KHNPDCDRAIsPEm Resource

From: Ciocco, Jeff
Sent: Thursday, November 05, 2015 6:47 AM
To: apr1400rai@khnp.co.kr; KHNPDCDRAIsPEm Resource; Harry (Hyun Seung) Chang; Andy Jiyong Oh; James Ross
Cc: Carlson, Donald; McKirgan, John; Olson, Bruce; Vera, John; Lee, Samuel
Subject: APR1400 Design Certification Application RAI 293-8332 (04.03 - Nuclear Design)
Attachments: APR1400 DC RAI 293 SRSB 8332.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, 45 days to respond to question 04.03-6. We may adjust the schedule accordingly.

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

Thank you,

Jeff Ciocco
New Nuclear Reactor Licensing
301.415.6391
jeff.ciocco@nrc.gov

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From: Ciocco, Jeff

Created By: Jeff.Ciocco@nrc.gov

Recipients:
"Carlson, Donald" <Donald.Carlson@nrc.gov>
Tracking Status: None
"McKirgan, John" <John.McKirgan@nrc.gov>
Tracking Status: None
"Olson, Bruce" <Bruce.Olson@nrc.gov>
Tracking Status: None
"Vera, John" <John.Vera@nrc.gov>
Tracking Status: None
"Lee, Samuel" <Samuel.Lee@nrc.gov>
Tracking Status: None
"apr1400rai@khnp.co.kr" <apr1400rai@khnp.co.kr>
Tracking Status: None
"KHNPDCDRAIsPEm Resource" <KHNPDCDRAIsPEm.Resource@nrc.gov>
Tracking Status: None
"Harry (Hyun Seung) Chang" <hyunseung.chang@gmail.com>
Tracking Status: None
"Andy Jiyong Oh" <jiyong.oh5@gmail.com>
Tracking Status: None
"James Ross" <james.ross@aecom.com>
Tracking Status: None

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REQUEST FOR ADDITIONAL INFORMATION 293-8332

Issue Date: 11/05/2015
Application Title: APR1400 Design Certification Review – 52-046
Operating Company: Korea Hydro & Nuclear Power Co. Ltd.
Docket No. 52-046
Review Section: 04.03 - Nuclear Design
Application Section:

QUESTIONS

04.03-4

Question 4.3-4: Load-Follow Operations

REQUIREMENTS AND GUIDANCE

10 CFR Part 50 Appendix A, General Design Criterion (GDC) 10 requires the reactor core design to include appropriate margin to ensure that specified acceptable fuel design limits (SAFDLs) are not exceeded during normal operation or anticipated operational occurrences (AOOs). GDC 11, "Reactor Inherent Protection," requires that, in the power operating range, the prompt inherent nuclear feedback characteristics tend to compensate for a rapid increase in reactivity. GDC 20, "Protection System Functions," requires automatic initiation of the reactivity control systems to assure that SAFDLs are not exceeded as a result of AOOs and that automatic operation of systems and components important to safety occurs under accident conditions. In addition, GDC 28, "Reactivity Limits," requires that the effects of postulated reactivity accidents neither result in damage to the reactor coolant pressure boundary greater than limited local yielding nor cause sufficient damage to impair significantly the system's capability to cool the core.

To assess compliance with these requirements, Section 4.3 of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," (SRP) guides the staff to review the applicant's analysis of reactivity coefficients and power distributions for "steady-state operations and allowed load-follow transients." In addition, SRP Section 15.0 guides reviewers to ensure that the application "specifies the permitted fluctuations and uncertainties associated with reactor system parameters and assumes the appropriate conditions, within the operating band, as initial conditions for transient analysis."

ISSUE

Noting that the applicant refers to load-follow operations and transients in DCD Sections 4.3 and 4.4, the staff is concerned that the application lacks much of the information that would necessary for approving the APR1400 design for load-follow operations. For example, the DCD does not specify the ranges of allowed load-follow power maneuvers (e.g., power swings, power ramp rates), does not detail how load-follow power maneuvers and resulting xenon transients would be controlled with rods versus soluble boron, and does not include analyses of core and system transients associated with load-follow operations. Moreover, the analyses presented in DCD Chapter 15 do not explicitly consider transient load-follow operational conditions in determining the most limiting initial operating conditions for analyzed transients and accidents.

INFORMATION NEEDED

In its response, the applicant should either provide all information necessary for the consideration of load-follow operations or else state that it is seeking approval of the APR1400 design only for defined base-load operations. The applicant should then revise the affected parts of the DCD and its incorporated references accordingly.

04.03-5

Question 4.3-5: CEA Service Limits

REQUIREMENTS AND GUIDANCE

General Design Criterion (GDC) 10 requires the reactor design to include appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during normal operation or anticipated operational occurrences (AOOs). GDC 20, "Protection System Functions," requires automatic initiation of the reactivity control systems to assure that SAFDLs are not exceeded as a result of AOOs and that automatic operation of systems and components important to safety occurs under accident conditions. In addition, GDC 28, "Reactivity Limits," requires that the effects of postulated reactivity accidents neither result in damage to the reactor coolant pressure boundary greater than limited local yielding nor cause sufficient damage to impair significantly the capability to cool the core. All of these requirements involve accurate knowledge of the total and differential reactivity worths of the control element assemblies (CEAs).

SRP Section 4.3 guides the reviewer to address the following: "The adequacy of the control systems to assure that the reactor can be returned to and maintained in the cold shutdown condition at any time during operation. The applicant shall discuss shutdown margins. Shutdown margins need to be demonstrated by the applicant throughout the fuel cycle."

ISSUE

The applicant's nuclear design includes full-strength and part-strength CEAs. The full-strength CEAs use B_4C as neutron absorber. On page 4.3-7, the DCD states: "Methods of controlling the power distribution include the use of full- or part-strength CEAs to alter the axial power distribution; decreasing CEA insertion by boration, thereby improving the radial power distribution; and correcting off-optimum conditions that cause margin degradations such as CEA misoperation." On page 4.3-17, the DCD also indicates: "The regulating CEA groups can be used to compensate for changes in reactivity associated with routine power level changes. In addition, they can be used to compensate for minor variations in moderator temperature and boron concentration during operation at power and to dampen axial xenon oscillations." On page 4.3-24, the DCD states: "Control action with part-strength rods or full-strength rods may be required to limit the magnitude of the oscillation." As such, some or all of the regulating rods may be inserted into the core for extended periods of time and at various depths during power operations. The staff is therefore concerned that progressive poison burnout in the affected regulating rods could unacceptably degrade their effectiveness for control and safe shutdown.

On June 23, 2015, staff issued RAI No. 48-7943, Question 4.03-2, requesting specific information to address this concern. On July 22, 2015, ADAMS Accession No. ML15203A536, the applicant responded with the requested information. In addition to computed estimates showing substantial peak B-10 burnout near the CEA tips, the response also included a summary of physics test results from operating OPR1000 cores that are similar in this regard to APR1400. The latter showed that total rod bank worths measured after multiple operating OPR1000 fuel cycles still matched predictions within allowed uncertainty limits even though the predictions neglected B-10 depletion. The staff also audited related calculation notes provided by the applicant that further detail the applicant's bases for the provided B-10 burnout estimates.

The staff notes that the reported insertion histories of the physics-tested OPR1000 regulating rods were significantly less than assumed in the provided burnout estimates. The staff further notes that the reported B-10 burnout estimates were substantial even though they were based on CEA insertion history assumptions (i.e., with regulating full-strength CEAs partly inserted for a total of only 8 months over 10 years of operation at 87 percent capacity) that were not shown to be conservative or bounding. Accordingly, the staff is concerned that the effects of B-10 burnout on CEA worths could in fact become unacceptable unless prevented by the specification of appropriate CEA service limits. Such limits could be placed for example on either CEA replacement intervals or allowed CEA insertion histories.

INFORMATION NEEDED

The applicant is requested to either (a) specify CEA service limits as necessary to prevent unacceptable levels of B-10 burnout in full-strength CEAs used as regulating rods, or else (b) demonstrate that no such CEA service limits are necessary.

04.03-6

Question 4.3-6: Vessel Fluence Analysis and Surveillance

REQUIREMENTS AND GUIDANCE

The requirements pertaining to vessel fluence analysis and surveillance are as follow:

- 10 CFR Part 50 Appendix A, General Design Criterion (GDC) 14 as it relates to ensuring an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture of the reactor coolant pressure boundary, in part, insofar as it considers calculations of neutron fluence.
- GDC 31 as it relates to ensuring that the reactor coolant pressure boundary will behave in a nonbrittle manner and that the probability of rapidly propagating fracture is minimized, in part, insofar as it considers calculations of fluence.
- Appendix G, to 10 CFR Part 50, as it relates to reactor pressure vessel material fracture toughness requirements, in part, insofar as it considers calculations of neutron fluence.
- Appendix H, to 10 CFR Part 50, as it relates to reactor pressure vessel material surveillance program requirements, in part, insofar as it considers calculations of neutron fluence.
- 10 CFR 50.61 as it relates to fracture toughness criteria for PWRs relevant to pressurized thermal shock events, in part, insofar as it considers calculations of neutron fluence.

SRP 4.3 and SRP 5.3 guide the reviewer to apply the following acceptance criteria:

- There is reasonable assurance that the proposed design limits can be met for the expected range of reactor operation, taking into account analysis uncertainties.
- There is reasonable assurance that during normal operation the design limits will not be exceeded.
- The acceptance criteria of Regulatory Guide 1.190, “Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence.”
- The acceptance criteria of Regulatory Guide 1.99, “Radiation Embrittlement of Reactor Vessel Materials.”

ISSUES

(a) The staff reviewed the nuclide compositions of the modeled reactor materials and the fission spectra and neutron source spectrum data provided respectively in Tables 2-1 and 2-2 of the applicant’s technical report by performing hand calculations and comparing the source spectrum with published independent data. The staff found no erroneous data but was not able to discern and confirm the nuclide fractions the applicant uses for mixing the fission source spectra.

(b) The staff’s review noted that the technical report does not identify the numerical options (e.g., differencing schemes) used in the applicant’s DORT code fluence calculations.

(c) The staff’s review compared the calculated-to-measured (C/M) data reported by the applicant with those reported in a published VENUS-1 benchmarking study and confirmed that they are mutually consistent. The technical report indicates that the applicant has used the C/M ratios to determine the bias in the calculated vessel fluence. However, the report does not explain how the reported total bias of 6 percent was calculated.

(d) The applicant's technical report includes a brief description of the use of in-vessel surveillance capsules. The staff however was not able to discern from the report the axial locations of the capsules.

(e) The staff reviewed the calculated flux and fluence values presented in Table 5.1 and Figures 5.1 and 5.2 of the applicant's technical report and found them to show relative behaviors consistent with those reported for similar designs in independent published studies. The staff is concerned, however, that the report does not state the fluence limits for the APR1400 vessel. Because of this, the staff cannot discern whether the calculated peak fluence for 55.8 effective full power years would meet the limits for this design.

INFORMATION NEEDED

To address the above concerns, the applicant should provide the following information and update the affect parts of the DCD and its incorporated references accordingly:

a) The fission nuclide mixing fractions used in calculating the neutron source spectrum
b) The DORT code numerical options used for the vessel fluence calculations
c) The method used for determining vessel fluence bias value of 6 percent
d) The axial locations of the in-vessel surveillance capsules
e) The vessel fluence limits in relation to the calculated peak fluences.

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