KHNPDCDRAIsPEm Resource

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Sent: Tuesday, March 01, 2016 10:09 AM
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Cc: Schaperow, Jason; Mrowca, Lynn; Steckel, James; Lee, Samuel
Subject: APR1400 Design Certification Application RAI 426-8492 (19 - Probabilistic Risk Assessment and Severe Accident Evaluation)
Attachments: APR1400 DC RAI 426 SPRA 8492.pdf

KHNP,

The attachment contains the subject request for additional information (RAI). This RAI was sent to you in draft form. Your licensing review schedule assumes technically correct and complete responses within 30 days of receipt of RAIs. However, KHNP requests, and we grant, 60 days to respond to this RAI. We may adjust the schedule accordingly.

Please submit your RAI response to the NRC Document Control Desk.

Thank you,

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REQUEST FOR ADDITIONAL INFORMATION 426-8492

Issue Date: 03/01/2016
Application Title: APR1400 Design Certification Review – 52-046
Operating Company: Korea Hydro & Nuclear Power Co. Ltd.
Docket No. 52-046
Review Section: 19 - Probabilistic Risk Assessment and Severe Accident Evaluation
Application Section:

QUESTIONS

19-53

10 CFR 52.47(a)(23) and 10 CFR 52.47(a)(27), in part, require that the applicant perform a probabilistic risk assessment and an analysis of design features for the prevention and mitigation of severe accidents.

Chapter 19.0 of the NRC's Standard Review Plan (SRP), Revision 3 (draft), includes the following guidance to the NRC reviewer: "…the reviewer carries out an independent assessment of the plant response to selected severe accident scenarios using the latest version of the MELCOR computer code. The assessment should examine accident scenarios from the PRA, which are chosen based on a combination of frequency, consequence, and dominant risk. Some of these scenarios should be similar or identical to sequences analyzed by the applicant and reported in the PRA."

Per the above SRP guidance, the staff has performed MELCOR confirmatory calculations. The calculations' objectives are to enable the staff to confirm the plant response to severe accidents based on the applicant's MAAP calculations and to identify potential discrepancies. Because the objectives include confirming the expected plant response based on the applicant's MAAP calculations, the staff used realistic (see further discussion below) assumptions in its calculations. The staff evaluates initial and boundary conditions, the nodalization of the plant, and the assumptions involving the operation of severe accident mitigation systems. Performing confirmatory calculations enables the staff to better understand the design and ask questions regarding the expected response of the design to a severe accident.

Effect of issues identified on all of the applicant's MAAP calculations
For the APR1400 design, the staff performed MELCOR calculations for five selected scenarios modeled by the applicant with MAAP for its analysis of PRA and severe accident design features. Per the SRP, these scenarios were selected based on their importance to core damage frequency (CDF) and/or risk. These scenarios are similar or identical to sequences analyzed by the applicant and reported in the PRA. The staff compared the MELCOR and MAAP results for these five scenarios and identified the potential issues described below. Some of the issues identified also may be applicable to the applicant's other MAAP calculations that use similar modeling or input assumptions. To minimize unnecessary regulatory burden, the staff has not reviewed the applicant's other MAAP calculations in detail. Nevertheless, the staff expects the applicant to revisit the other MAAP calculations to determine applicability of the issues identified by the staff to the other MAAP calculations.

Realism in the MAAP calculations
Severe accident models such as MAAP and MELCOR have been developed and validated to realistically simulate the progression of a range of severe accident scenarios for light-water

nuclear power plants based on plant response. To ensure that the PRA and severe accident design feature analysis are accurately quantified, the staff expects the applicant's MAAP calculations to be based on realistic assumptions. By realistic, the staff means that the assumptions are based on the actual plant design and the operator actions that would be expected to occur during an accident. The staff uses the term realistic to be synonymous with most likely or best estimate. Since some uncertainty may still exist in these code predictions, there may also be a need for sensitivity calculations. For example, if the plant has four pilot operated safety relief valves (POSRVs) and the procedures direct the operator to open all four POSRVs during an accident, then assuming that the operator opens four POSRVs is expected or realistic. Assuming the operator opens two POSRVs may be helpful to understand the potential change in plant response if only two POSRVs were open (i.e., sensitivity calculation). Also, if the plant has four safety injection tanks (SITs) that automatically and passively inject water into the reactor coolant system (RCS) when it depressurizes, then assuming the SITs inject is realistic. Assuming SIT injection does not occur when the RCS depressurizes could similarly be a sensitivity calculation. Furthermore, assumptions that are believed by the applicant to be conservative or to not affect the results need to be technically justified. One way to justify such assumptions could be through the use of sensitivity calculations to demonstrate that the assumption is conservative or does not affect the results. Another way could be to cite uncertainty in the plant operation or response and perform sensitivity calculations to explore this uncertainty.

Request for additional information
For the staff to reach a reasonable assurance finding that the MAAP simulations reflect the expected plant response, please respond to the items below and update the DCD as needed. Also, please provide justification if the response information is excluded from the DCD. The applicant's responses to the staff issues need to be sufficiently supported to enable the staff to reach the same safety conclusion as the applicant. For example, if the applicant response is that a particular modeling choice is conservative or does not affect the results, the applicant needs to provide data (e.g., sensitivity calculations) to support that statement. The items are grouped into four topical areas as shown below.

Area One: Assumptions Related to Operation of Systems
The MAAP calculations include assumptions regarding operation of systems. In some cases, the DCD and underlying documents do not identify these assumptions or provide justification for the use of these assumptions. Related requests for additional information are as follows:

1. The five MAAP calculations that the staff reviewed do not include SITs injection. Please provide justification.
2. One of the five MAAP calculations the staff reviewed does not include PARs operation. Please provide justification.
3. For four of the five MAAP calculations the staff reviewed, it was not clear to the staff how many valves (POSRVs, 3-way valves, and cavity flooding valves) were being opened. Please provide the justification for the assumed timing and number of valves opened.
4. The MAAP calculation for STC11 (emergency containment spray backup system (ECSBS) operation and no cavity flooding system operation) was performed using the normal containment spray with a reduced flow rate instead of ECSBS which draws water from outside containment. Please provide justification.

Area Two: Assumptions Related to Physical Phenomena

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The MAAP calculations include assumptions that do not appear to consider certain physical phenomena. In some cases, the DCD and underlying documents do not identify or provide justification for not considering these phenomena. Related requests for additional information are as follows:

5. The five MAAP calculations that the staff reviewed do not include reactor coolant pump seal leakage flow paths and the resulting flow in the analysis. Please provide justification.
6. The five MAAP calculations that the staff reviewed do not include reactor coolant pump seal failure flow paths and the resulting flow in the analysis. Please provide justification.
7. For the high pressure MAAP calculation the staff examined (Q03), the MAAP output plots indicate that severe accident induced hot leg rupture was neglected. Please provide justification.
8. MAAP case STC16 includes a hole in the containment as a result of a hydrogen burn around 100,000 sec. While this MAAP calculation models containment failure as a result of a burn, it does not model other physical effects of the burn (e.g., decrease in mole fractions of combustibles, increase in containment pressure). Please provide justification.
9. For the high pressure MAAP calculation the staff examined (Q03), the MAAP output plots indicate that the reactor vessel lower head ruptures when the reactor vessel is still at high pressure. However, it appears that the effects of the resulting high pressure melt ejection were not modeled. Please provide justification.

Area Three: Clarifications

10. Please explain the basis for the decay power used in the MAAP calculations. For example, on what fuel burnup, operating power, and time in the operating cycle (e.g., end of cycle) was the decay power based?
11. Please describe the assumptions made in the MAAP calculations for feedwater injection coastdown and MSIV closure timing.
12. Please explain what is being assumed for hydrogen sinks in the simulation. For example, are passive autocatalytic recombiners (PARs) and igniters assumed to be operating? Under what conditions are hydrogen burns assumed to occur?
13. Please explain why the MAAP output plots appear to show core debris exiting the vessel more slowly for the high pressure MAAP calculation the staff reviewed (i.e., Q03) than for the low pressure MAAP calculations (e.g., STC16).
14. The MAAP output plots appear to show more CO_2 being produced in the high pressure MAAP calculation the staff reviewed (i.e., Q03) than in the low pressure MAAP calculations (e.g., STC16). Please explain the basis for this.
15. For STC10, the MAAP RCS pressure plot indicates that the depressurization was stopped from 3640 sec to 4370 sec. Please explain why the depressurization was stopped.
16. For STC10, please explain the basis for the MAAP steam generator (SG) pressure to start trending down after 100,000 seconds.
17. For STC10, the MAAP SG water level plot seems to show that water level increases from a level of zero starting at 140,000 seconds. Please explain the basis for reintroduction of water into the SGs at this time.
18. For STC10, MAAP appears to be calculating no ablation, even though core debris is in contact with the cavity concrete floor. Please explain the basis for this modeling.

19. For STC11, from 12,400 to 55,000 sec, the MAAP cavity water level plot appears to show water in the cavity. However, the ablation depth and containment pressure plots during this time frame seem to indicate that the water is not taking away any heat from the core debris. Please explain the basis as to why overlying water is not taking away heat from the core debris.
20. For STC11, the MAAP cavity water level plot shows water level decreasing more slowly from 12,400 to 41,500 than from 41,500 to 55,000 sec. Please explain the basis as to why the water level decreases faster after 41,500 sec.
21. For STC11, starting at 55,000 sec, the MAAP cavity water level plot seems to show that water level drops below the bottom of the cavity (i.e., below 0 meters). Please explain the basis as to how the water can drop below the bottom of the cavity.
22. For STC11, after the ECSBS system starts (around 100,000 sec), the MAAP containment water level plot shows containment spray water going into the holdup volume tank but not into the cavity. Please provide the basis for containment spray water not reaching the cavity, which is the lowest point in the containment. If the basis is internal geometric obstacles, please describe these obstacles and how long the ESCBS would need to operate to overflow these obstacles.
23. For POS5, it is observed that the MAAP-predicted pressurizer pressure is higher than the MAAP-predicted containment pressure until RPV lower head failure. Please explain the basis for the predicted pressurizer pressure and why it is higher than containment pressure. Also, please explain how the flow path from the pressurizer to the containment representing the open 16-inch pressurizer manway was modeled and nodalized with MAAP, including justifying using a stuck-open POSRV to represent the manway.
24. For POS5, it is observed that MAAP-predicted cesium and tellurium release fractions (FREL(2) and FREL(3)). Please explain the basis for this.
25. LPSD Level 2 Modeling Notebook, APR1400-K-P-NR-013762-P, Table 4-2 has CsI and CsOH release fractions, respectively. The release fractions appear to be smaller than expected for source term categories (STCs) with early containment failure (hole sizes of 1 ft^2 and 527 ft^2 (49 m^2)). Please explain the basis for the release fractions. In other words, where did the CsI and CsOH deposit and why?

Area Four: Key Risk Insights Gained from the MAAP analyses

As stated in Chapter 19.0 of the NRC's Standard Review Plan (SRP), Revision 3 (draft), "The staff will determine that the applicant has identified risk-informed safety insights based on systematic evaluations of the risk associated with the design such that the applicant can identify and describe the following:

A. The design's robustness, levels of defense-in-depth, and tolerance of severe accidents initiated by either internal or external events
B. The risk significance of potential human errors associated with the design."

The staff is requesting that the following key design features and operator actions be included in the applicant's risk insights table or the staff is requesting a justification why these additions are not necessary:

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1. Operator actions to depressurize the RCS and redirect the resulting flow from the RCS bypassing the in-containment refueling water storage tank (IRWST) (e.g., opening POSRV and 3-way valves), due to its potential to affect containment pressurization, containment failure due to hydrogen combustion, and source term.
2. The design of the key flow paths for molten debris and hot gasses from the cavity below the reactor vessel to the containment reducing the potential for direct containment heating.

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