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.: **85-7949**

SRP Section: **03.09.04 – Control Rod Drive Systems**

Application Section: **SRP 3.9.4**

Date of RAI Issue: **07/16/2015**

Question No. 03.09.04-1

Are the functional requirements of the APR1400 CEDM identical to those of the first production tests, i.e. 76.2 cm/min for maximum stepping speed and 159kg for design drive line load, as described in FSAR Section 3.9.4.4? If not, what are they?

Also, in DCD Section 3.9.4.1, it states that the design duty requirement for the CEDM is a total cumulative CEA travel of 30,480 m (100,000 ft) operation without loss of function. The staff requests the applicant to clarify the basis of the design duty requirement of 100,000ft of travel. The functional requirements of the CEDM and the basis for the design duty requirement should be clearly stated in the DCD.

This information is necessary to complete the area of review described in SRP 3.9.4, Item I.1, which states that "[t]he descriptive information, including design criteria, testing programs, drawings, and a summary of the method of operation of the control rod drives, is reviewed to permit an evaluation of the adequacy of the system to perform its mechanical function properly."

Response

1) The functional requirements of the CEDM are very similar to those of the first production tests. The maximum stepping speed requirement, 76.2 cm/min (30 in/min), is the same, but the drive line load requirement is slightly different. The CEDM is designed to be capable of operating with a minimum and maximum weight of the CEA and ESA of 100 kg (220 lbs) and 204kg (450 lbs), respectively. The drive line load requirement to be used for stress analyses is 156 kg (345 lbs), which corresponds to the estimated weight of the heaviest CEA and ESA. The production test requirement is 159 kg (350 lbs), which is a slightly more conservative value compared to the estimated weight of the heaviest CEA and ESA and bounds the weight used in the stress analyses. The functional requirement of lifting force is 600 lbs and the number of full height drops is 1,000. These values will be incorporated into DCD Section 3.9.4.1.

2) Design duty requirement of 100,000 ft of travel was determined by operational experience taking into account 40-year life time of the active components such as the motor assembly and extension shaft assembly. [

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Impact on DCD

DCD Section 3.9.4.1 will be revised as indicated in Attachment.

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 Environmental Reports.

The CEDM is capable of operating at the maximum speed of 76.2 cm/min (30 in/min) with minimum and maximum weight of the ESA and CEA, 100 kg (220 lbs) and 204kg (450 lbs), respectively. The CEDM is capable of exerting 600 lbs minimum up force on the CEA and ESA.

3.9.4 Control Element Drive Mechanisms

The CEDM is designed, constructed, and tested to meet the requirements of GDC 1, 2, 4, 14, 26, 27, and 29, as well as 10 CFR 50.55a.

3.9.4.1 Descriptive Information of Control Element Drive Mechanism

The control element drive mechanism (CEDM) is a magnetic jack-type driving apparatus used to vertically position the control element assemblies (CEAs) as an independent reactivity control system. Each CEDM is capable of withdrawing, inserting, holding, or tripping the CEA from any point within its 3.8 m (150 in.) stroke in response to operation signals.

The CEDM is designed to function during and after all plant transients. The CEA drop time for 90 percent insertion is 4.0 seconds maximum. The drop time is defined as the interval between the time the power is removed from the CEDM coils and the time the CEA has reached 90 percent of its fully inserted position. Drop motion begins within 0.5 second after the removal of power. The CEDM is designed to function normally during and after being subjected to seismic loads. The vibratory motion of the SSE is included in the fatigue evaluation in accordance with Subsection 3.9.2.2.3. The CEDM allows for tripping of the CEA during and after an SSE.

The design and construction of the CEDM pressure housing fulfills the requirements of ASME Section III, Subsection NB. The pressure housings are capable of withstanding, throughout the design life, all normal operating loads, including the steady-state and transient operating conditions specified for the vessel. Mechanical excitations are also defined and included as a normal operating load. Design condition of the CEDM pressure housings is 17.2 MPa (2,500 psia) at 343.3 °C (650 °F), and normal operating condition is 15.5 MPa (2,250 psia) at 323.9 °C (615 °F). The loading combinations and stress limit categories are presented in Table 3.9-11 and are consistent with those defined in the ASME Section III.

The design duty requirement for the CEDM is a total cumulative CEA travel of 30,480 m (100,000 ft) operation without loss of function.

The test programs performed in support of the CEDM design are described in Subsection 3.9.4.4.

and a total number of full-height CEA drops of 1,000.

3.9.4.1.1 Control Element Drive Mechanism Design Description

The CEDMs are mounted on nozzles on the top of the reactor vessel closure head. A CEDM consists of upper pressure housing, motor housing, motor assembly, coil stack assembly, two reed switch position transmitter (RSPT) assemblies, and an extension shaft assembly (ESA). The CEDM is shown in Figure 3.9-7. The drive power is supplied by the coil stack assembly, which is positioned around the motor housing. Two RSPT assemblies are supported by the upper shroud which encloses the upper pressure housing assembly.

The lifting operation consists of a series of magnetically operated step movements. Two sets of mechanical latches are used to engage an ESA. The magnetic force is obtained from the coil stack assembly mounted on the outside of the motor housing.

The CEDM control system actuates the stepping cycle and moves the CEA by a withdrawal or insertion stepping sequence. CEDM-hold is obtained by energizing a latch coil at a reduced current, while all other coils are de-energized. The CEAs are tripped upon interruption of electrical power to all coils. Each CEDM is connected to the CEAs by an ESA.

The axial position of a CEA in the core is indicated by three independent readout systems. One system counts the CEDM steps electronically, and the other two consist of magnetically actuated reed switches located at regular intervals along the upper pressure housing.

3.9.4.1.1.1 Control Element Drive Mechanism Pressure Housing

The CEDM pressure housing consists of the motor housing assembly and the upper pressure housing assembly. The motor housing assembly is attached to the reactor vessel

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Question No. 03.09.04-2

From June 30 to July 2, 2015, the staff performed an audit of the CEDM summary stress report, CEDM design specification, and CEDM scram time qualification test report to verify the scramability of the CEDM established by analysis or test. The staff found that DCD Section 3.9.4.3 does not clearly state the differences between the APR1400 CEDM and those used in the production tests and deflection drop tests, including changes made such as seismic supports in upper portions of CEDM shroud, shroud tube wall thickness increase, and outside diameter increase of longer CEDM nozzle. The staff requests the applicant to clarify the exact differences between the APR1400 CEDMs, production test CEDMs, and deflection drop test CEDMs, in regard to supports, structural, material, and any other measurable differences so that the staff can determine if these tests can be used to confirm the seismic capability of the CEDM design to meet GDC 2. A comparison table and a short summary of the deflection test, along with design limits for the CEDM to ensure insertability under seismic conditions should be in incorporated into the DCD.

Response

1) Production tests are performed to check operability of the motor assembly. All production tests are performed with the actual motor assemblies to be used for the corresponding plants. So, there is no difference between the APR1400 CEDMs and production test CEDMs.

2) The differences between the APR1400 CEDMs and deflection drop test CEDMs are as follows;
   - Seismic support is installed [ ]^{TS}.
   - The wall thickness of the CEDM shroud tube was increased [ ]^{TS}.
   - The outside diameter of the longer RV head nozzle (CEDM nozzle) was increased [ ]^{TS}.
   - Material of the RV head nozzles and motor housing lower end fitting was changed to Alloy 690TT from Alloy 600.

Among the differences listed above, some items related to the CEDM are already described in DCD section 3.9.4.4. Other items related to the interfacing components will be incorporated into the DCD as Attachment 1 as description rather than a table due to the proprietary nature of the information.

3) A short summary of the deflection test along with design limits for the CEDM to ensure insertability under seismic conditions will be in incorporated into the DCD as Attachment 2.

Impact on DCD

DCD Section 3.9.4.4 and 3.9.2.7.3 will be revised as indicated in Attachments 1 and 2, respectively.

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 Environmental Reports.

motor housing lower end fitting was changed to Alloy 690TT from Alloy 600 to improve structural integrity against PWSCC, and thickness of the upper shroud was increased to improve mechanical strength. These changes enhance the structural integrity of the CEDM and do not affect the safety-related functions of the APR1400 CEDM. The following describes the tests performed during development of System 80 CEDM, which provides design verification for the APR1400 CEDM.

Besides the design changes of the CEDM, there have been design changes of interfacing components. Material of the RV head nozzle was changed to Ally 690TT from Alloy 600, and the outside diameter of longer RV head nozzle (CEDM nozzle) was increased. Seismic support was installed at the upper portion of the CEDM to restrain horizontal deflection.

During the CEA scram test, 300 full-height drops were completed. All release times were less than 0.3 second, and CEA drop times to 90 percent of full insertion were less than 4.0 seconds, which meets the design criterion.

Operating experience also provides design verification of the APR1400 CEDM. The APR1400 CEDM is essentially identical to the CEDM of Palo Verde, HBN 3&4, HBN 5&6, HUN 3&4, HUN 5&6, SKN 1&2, and SWN 1, which are all in operation. The experience has demonstrated that the CEDM operates without malfunction.

First production test programs were completed on the CEDM to verify operability. During the course of this program, more than 1,219 m (4,000 ft) of travel was accumulated and 30 full-height gravity drops were made without mechanism malfunction or measurable wear on operating parts. The program included the following:

a. Operation at 76.2 cm/min (30 in/min) traveling 159 kg (350 lb) of weight at ambient temperature and a gauge pressure of 0.7 MPa (100 psig) for 15.2 m (50 ft)

b. Fifteen full-height drops at simulated reactor operating conditions with 159 kg (350 lb) of weight during the first 61 m (200 ft) travel at 76.2 cm/min (30 in/min)

c. Fifteen full-height drops at simulated reactor operating conditions with 159 kg (350 lb) of weight after traveling 1,162 m (3,812 ft)

The dynamic analysis models for the faulted condition are developed using the dynamic characteristics measured in the test of the prototype.

3.9.2.7 Dynamic System Analysis of the CEDM

The pressure-retaining components of the control element drive mechanism (CEDM) are designed to the appropriate stress criteria of ASME Section III for all loadings specified. The structural integrity of the CEDM for the seismic loadings is verified by combination of test and analysis. Methods of dynamic analysis using response spectrum analysis or time-history analysis are supported with experimentally obtained information.

3.9.2.7.1 Input Excitation Data

For the dynamic analyses, response spectra or time-history definition of the excitation at the base of the CEDM nozzle is obtained from the seismic analysis of the RCS. The excitation is applied simultaneously in three mutually perpendicular directions (two horizontal and one vertical).

3.9.2.7.2 Analysis

A dynamic analysis of the mathematical structural model is performed using one or more of the computer programs described in Subsection 3.9.1.2.

3.9.2.7.3 Functional Test

~~A functional test using a minimum drop weight was performed to verify that drop characteristics meet the input design requirements. Results from this test are compared to the calculated CEDM deflections under seismic loading for the individual site. Verification of the proper function is thus established based on both analytical and test results~~.

Scram test using a minimum drop weight was performed by applying an increamental static deflection to the CEDM. From the test, the minimum radius of curvature of 2,025 inches for the upper pressure housing was obtained as the most critical criterion to ensure scramability. Deflection of the CEDM under seismic loading calculated by structural dynamic analysis is compared with the test result to verify scramability.