0	°F
Initial Reactor Vessel Outlet Temperature	615	615.9	°F
Low Pressurizer Pressure Reactor Trip Setpoint	1,555	1555	psia
SIAS Setpoint on Low Pressurizer Pressure	1,555	1555	psia
SIT Gas Pressure	584.7	584.7	psia

Table (3)-2 Comparison of Safety Injection Pumps Minimum Delivered Flow to RCS between System80+ and APR1400

RCS Pressure (psig)	Flow Rate Per Injection Point, (gpm)	
	System 80+	APR1400
1,600	0	0
1,400	296	403
1,200	432	557
1,000	560	672
800	676	767
600	784	850
400	892	924
200	920	991
100	956	1,023
0	980	1,053

(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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Figure (4)-1. Influence of ECC Injection Model on Annulus Pressure Transient

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Figure (4)-2. Nodalization of DVI line break for CEFLASH-4AS

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Figure (4)-3. HPSI flowrate

Figure (4)-4. Core Pressure

Figure (4)-5. Break flowrate

Figure (4)-6. Core Mixture Level

(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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Figure (5)-1 Core Pressure

Figure (5)-2 Break Flow Rate

Figure (5)-3 Core Void Fraction

Figiure (5)-4 Peak Clad Temp

(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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Figure (6)-1 CENPD SBLOCA codes with Interface Data

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Table (6)-1 CEFLASH to STRIKIN

Table (6)-2 STRIKIN to PARCH

Table (6)-3 CEFLASH to PARCH

Table (6)-4 PARCH to COMPERC

Table (6)-5 CEFLASH to COMPERC

Table (6)-6 COMPERC to PARCH

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Figure (6)-2 STRIKIN input data for enthalpy, pressure, power, flowrate generated automatically from CEFLASH output.

Figure (6)-3 Sample of interface data between STRIKIN and PARCH

Figure (6)-4 Sample of interface data between PARCH and COMPERC (1/2)

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Figure (6)-5 Sample of interface data between PARCH and COMPERC (2/2)

Figure (6)-6 Sample of interface data between CEFLASH and COMPERC

Figure (6)-7 Sample of interface data between COMPERC and PARCH

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Figure (6)-8 Example of selection for COMPERC inputs of Containment Pressure from CEFLASH output

Figure (6)-9 Example of selection for PARCH inputs of core pressure, 2-phase level, Liquid mass from CEFLASH output

(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, etc.) 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. TS

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.

[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.

Item 7 Action Items from Nov 18 Teleconference:

1. KHNP needs to clarify the criteria and processes used to determine when all three groups of constants are updated and the basis and frequency to update them. The response shall be in writing for staff to review further.

[Response]

CPCS design is performed following the CPCS design procedure of Reference 1. The definitions, the changing criteria and frequency of the CPCS constants are described in Reference 1 as follows:

CPCS constants are divided into Non-Reload Data Block (RDB) constants, RDB constants and Addressable constants.

CPCS Non-RDB constants are cycle independent constants. However, Non-RDB constants are verified each cycle to check the correctness of the constants. Non-RDB constants are a group of constants that are located in protected memory of the CPC and CEAC with the associated algorithms. A change to any Non-RDB constants is a software change and can only be done using the CPCS software change procedure.

Cycle dependent constants are RDB constants and addressable constants. The RDB is a group of constants that is located in protected memory of the CPC and the CEAC, separate from other non-addressable constants. RDB constants are possibly cycle dependent but are not expected to change often. Most RDB constants will not change more than a few times during the life of the plant and then only due to a design change (e.g. revised CEA pattern, major change in CHF correlation, etc.) or major fuel management changes. RDB constants are installed from special RDB disks after loading the CPC or CEAC system software and can be changed without requiring a CPCS software change.

Addressable constants are likely to change at least once per cycle (e.g., SAM, BPPCC,…) and possibly as often as daily (e.g., KCAL, TPC,…). Addressable constants are constants which can be changed by operator under Administrative Control and have point ID's.

Addressable constants are a selected set of constants which may be changed on-line by plant personnel whereas other constants may be changed only by a change in software or specific software loading from the Reload Data Block disk. Each addressable constant has an acceptable range. The CPCS rejects any attempt to enter an addressable constant outside the acceptable range. Entering a value of an addressable constant within the acceptable range may result in a momentary channel trip. Changes in certain constants results in instantaneous changes in certain CPCS parameters (Power, Flow etc.). It is recommended that the channel be bypassed when changing constants. Examples of addressable constants are thermal power calibration constants, neutron flux power calibration constants, flow calibration constants, azimuthal tilt allowance, CPCS uncertainties and power distribution related constants determined during startup.

The addressable constants serve two primary functions: allow for periodic update and calibration of the CPCS during operation (Type 1) and allow for adjustment of cycle to cycle differences without requiring a software upgrade (Type 2). In addition, the availability of the addressable constants makes it possible to select values for other CPCS constants early in the design process with the ability to adjust for any later changes using related addressable constants.

Table 1 shows the CPCS addressable constants [Ref. 2]. The addressable constants whose values are not expected to change or whose values are expected to change very infrequently during the fuel cycle are designated as Type 2. All other addressable constants (FC1, CINOP, KCAL, TPC,…) are designated as Type 1. For example, the flow rate calibration constant (FC1) will be checked every 12 hours and power calibration constants (KCAL, TPC) will be checked every 24 hours following the surveillance requirements of Technical Specifications. Meanwhile, CEAC inoperable flag (CINOP) can be change as required during operation.

The operator shall be able to change addressable constants using the OM (Operator's Module) or MTP (Maintenance and Test Panel). Modification of addressable constants shall be permitted only when a manual interlock has been activated. In addition, means shall be provided to prevent modification of any constants not designated "addressable".

References:

1. KNF, "COLSS/CPCS Design for OPR1000 and APR1400 Nuclear Power Plant," DP-30-04, Rev.08, November 3, 2014.
2. KNF, "Functional Design Requirements for a Core Protection Calculator System for APR1400," APR1400-F-C-NR-14003-P, Rev.0, August 2014.

Table 1. CPCS Addressable Constants [Ref. 2]

TS

(8) Follow Up Question Related to Prior Clarification Teleconference – October 14, 2015

NRC staff has reviewed the information provided as answers to our questions regarding core reflector region material composition and we have one follow up item for clarification:

Please confirm that the stainless steel and Inconel materials referenced in Table 2-1 of the "Discussion Initiators for KHNP/NRC Public Teleconference October 14, 2015" document refer to Stainless Steel 304 and Inconel 625, respectively. Otherwise, provide the composition number of the alloys to which these columns refer.

[Response]

The stainless steel (S.S.) in Table 2-1 of the "Discussion Initiators for KHNP/NRC Public Teleconference October 14, 2015" document refers to [ ]TS. The Inconel in Table 2-1 consists of two kinds of materials, [ ]TS. The detailed fraction for each material is shown in Table 2-1a.

Table 2-1a Volume Fraction of Structural Materials for each Reflector Region

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Note) The top reflectors (CA1~CA6) in the above data include control rod materials. The volume fractions for the unrodded top reflector regions are as follows.

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