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.:	**394-8460**
SRP Section:	**06.02.01.03 – Mass and Energy Release Analysis for Postulated Loss-of-Coolant Accidents (LOCAs)**
Application Section:	**6.2.1.3**
Date of RAI Issue:	**02/03/2016**

Question No. 06.02.01.03-6

DCD Tier 2, Section 6.2.1.3 makes the following two statements regarding the nature of two-phase flow from the LOCA break: (1) “During blowdown, most of the initial primary coolant is released to the containment as a two-phase mixture.” (2) “The onset of the two-phase release to the containment may or may not occur before the end of reflood; typically, this occurs close to the end of the reflood.” The applicant is requested to reconcile the two statements and update the DCD accordingly.

Response

(1) During the blowdown phase of the discharge leg break or the suction leg break, most of the initial primary coolant in reactor vessel goes to the cold leg break bypassing the core and is released to the containment through the break. This flow has relatively low enthalpy because of bypassing the core and the steam generator. Meanwhile, the primary inventory in the ruptured side steam generator is also released to the containment through the break. This flow has relatively high enthalpy by going through the core and the steam generator.

The total break flow is the sum of the break flow from the reactor vessel with low enthalpy and the break flow from the steam generator with high enthalpy. Thus, due to the mixed enthalpy of the summed flow, most of the initial primary coolant is released to the containment as a two-phase mixture during blowdown.

During the blowdown of the hot leg break, the flow from the reactor vessel passes through the core and is released to the containment. This flow has relatively slowly increasing enthalpy due to the core decay heat transfer and SIT injection, which reaches saturated steam condition around the end of blowdown. Meanwhile, the primary inventory in the steam generator flows backward to the hot leg break and is also released to the containment. The enthalpy of this flow is relatively rapidly increased due to the reversed heat transfer in the

steam generator and reaches steam condition at the middle of the blowdown period.

Since the total break flow of the hot leg break is the sum of these flows, the total break flow is released as a two-phase mixture though the total break flow has higher enthalpy than that of the discharge leg break or suction leg break.

(2) During the reflood phase of the discharge leg break or the suction leg break, as mentioned in DCD Section 6.2.1.3.c, a significant amount of the SIS water entering the core is postulated to be carried out of the core by the steaming action of the core-to-coolant heat transfer process. This fluid then passes through a steam generator where reverse (i.e., secondary to primary) heat transfer heats it before it reaches the containment. The residual steam generator secondary energy is sufficient to convert all of this fluid to superheated steam during the initial part of the reflood period. Subsequently, as the steam generators are cooled by this process, there is not enough heat transfer to boil all of the fluid passing through the tubes. This causes the break flow to change from pure steam to two-phase.

The onset of the two-phase release to the containment due to the cooled down steam generator may or may not occur before the end of reflood; typically, this occurs close to the end of the reflood.

The DCD and TeR will be revised for this information as Attachment 1 and 2.

Impact on DCD

DCD Tier 2, Section 6.2.1.3 will be revised, as indicated in Attachment 1 to this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

Technical report APR1400-Z-A-NR-14007, “LOCA Mass and Energy Release Methodology,” Section 3.2 will be revised, as indicated in Attachment 2 to this response.

most of the initial primary coolant is released to the containment as a two-phase mixture. Following blowdown, the water for releases is supplied from the safety injection system (SIS).

For the discharge leg break or the suction leg break, the major portion of the primary coolant in the reactor vessel directly goes to the cold leg break bypassing the core and the steam generator, thus has relatively low enthalpy. For the hot leg break, the break flow from the reactor vessel side has relatively slow increasing enthalpy due to the core decay heat transfer and SIT injection. The two-phase mixture break flow is mainly due to the low enthalpy flow from the reactor vessel side during the blowdown phase.

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LOCA post-
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passing throu
releasing the
only the blow
break and suction leg break, the water passes through a steam generator before reaching the containment so the post blowdown releases to the containment are considered for cold leg breaks.

b. The first post-blowdown period is refill. During refill, the SIS water refills the bottom of the reactor vessel to the bottom of the core. This period is conservatively omitted from the analysis.

c. The second post-blowdown period is the reflood period. During reflood, SIS water floods the core. Reflood is assumed to end when the liquid level in the core is 0.6096 m (2 ft) below the top of the active core. During reflood, a significant amount of the SIS water entering the core is postulated to be carried out of the core by the steaming action of the core-to-coolant heat transfer process. This fluid then passes through a steam generator where reverse (i.e., secondary to primary) heat transfer heats it before it reaches the containment. The residual steam generator secondary energy is sufficient to convert all of this fluid to superheated steam during the initial part of the reflood period. Subsequently, as the steam generators are cooled by this process, there is not enough heat transfer to boil all of the fluid passing through the tubes. This causes the break flow to change from pure steam to two-phase.

As the entire NSSS cools, the flow to the containment becomes eventually subcooled because the safety injection water is subcooled. The onset of the two-phase release to the containment may or may not occur before the end of reflood; typically, this occurs close to the end of the reflood. The potential

3 METHODOLOGY DESCRIPTION FOR LOCA MASS AND ENERGY RELEASE

3.1 Acceptance Criteria

The methodology of the mass and energy release analysis incorporates the acceptance criteria described in Standard Review Plan (SRP) Section 6.2.1.3, “Mass and Energy Release Analysis for Postulated Loss-of-Coolant-Accident (LOCA)” (Reference 1). The SRP acceptance criteria are based on meeting the relevant requirements of the following regulations:

- General Design Criterion 50, as it relates to the containment and subcompartments being designed with sufficient margin, requires that the containment and its associated systems can accommodate, without exceeding the design leakage rate, and the containment and subcompartment design can withstand the calculated pressure and temperature conditions resulting from any LOCA.

- 10 CFR Part 50, Appendix K, as it relates to sources of energy during the LOCA, includes requirements to provide assurance that all the energy sources have been considered.

Conservative assumptions for the input conditions based on the acceptance criteria are considered in the mass and energy release analysis. However, any specific limitation to the results based on the acceptance criteria is not applicable to the mass and energy release, since the mass and energy release results are the process parameters at the intermediate stage of the containment analysis.

The final results of the containment analysis show the behaviors of the containment pressure and temperature. The limitation based on the acceptance criteria is applied to the calculated containment pressure as the containment design pressure of [ ]TS. The containment design pressure is calculated in accordance with the guideline of Reference 5.

3.2 Accident Description for LOCA Mass and Energy Release

LOCA mass and energy release analyses are categorized as the following phases: blowdown, refill, reflood, post-reflood, and decay heat period.

a. The blowdown period extends from time zero until the primary system depressurizes and equalizes with the containment pressure. During blowdown, most of the initial primary coolant is released to the containment as a two-phase mixture. Following blowdown, the water for releases is supplied from the safety injection system (SIS).

   There is an important distinction between hot leg breaks and cold leg breaks for LOCA post-blowdown analyses. For a hot leg break, most of the SIS-supplied water leaving the core can vent directly to the containment without passing through a steam generator. Therefore, there is no mechanism for releasing the steam generator energy to the containment for a hot leg break, and only the blowdown period is considered. In contrast, for cold leg breaks like discharge leg break and suction leg break, the water passes through a steam generator before reaching the containment. Therefo
   leg breaks.

b. The first post-blowdo
   vessel to the bottom

For the discharge leg break or the suction leg break, the major portion of the primary coolant in the reactor vessel directly goes to the cold leg break bypassing the core and the steam generator, thus has relatively low enthalpy. For the hot leg break, the break flow from the reactor vessel side has relatively slow increasing enthalpy due to the core decay heat transfer and SIT injection. The two-phase mixture break flow is mainly due to the low enthalpy flow from the reactor vessel side during the blowdown phase.

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Question No. 06.02.01.03-7

SRP Section 6.2.1.3 Acceptance Criterion No. 1C(ii) suggests that calculations of heat transfer from the secondary coolant to the steam generator (SG) tubes for pressurized water reactor (PWRs) should be based on natural convection heat transfer for tube surfaces immersed in water and condensing heat transfer for the tube surfaces exposed to steam. It is not clear whether the application has followed the suggested approach. The applicant is requested to add an appropriate description in the DCD and justify the approach used.

Response

An appropriate description of the heat transfer from the secondary coolant to the steam generator (SG) tubes is provided in Section 3.5 item g of TeR (APR1400-Z-A-NR-14007, Rev. 00). The description is as follows:

> Heat transfer across the steam generator tubes is modeled with the same heat transfer coefficient in both the forward and reverse directions. This is conservative since it maintains a nucleate boiling heat transfer coefficient on the secondary side during the LOCA blowdown.
>
> In reality, the reactor trip following the LOCA would result in a turbine trip that would close the turbine stop valves and then the heat transfer in the secondary side would be through natural convection, in which the heat transfer coefficient has a small value.
>
> However, in this analysis, it is conservative to assume the overall heat transfer coefficient in the initial steady state at full-power operation since it maximizes the reverse heat transfer.

The DCD will be revised to include this information.

Impact on DCD

DCD Tier 2, Section 6.2.1.3.3 will be revised, as indicated in the Attachment to this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environment Report.

sources and amounts of stored energy is given in Table 6.2.1-38. The items of energy sources are broken down into the detail specific sources.

6.2.1.3.3 Description of Blowdown Model

Blowdown M&E release rates are calculated using the CEFLASH-4A computer code. A description of the CEFLASH-4A code, including the conservatisms in modeling, is given below. This section includes the justification of the heat transfer correlations. The following assumptions are used in selecting input data for the code. Detailed descriptions of the assumptions of blowdown model are provided in Reference 3.

a. The CEFLASH-4A code model of the heat transfer in a node allows only one wall per node.

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Heat transfer across the steam generator tubes is modeled with the same heat transfer coefficient in both the forward and reverse directions. This is conservative since it maintains a nucleate boiling heat transfer coefficient on the secondary side during the LOCA blowdown.

In reality, the reactor trip following the LOCA would result in a turbine trip that would close the turbine stop valves and then the heat transfer in the secondary side would be through natural convection, in which the heat transfer coefficient has a small value.

However, in this analysis, it is conservative to assume the overall heat transfer coefficient in the initial steady state at full-power operation since it maximizes the reverse heat transfer.

f. Two-phase heat transfer correlation (Jens Lottes) is used for the core-to-coolant heat transfer whenever the flow through the core is not pure steam.

g. ~~Heat transfer across the steam generator tubes is modeled with the same heat transfer coefficient in both the forward and reverse directions.~~

h. The turbine stop valves are assumed to close at 0.01 second. This is conservative because it keeps energy within the NSSS, which is a source of energy for containment pressurization.