RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**397-8519**
SRP Section:	**15.00.02 – Review of Transient and Accident Analysis Methods**
Application Section:	**15.00.02**
Date of RAI Issue:	**02/03/2016**

Question No. 15.00.02-5

Item (A) in Section II.1 of the SRP for 15.0.2 states that the documentation must include "An overview of the evaluation model which provides a clear roadmap describing all parts of the evaluation model, the relationships between them, and where they are located in the documentation."

Sections 2.5.2 and 3.2 of technical report APR1400-Z-A-NR-14006-P do not specifically identify any Chapter 15 non-LOCA safety analysis applications for COAST. Section 5 of the technical report does not identify COAST being used in combination with any other code. The technical report does not discuss any application of COAST except as an independent computer program used to verify CESEC-III. However, Figure 2.6-3 of the technical report shows COAST being used to calculate time-variant core flow rate that is input into HERMITE as part of the analysis process for a single RCP rotor seizure event. However, Section 15.3.3.3 of the APR1400 DCD does not identify the use of COAST for a single RCP rotor seizure analysis. The inconsistencies between information in various sections of the technical report and APR1400 DCD Section 15.3 has caused NRC staff to question how COAST is used in the analysis of the APR1400. NRC staff requests that the DCD and APR1400-Z-A-NR-14006-P be updated as appropriate to accurately and consistently reflect the use of COAST in transient analyses of the APR1400.

Response

The COAST code is used to calculate the time-variant core flow rate that is the input into the HERMITE code to simulate the short-term core response during the loss of forced reactor coolant flow event, the postulated RCP rotor seizure event, and the reactor coolant pump shaft break event. The COAST code was not used in combination with other codes, but used alone. To make the use of COAST code clear, Sections 3.2 and 5 of the technical report APR1400-Z-A-NR-14006 and DCD subsection 15.3.1.3.1 and 15.3.3.3.1 will be appropriately revised.

Impact on DCD

DCD subsection 15.3.1.3.1 and 15.3.3.3.1 will be revised as shown in the Attachment 1.

Impact on PRA

There is no impact on PRA.

Impact on Technical Specifications

There is no impact on Technical Specifications.

Impact on Technical/Topical/Environmental Report

Technical Report of APR1400-Z-A-NR-14006-P/NP Sections 3.2 and 5 will be revised as shown in the Attachment 2.

Factors that cause a decrease in local DNBR are as follows:

a. Increasing coolant temperature

b. Decreasing coolant pressure

c. Increasing local heat flux

d. Decreasing coolant flow

For the loss of offsite power event, the minimum DNBR occurs during the first few seconds of the transient and the reactor is tripped by the CPCs on the approach to the DNBR limit. Therefore, any single failure that would result in a lower DNBR during the transient would have to affect at least one of the above parameters during the first few seconds of the event. None of the single failures listed in Table 15.0-4 has any effect on the transient minimum DNBR during this period of time.

None of the single failures listed in Table 15.0-4 has any effect on the peak primary system pressure. The loss of offsite power makes unavailable any systems whose failure could affect the calculated peak pressure.

A loss of offsite power event with a single failure is no more adverse than the loss of offsite power event in terms of the minimum DNBR and peak primary system pressure.

Non safety-related systems are not assumed to mitigate the consequences of this event as described in Subsection 15.0.0.5.

15.3.1.3 Core and System Performance

15.3.1.3.1 Evaluation Model

COAST,

The total loss of reactor coolant flow methodology is described in Subsection 15.0.2.

The computer programs employed are CESEC-III, HERMITE, and CETOP as described in Subsection 15.0.2. The nuclear steam supply system (NSSS) response to a complete loss of reactor coolant flow is simulated using the CESEC-III computer program. The

The COAST computer program is used to calculate the time-variant core flow rate that is the input into the HERMITE code to simulate the short-term core response.

15.3.3.3 Core and System Performance

15.3.3.3.1 Evaluation Model

The NSSS response to an RCP rotor seizure with loss of offsite power concurrent with turbine trip is simulated using the CESEC-III described in Subsection 15.0.2.2.1. The HERMITE Code, described in Subsection 15.0.2.2.5, is used to determine the short-term response of the reactor core during the postulated RCP rotor seizure event. The DNBR is calculated using the TORC and CETOP computer codes (Subsection 15.0.2.2.4), which use the KCE-1 CHF correlation.

The COAST code, described in Subsection 15.0.2.2.2, is used to calculate the time-variant core flow rate that is the input into the HERMITE code to simulate the short-term core response.

15.3.3.3.2 Input Parameters and Initial Cond

The ranges of initial conditions considered are given in Table 15.0-3. Table 15.3.3-2 gives the initial conditions used in the analysis of the RCP rotor seizure event.

Based on the parametric studies, the most adverse combination of initial conditions is selected to maximize the amount of failed fuel. Using the highest core power maximizes the RCS heatup, which is the driving force of the secondary steam release. A high primary system pressure, a low core inlet temperature, and low reactor coolant flow are chosen in conjunction with the radial peaking factor compatible with these initial conditions, to initiate the event from a power operating limit (POL) allowed by core operating limit supervisory system (COLSS).

The moderator temperature coefficient is assumed to have the maximum value as defined in Subsection 15.0.0.2.3. The Doppler coefficient is assumed to have the least negative value, as defined in Subsection 15.0.0.2.3. Use of these values maximizes the heat flux in the initial stage of the transient. The minimum shutdown CEA worth is assumed as defined in Subsection 15.0.0.2.3.

15.3.3.3.3 Results

The responses of key parameters as a function of time are presented in Figures 15.3.3-1 to 15.3.3-12 for this event.

Table 15.3.3-1 summarizes the sequence of events and significant results of the event.

3.2 COAST CODE [7]

3.2.1 COAST Application

COAST is applied to perform the DCD, Tier 2 Chapter 15 licensing analyses for the following events;

a. Loss of Forced Reactor Coolant Flow (Section 15.3.1)
b. Reactor Coolant Pump Rotor Seizure (Section 15.3.3)
c. Reactor Coolant Pump Shaft Break (Section 15.3.4)

3.2.2 ~~3.2.1~~ COAST Model

The COAST code analyzes reactor coolant flow in a two loop-four pump plant. As shown in Figure 3.2-1, seven paths are considered; core region, two hot legs and four cold legs with reactor coolant pumps. The code can analyze the flow coastdown transient for any combination of active and inactive pumps including forward and reverse flow in any section.

As shown in Figure 3.2-1, the reactor coolant system is divided into seven flow sections and four nodal points. Under steady state four pump operation, all coolant flow passes through the first flow section consisting of the reactor vessel, core, and internals. One half the total flow enters each steam generator flow section which consists of the reactor vessel outlet nozzle, hot leg piping, and steam generator inlet plenum and tubes. One quarter of the total flow passes through each cold leg flow section which consists of a steam generator outlet nozzle, cold leg piping, reactor coolant pump, and reactor vessel inlet nozzle. The nodal points are located in the reactor vessel inlet and outlet plenums, and in the outlet plenum of each of the two steam generators. The nodal points are chosen at the junction of the loop flow sections where a common nodal pressure exists.

The equation for conservation of mass is written for each of the four nodal points. The equation for conservation of momentum is written for each of the seven flow segments assuming unsteady, one-dimensional flow of an incompressible fluid. Pressure losses due to friction, bends, and shock losses are assumed to be proportional to the flow velocity squared. Pump dynamics are modeled with the aid of the traditional head-flow characteristic curve for fully operable pumps and with the 4-Quadrant diagram (parametric curves of pump head and torque on coordinates of speed versus flow) for pumps at other than rated speed.

The pump dynamic equations are different in form depending on whether the pump is coasting down (inactive) or supplied with electrical power (active). For an active pump, it is assumed that the electrical torque provided by the pump motor is sufficient to maintain constant pump speed. In this case, the familiar head-flow characteristic curve is supplied as the pump dynamic equation. For an inactive pump, an equation expressing the conservation of angular momentum is written in terms of pump-motor inertia and torque exerted on the pump impeller by the coolant. The coolant momentum equation and pump momentum equation are coupled through the pump 4-Quadrant diagram. The governing conservation equations of fluid mass and loop momentum are solved simultaneously with the pump dynamics equations using conventional numerical integration techniques to obtain the transient flow coastdown.

Input to COAST includes the pressure loss coefficients for both forward and reverse flow and the fluid densities and momentum averaged fluid weights for each of the flow segments. The pump head-flow characteristic curve, pump inertia and the initial pump operating conditions are also code input. The code output consists of the time dependent speed of each pump and the transient flow rate in each flow section.

In the plant the low flow trip system sums the steam generator differential pressure measurements and trips the plant when the measurement is less than a pre-determined value. The COAST output contains the time dependent steam generator pressure data representative of the actual pressure measurements from nozzles in the hot leg piping and in the steam generator outlet plena. The values are computed in a separate subroutine which utilizes the transient loop flow rates and code input pressure loss coefficients (for both forward and reverse flow) for the flow path between the nozzle taps. The time dependent loop flow rates and the calculation of the steam generator differential pressure measurements are input to another digital code simulation for purposes of core thermal margin analysis.

5 Results

The object of this technical report is to provide methods of analysis, details, and acceptance criteria of the application of KHNP non-LOCA accident analysis to the APR1400 such that questions or issues can be identified as early as possible in the licensing process. As discussed in Section 2, the CESEC-III, TORC/CETOP, COAST, STRIKIN-II, HRISE, and HERMITE computer codes are the principle computer codes used by KHNP for the APR1400 non-LOCA analyses. Depending on the specific nature and computational capabilities needed for specific accidents, these programs are either used alone or in combination with another. Events utilizing computer codes for the non-LOCA accident analysis fall into one of the following categories based on the combination of codes used:

- Analyzed using CESEC-III and CETOP in sequence
- Analyzed using CESEC-III and HRISE in sequence
- Analyzed using HERMITE and TORC/CETOP in sequence
- Analyzed using STRIKIN-II

The first category that uses CESEC-III in combination with the CETOP includes most of the non-LOCA transients that challenge the design limits for the RCS and main steam system pressure limits, as well as loop-symmetric accidents at full-flow conditions that fall within the capabilities of the simplified CETOP DNBR model. These accidents do not require detailed calculation of localized fuel parameters and do not require spatially dependent transient calculations for accident-specific power levels or power distributions.

The second category that uses CESEC-III in combination with the HRISE is used for accident that challenges the DNB design limits such as a RTP during SLB. The loop-dependent and core total flow, core inlet conditions, pressure and power are calculated using the CESEC-III program, and then the HRISE code is used to determine the few-group space- and time-dependent neutron diffusion equation in order to consider integral effect of space and time in transient state. It could be used to calculate the feedback effects of fuel temperature, coolant temperature, coolant density, xenon distributions and control rod motion. HRISE has not been used in the DCD, Tier 2 Chapter 15 because the return-to-power has not been occurred during the post-trip steam line break event in APR1400.

The third category that uses HERMITE in combination with TORC/CETOP is used for accidents that challenge the DNB design limits under reduced flow conditions such as the partial loss of flow, complete loss of flow, locked RCP rotor, or RCP sheared shaft conditions. The loop-dependent and core total flow, core inlet temperature, RCS pressure are input to the HERMITE code to determine the state point for TORC/CETOP code which is used to calculate the minimum DNBR.

The fourth category that uses STRIKIN-II is used for the CEA ejection accident that challenges the DNB design limit and the enthalpy design limit for the reactivity induced accident. STRIKIN-II code is used to determine the hot channel or hot spot fuel response including minimum DNBR, fuel temperatures, and cladding temperature.

In summary, this technical report demonstrates the wide spectrum of key analytical methods (combinations of codes) and specialized models used by KHNP in the non-LOCA analysis for the APR1400. These events represent the SRP accident categories such as AOOs and PAs.

The core flow rate as a function of time is computed by the COAST code during these events. And these data are input into the HERMITE code.