Response to CEDM Audit Open Items – Section 3.9.4

Open Item 1 (AI 3-34.3)

Dead weight is listed as 350lbs in DCD Section 3.9.4.4, page 3.9-77. However in the CEDM Summary Stress Report, the ESA and 12 finger CEA sum up to only 345lbs. What accounts for the weight discrepancy?

Response

In accordance with the CEDM Operability Assurance Program, Production testing is performed prior to shipment to confirm the capability of the CEDM to meet operational requirements. In the Production test, the CEDM operated with a 350 lb dead weight pendulum to bound the design for conservatism.

The APR1400 CEDM design considered the following information:

Extension Shaft Assembly: [ ]TS lbs
12 Finger CEA: [ ]TS lbs
Sum of all: 345 lbs

The weight used to design APR 1400 CEDM reflected the actual weight of 345 lbs.

To clarify the noted weight discrepancy, the following note will be added to the summary stress report for the CEDM.

"* Dead weight for design is 345 lbs combined and dead weight for Production test is 350 lbs for conservatism."

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 Specification.

Impact on Technical/Topical/Environmental Reports

The Summary Stress report Section 7.3.2, Table 7-8, Note (8) for the CEDM will be revised as indicated in the Attachment.

7.3.2 Mechanical Loads

Table 7-8 External Loads on CEDM

Loading	Location	Axial[kips]	Shear[kips] (1)	Bending[in-kips] (1)
Periodic and Random Mechanical Base Loads(5)	Nozzle(2)			
	Motor Housing(3)			
	Upper Pressure Housing			
	Shroud			
	Shroud Bolt(4)			
NOP loads due to RVCH Expansion	Nozzle(2)			
	Motor Housing(3)			
	Upper Pressure Housing			
	Shroud			
	Shroud Bolt(4)			
Faulted Loads(6)	Nozzle(2)			
	Motor Housing(3)			
	Upper Pressure Housing			
	Shroud			
	Shroud Bolt(4)			

TS

Notes)
(1) Shear and bending are SRSS of two horizontal directions
(2) Nozzle loads are at the RVCH/nozzle interface
(3) Loads apply anywhere on the motor housing
(4) Shroud bolts for connecting shroud with coil stack assembly
(5) The base excitation due to pump overspeed transients is also considered.
(6) Faulted Loads are SRSS of the SSE and BLPB with IRWST Loads.
Faulted Loads = $[SSE^2+(BLPB+IRWST)^2]^{1/2}$
(7) Impulse Loads due to stepping the CEDM : 8000 lbs
(8) Dead Weights : TOTAL 1385 lbs
Control Element Drive Mechanism : 1040 lbs
* Extension Shaft Assembly : 133 lbs
12 Finger CEA : 212 lbs

Insert

* Dead weight for design is 345 lbs combined and dead weight for Production test is 350 lbs for conservatism.

Response to CEDM Audit Open Items – Section 3.9.4

Open Item 2 (AI 3-34.4)

On page 14 (pdf 24) of the CEDM summary stress report, Code Case N-4-12 is referred to for the material specification for the motor housing. However, in DCD Section 4.5.1, page 4.5-1, the motor housing is stated as using Code Case N-4-13, in accordance with NRC Regulatory Guide 1.84, Rev.36, which is reference no. 6 on page 4.5-14 of the DCD. Why are the code cases not consistent?

Response

In accordance with Regulatory Guide 1.84 Rev. 36, Code Case N-4-13 is correct. The Summary Stress report for the CEDM will be revised to reflect Code Case N-4-13.

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 Specification.

Impact on Technical/Topical/Environmental Reports

The Summary Stress report for the CEDM Tables 7-1 and 7-5 and Reference 11.A.1 will be revised as indicated in the Attachment.

List of Tables

7. Design Input

7.1 Geometry

The APR1400 CEDM component design drawings used for the analyses are taken from Ref.E. Figures describing the detailed geometry and dimensions of the parts evaluated are provided in the Section 10.

7.2 Material

The materials of construction of the CEDM are listed in Table 7-1.
The material properties used in the stress evaluation are provided in Tables 7-2 through 7-X, below. All the material properties are excerpted from ASME Section II (Ref.A.2).

Table 7-1 Materials of Construction

Part or Assembly	Material Specification
Housing Nut	SA-479 Type 316
Vent Stem	SA-479 Type 316
Upper Pressure Housing – Upper End Fitting	SA-479 Type 316
Upper Pressure Housing	SA-213 Type 316
Motor Housing – Upper End Fitting	SA-182 F347
Motor Housing	Code Case ~~N-4-12~~ N-4-13
Motor Housing – Lower End Fitting	SB-166 (N06690)

N-4-13

Table 7-5 Material Strength for Code Case ~~N-4-12~~

Temperature [°F]	S_m [ksi]	S_y [ksi]	S_u [ksi]
70	36.70	90.00	110.00
100	36.70	90.00	110.00
200	36.70	82.80	110.00
300	35.90	79.90	107.80
400	35.30	78.50	105.90
500	34.80	77.40	104.30
600	33.90	75.80	101.70
700	32.40	72.80	97.30

Table 7-6 Material Strength for SB-166 (N06690)

Temperature [°F]	S_m [ksi]	S_y [ksi]	S_u [ksi]
70	23.30	35.0	85.00
100	23.30	35.00	85.00
200	23.30	31.70	85.00
300	23.30	29.80	84.00
400	23.30	28.60	82.00
500	23.30	27.90	80.80
600	23.30	27.60	80.20
700	23.30	27.50	79.80

7.3 Loads, Load Combinations, and Transients

The loads, load combinations, and transients are defined the Design Specification (Ref.B.1). Following is the summary of those used for the CEDM structural evaluations.

7.3.1 Pressure Loads and Temperature

Table 7-7 Pressures and Temperatures

Parameter	Value
Design Pressure	2500 psia (2485 psig)
Design Temperature	650 °F
Normal Operating Pressure	2250 psia
Hydrostatic Test Pressure	3125 psia (3107 psig)

11. References

A. Codes / Standards / Regulations

1. ASME Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Facility Components, 2007 Edition with 2008 Addenda except the following requirements:
   The requirements re[illegible]ersing dynamic loads, NB-3200 and NB-3600 of ASME 1992 Edition with 1992 and 1993 Addenda shall be applied.
   Code Case ~~N-4-12,~~ N-4-13 Special Type 403 Modified Forging or Bars, Section III, Division I, Class 1 and CS.
2. ASME Boiler and Pressure Vessel Code, Section II, Materials, Part D – Properties (Customary), 2007 Edition with 2008 Addenda.
3. USNRC Regulatory Guide 1.100, Revision 3 (September 2009), Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants.

B. Specifications / Contract Documents

1. 11A60-ME-DS250-00, Rev.3, Design Specification for Control Element Drive Mechanism and CEA Extension Shaft Assemblies for APR1400 DC, KEPCO E&C(N), May. 2015.
2. Specification No. DA-132ES-001, Revision 1, Manufacturing Specification for Control Element Drive Mechanism and CEA Extension Shaft Assemblies for APR1400 DC.

C. Papers / Textbooks

1. USAEC Corrosion & Wear Handbook for Water Cooled Reactors, D. J. Depaul Editor, Mcgraw-Hill, 1957.
2. Machinery's Handbook, 23rd Edition, Industrial Press Inc., New York, 1988.
3. Roark's Formulas for Stress and Strain, W. C. Young and R. G. Budynas, 7th Edition, McGraw-Hill, 2002.
4. Marks' Standard Handbook for Mechanical Engineers, E. A. Avallone and T. Baumeister III, 9th Edition, McGraw-Hill, 1987.
5. Thin elastic shells, Kraus, H., John Wiley & Sons, New York, 1967.
6. Tentative structural design basis for reactor pressure vessels and directly associated components (pressurizer water-cooled systems) PB151987 ; office of technical service, U.S. Department of Commerce.
7. Stress Concentration Factors, R.E. Peterson, John Wiley & Sons, Inc., New York, 1974.
8. Frank Kreith, Principles of heat transfer, 4th Edition, International textbook company, Scranton pennsylvania, 1961.
9. J.P. Holman, Heat Transfer, 6th Edition, McGraw-Hill Book Company, 1986.

Response to CEDM Audit Open Items – Section 3.9.4

Open Item 3 (AI 3-34.5)

On Table 2-3, Summary of simplified elastic plastic: can you explain the basis of the Ke factor evaluation.

Response

The Ke factor is calculated in accordance with NB-3228.5(b).

From the Summary Stress Report Table 2-3,

Requirement of NB-3228.5		Area of Interest	Evaluation	Criteria
(2)	Application of Ke Factor	[ ]TS	Ke factor is used in the fatigue usage factor calculation.	

Parameter for Ke factor at Cut 6,

Mat. SA-182 F347
Sm = 18.3 ksi
m=1.7
n=0.3

Cut I.D.	Load Set	S_n (ksi)	$3S_m$ (ksi)	S_p (ksi)	Ke	S_a (ksi)
Cut 6	F02-C01	[ ]TS	54.90	[ ]TS	[ ]TS	[ ]TS
	G22-C01	[ ]TS	54.90	[ ]TS	[ ]TS	[ ]TS

Note)

- Load Set : (CXX : Plant Heat-up, FXX : Test – Cool down, GXX : Test – Heat-up)
- Sn : Primary plus Secondary Stress Intensity Range, Sm : Design Stress Intensity
- Sp : Total Stress Intensity Range,
- Ke : Strain distribution factor used in elastic-plastic fatigue calculation
- m, n values from Table NB-3228.5(b)-1

Ke is determined based on the Primary plus Secondary Stress Intensity Range

Ke = 1.0, for $Sn \le 3Sm$

= 1.0 + [(1-n)/n(m-1)](Sn/3Sm-1), for $3Sm < Sn < 3mSm$

= 1/n, for $Sn \ge 3mSm$

Response to CEDM Audit Open Items – Section 3.9.4

In this case,
Sn = [ ] TS ksi
3Sm = 54.90ksi
3mSm = 93.33ksi

Ke factor is determined by the following formula:

Ke = 1.0 + [(1-n)/n(m-1)](Sn/3Sm-1), for 3Sm < Sn < 3mSm
= [ ] TS
= [ ] TS
= [ ] TS

Both load sets have the same parameters for calculating the Ke factor.
The Ke factor for Load set F02-C01 and G22-C01 is the same value [ ] 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 Specification.

Impact on Technical/Topical/Environmental Reports
There is no impact on any Technical, Topical or Environmental Reports.

Response to CEDM Audit Open Items – Section 3.9.4

Open Item 5 (AI 3-34.7)

On page 22 of the TSSA Technical evaluation report – Structural damping and CEA/ESA insertion criteria for control element drive mechanisms for SHIN-KORI, Unit 3&4 (hereafter referred to as 'TSSA report'), it states that the traces in Figure B were shifted with respect to their true positions to facilitate comparison between the two curves. Please clarify the process of converting the displaced shape from Figure A to B.

Response

Figure A indicates that the peak displacement of the drop time test curve occurs closer to the motor housing than for the Shin-Kori 3&4 curve. The traces depicted in Figure B were shifted with respect to their true positions to facilitate comparison between the two curves.

The two curves were simply transferred without shape changes or relative value changes to facilitate the comparison.

To confirm the above transfer was appropriate, first the two graphs, x axis and y axis of the Figure A were scaled to coincide with the unit axis. The curves for SKN34 (Red) and the Test Curve (Blue) were extracted to compare curves in the Figure A and Figure B.

Figure 1. Scaled X axis and Y axis of the Figure A for comparison with Figure B

TS

Each extracted curve from Figure 1 is matched to Figure B as can be seen in the following figures.

Figure 2. Comparison of the SKN 34 Curve to Figure B

TS

In Figure 2, the extracted red curve of Figure 1 and the SKN 34 curve of Figure B have the same shape and values.

Figure 3. Comparison of the Test Curve to Figure B

TS

In Figure 3, the extracted blue curve of the Figure 1 and the SKN 34 curve of Figure B have the same shape and values.

Response to CEDM Audit Open Items – Section 3.9.4

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 Specification.

Impact on Technical/Topical/Environmental Reports
There is no impact on any Technical, Topical or Environmental Reports.

Response to CEDM Audit Open Items – Section 3.9.4

Open Item 6 (AI 3-34.8)

Limiting displacements are 1.0 inch at reference point 1 and .85 inch at reference point 2 on Figure 13. What is the basis for these limiting displacements?

Response

The basis of the displacements comes from a test report, Double Step CEDM Scram Time Qualification, TR-ESE-259. In Table 2, Mode 3 Deflection Drop Times, of TR-ESE-259, the maximum displacement of the Extension Shaft Assembly drop was 1.0 inch deflection at the 225 inch level.

In Figure 13 of the TSSA report (Damping & Insertion Criteria), the ratio of reference point 1 to reference point 2 is 1 : 0.85. Therefore, if the value of reference point 1 is 1inch, then the value of reference point 2 is 0.85 inches.

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 Specification.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical or Environmental Reports.

Response to CEDM Audit Open Items – Section 3.9.4

Open Item 7 (AI 3-34.9)

In Section 2.5 of the TSSA report, page 23, it lists conditions where CEA insertion may become a problem. How are conditions 1 and 2 prevented from occurring?

Response

Condition 1 - Binding between the ESA and the CEDM upper pressure housing can occur if the arc length or its associate cord length, over which bending occurs, are sufficiently small such that either the ESA or portions thereof cannot freely conform to the displaced shape or that the forces needed to do so are large enough that free fall is prevented.

Condition 2 - The inclination of the ESA at the point where it enters the small diameter guide tube of the CEDM motor is important. If the entry angle is too large with respect to vertical, the ESA may bind up at this location.

These conditions are considered with respect to identification of independent criteria for evaluating CEA/ESA insertion during postulated SSE or design bases events that include SSE excitation.

In the TSSA report, page 24, the “D” Criterion deals with Condition 1 and states:

D. The arc length or the associated cord length over which curvature in the CEDM upper pressure housing occurs should not be smaller than the corresponding lengths identified by the CEA/ESA drop time curve identified in Figures A, B, or 13 of this report.

In the TSSA report, page 24, the “E” Criterion deals with Condition 2 and states:

E. The lower tube end of the CEDM upper pressure housing should remain as straight as possible with respect to the motor housing to ensure proper entry of the ESA into the small diameter guide tube portion of the CEDM motor. The entry angle should not deviate by more than the corresponding value obtained from the CEA/ESA drop time curve identified in Figures A, B, or 13 of this report.

The above criteria is included in the Summary Stress report of the CEDM. The CEDMs for the APR1400 plant meet the requirement for insertion stated in the TSSA report and, therefore, Conditions 1 and 2 will not occur in the CEDMs for the APR1400 Plant.

Impact on DCD
There is no impact on the DCD.

Impact on PRA
There is no impact on the PRA.

Response to CEDM Audit Open Items – Section 3.9.4

Impact on Technical Specifications

There is no impact on the Technical Specification.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical or Environmental Reports.