RESPONSE TO AUDIT ISSUES

APR1400 Topical Reports

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

Docket No. PROJ0782

Review Section	**TR Realistic Evaluation Methodology for LBLOCA of the APR1400**
Application Section	**Topical Report: APR1400-F-A-TR-12004 Realistic Evaluation Methodology for Large-Break LOCA of the APR1400**
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Audit Issues No. 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).

Response

[

]TS The complexity made the downcomer phenomena impossible to be separated and the downcomer phenomena were considered as being merged altogether. [

]TS

However, the phenomenon "Flashing" need not to be treated as part of bias but seems to be included in the uncertainties of other parameters, just like the way that the flashing in the other components was treated due to the knowledge level shown in Table 1. The reason why the uncertainty of "Flashing" is treated by the uncertainties of other parameters is because of the calculation method of the RELAP5 code. In RELAP5, flashing is not considered by a correlation, but as a result of governing equations and state equations. [

]TS

In summary, the uncertainty of the flashing is considered by the uncertainty of critical flow, interfacial heat transfer, interfacial drag, etc. The uncertainties of the interfacial heat transfer and interfacial drag model during blowdown period are considered as being not important due to the low value in the importance rank from the PIRT. In CAREM, the uncertainty of the flashing is considered by the uncertainties in break flow and initial pressure as described in Section 4.2.2.1.2 of the topical report. The descriptions in Section 4.2.2.2 of the topical report will be revised in the future.

Table 1. The flashing in the downcomer phenomenon in the reference [5] of the topical report TS

Impact on DCD

There is no impact on the DCD.

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 Report

Topical report will be revised as mentioned above. Revised PIRT is described in the attachment for the response of Audit Issue No. 14.

There is no impact on any Technical or Environmental Report.

The increase of the vapor temperature above the saturation temperature is governed by the heat transfer from the hot core structures. Vapor superheating is not a cause but a result of the core heat. Therefore the uncertainty of vapor superheating can be described by the uncertainties of core heat transfer parameters. Core heat transfer parameters are already described above. There is no need to determine an additional parameter for vapor superheating.

Interfacial Heat Transfer

Interfacial heat transfer is strongly dependent on the interface area between the phases. The volumetric interface area is often calculated as a function of droplet diameter. The droplet diameter is determined by the Weber number in RELAP5/MOD3.3. Selection of the [ ]^{TS} as an uncertainty parameter for interfacial heat transfer is probable. And it has another advantage of describing the uncertainty of interfacial drag as well, because the drag is also dependent on the interfacial area. Therefore, the [ ]^{TS} is selected as a code parameter to describe the uncertainty of interfacial drag and heat transfer. By referring to the code manuals of COBRA-TF and RELAP5, the uncertainty range of the [ ]^{TS} has been determined. The maximum and minimum values of the [ ]^{TS}, respectively. A [ ]^{TS}.

- Parameter; [

]^{TS}

Countercurrent Flow at Top Nozzles

Except for the blowdown period, countercurrent flow is frequently calculated at the top nozzles of the fuel assemblies. At the top nozzles, steam flows upward while liquid flows downward. This countercurrent flow can affect the probable water accumulation at the upper plenum. Upflowing steam from the core can entrain the water in the upper plenum ultimately into the steam generator u-tubes. Because the steam generator secondary side is hotter than the primary side during reflood, the entrained droplets evaporate and the steam becomes superheated in the u-tubes. This droplet evaporation and steam superheating phenomena result in steam binding. The effect of steam binding on peak clad temperature is quantified as a separate bias in Section 4.2.3. Therefore, the uncertainty parameter for this countercurrent flow at the fuel assembly top nozzles is not determined.

4.2.2.2 Code Parameters and Their Ranges for Phenomena in the Reactor Vessel

4.2.2.2.1 Reactor Vessel Downcomer

As summarized in CSAU [1], the downcomer is one of the components where scale distortion is inevitable in scaled-down test facilities. Many facilities, especially when power-to-volume scaling is applied, preserve the height of the prototype but reduce the diameter of fluid volumes considerably. Due to a large height-to-diameter ratio, the facilities become tall and skinny. Consequently the downcomer not only has a narrow gap but also has a very large surface-to-volume ratio. These distortions will affect the ECC bypass process which is a consequence of many complex processes such as condensation, ~~flashing~~, interface momentum transfer, entrainment, de-entrainment, single- and two-phase pressure drops. The ECC bypass is also affected by multidimensional and countercurrent flow phenomena in the downcomer. Therefore, the phenomena or processes observed in scaled facilities become atypical to those occurring in the full-scale power plant. Therefore, the observations cannot be directly applied to full-scale power plants. As there is no one code parameter that characterizes the ECC bypass phenomenon, it is necessary to evaluate the ECC bypass as a separate bias.

Except for these ~~three~~ four processes or phenomena of "flashing," "vessel stored energy release," "boiling in the downcomer," and "non-condensable gas effect," ~~13~~ 12 among16 important processes or phenomena of the downcomer identified in Table 3-2 are treated in the evaluation of scale bias in Section 4.2.3.

Vessel Stored Energy Release and Boiling in the Downcomer

If enough cooling water is not supplied, the downcomer water would lose its subcooling and begin to boil. This is especially true in the late reflood period where SIPs only provide the emergency core cooling water. Therefore in order to describe the uncertainty of downcomer boiling, we need to consider the amount of ECCW supply and the wall stored energy. The SIP injection flow rate is treated as one of the plant parameters in Section 5.1.5. Wall stored energy can be described by material properties such as the heat capacity and conductivity. The material properties of the reactor vessel wall are dependent on the system design of the power plant. Therefore, the uncertainties of the material properties are described in Section 5.1.6.

[ ]^{TS}.

Direct Vessel Injection Jet Flow

DVI jet impingement produces dispersed droplets and affects the ECC bypass. This phenomenon is an attributor to the ECC bypass. Code parameter relevant to this phenomenon is not determined, and the effect is evaluated as a scale bias in Section 4.2.3.

Flashing

~~This phenomenon is an attributor to the ECC bypass. Code parameter relevant to this phenomenon is not determined and the effect is evaluated as a scale bias in Section 4.2.3.~~

As described in Section 4.2.2.1.2, the uncertainty of the flashing phenomenon is represented by the uncertainties of the break flow model and system pressure.

Level

This phenomenon is an attributor to the ECC bypass. Code parameter relevant to this phenomenon is not determined and the effect is evaluated as a scale bias in Section 4.2.3.

Entrainment and De-entrainment

These processes are attributors to ECC bypass. Code parameters relevant to these processes are not determined and the effects are evaluated as a scale bias in Section 4.2.3.

Multidimensional Flow, Condensation, Countercurrent Flow, and Bulk Mixing

These processes or phenomena are attributors to ECC bypass. Code parameters relevant to these are not determined and the effects are evaluated as a scale bias in Section 4.2.3.

Single- and Two-phase Pressure Drop

This phenomenon is an attributor to ECC bypass. Code parameter relevant to this phenomenon is not determined and the effect is evaluated as a scale bias in Section 4.2.3.

Non-condensable Gas Effect

Non-condensable gas in the downcomer is mainly nitrogen from SIT after the depletion of its water inventory. The nitrogen increases downcomer pressure because its pressure is higher than the downcomer pressure at its appearance time. The higher pressure pushes down the downcomer water column into the core and enhances core reflood. On the other hand, the nitrogen might affect the condensation in the downcomer. Ingression of the nitrogen into the core is not probable or considerable because of the existence of the water column in the downcomer. [

]^{TS}

The release of non-condensable gas from the SIT after the depletion of the SIT water is dependent on the SIT pressure, nitrogen volume and temperature. These SIT parameters are dependent on the safety system design of the NPP. Therefore, the uncertainties of these SIT parameters are treated as plant input parameters, and are discussed in Section 5.1.

4.2.2.2.2 Reactor Vessel Lower Plenum

As summarized in the CSAU [1], the lower plenum is one of the components where scale distortion is inevitable in the scaled-down test facilities. The phenomena or processes observed in scaled facilities become atypical to those occurring in the full-scale power plant. Therefore, it is necessary to evaluate the effects of the phenomena or processes except for those which code parameters can be determined.

Stored Energy Release and Boiling

The initial steady-state energy is released by conduction during the transient from the reactor vessel lower plenum walls. Consequently, boiling and vapor generation can occur in the lower plenum due to the energy release from the internal structures and the vessel wall. The parameters governing these phenomena are the material properties, such as heat capacity and conductivity, of the vessel lower plenum wall. The material of the reactor vessel lower plenum wall is dependent on the system design of the NPP. Therefore, the uncertainties of these governing parameters are treated as plant input parameters, and are discussed in Section 5.1.

Level

This phenomenon is an attributor to, or a result of, ECC bypass. Code parameters relevant to this phenomenon are not determined, and the effect is evaluated as a scale bias in Section 4.2.3.

Multidimensional Flow, Entrainment, and Bulk Mixing

Multidimensional flow, entrainment (i.e., sweep-out) and bulk mixing have an impact on the initiation time of core reflooding because these phenomena govern the water level in the lower plenum and the ECC bypass during the refill period. Therefore, the uncertainties of these phenomena can be described by a separate bias evaluation of the ECC bypass. Bias evaluation is described in detail in Section 4.2.3.

4.2.2.2.3 Reactor Vessel Upper Plenum

Flashing

As described in Section 4.2.2.1.2, the uncertainty of the flashing phenomenon is ~~replaced~~ by the uncertainties of the break flow model and system pressure.

represented

Level

As described in Section 4.2.2.1.2, no specific code parameter for the water level has been identified because the water level is dependent on all the other phenomena.