ENCLOSURE 2

MFN 08-688

ESBWR Marathon and Marathon-5S Control Rod Finite Element Analysis Summary

Non-Proprietary Information

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1 to MFN 08-688 from which the proprietary information has been redacted. Portions of the document that have been removed are indicated by white space with open and closed double square bracket as shown here [[ ]].

ESBWR Marathon and Marathon-5S Control Rod Finite Element Analysis Summary

Analysis Description	ESBWR Marathon NEDE-33244P Rev. 1	Marathon-5S (BWR/2-6) NEDE-33284P Rev. 1	Geometry Inputs	Applied Loads	Material Properties	Acceptance Criteria
	LTR Section	LTR Section				
Thermal Analysis: Determines the temperature of boron carbide during operation. Uses heat generation due to neutron capture.	3.6.3	3.6.3	Absorber tube and capsule geometries. Worst-case geometries (largest helium gap) used. Internal tube assumed by assuming no heat flux to adjacent tubes. Conservative crud build-up used.	Peak boron carbide heat generation rates from nuclear analyses.	Thermal conductivities from various sources.	Thermal Stress less than allowable.
Lifting Load: Determines stresses in the handle while lifting the control rod.	3.7	3.7	Worst-case geometry from handle drawings.	ESBWR: 3x control rod weight M-5S: 2x control rod weight	Unirradiated linear-elastic material properties.	Maximum stress intensity or equivalent stress is compared to material allowable stress.
External Pressure + Channel Bow Lateral Load: Determines stresses in the absorber tube due to lateral loads imposed by bowed fuel channels combined with RPV operating pressure.	3.4.3	3.4.3	ESBWR: ¼ affected tube plus ½ adjacent tube. Nominal dimensions. (Note 1) M-5S: ¼ affected tube. Worst-case dimensions.	Lateral loads from fuel channel bow studies.	ESBWR: Unirradiated elastic-plastic true stress-strain curves. Also checked using irradiated material properties. M-5S: Unirradiated linear-elastic material properties. Also checked using unirradiated elastic-plastic true stress-strain curves.	Maximum stress intensity compared to material allowable stress.
Internal Pressure: Determines maximum allowable absorber tube internal pressure.	3.6.4	3.6.4	ESBWR: Nominal tube dimensions. Worst-case dimensions are bounded by a [[ ]] scaling factor based on burst pressure test results. Also checked the first tube attached to the tie rod. M-5S: Uses worst-case tube dimensions and allowable surface defects. No scaling factor since burst pressure results exceed worst-case FEA results used. Also checked first tube attached to the tie rod (tie rod modeled as an empty tube).	Reactor pressure vessel internal pressure to exterior of tubes for 'hot' cases. Unirradiated property analyses determine maximum allowable internal pressure. 'Check' analyses apply this pressure as appropriate.	Unirradiated elastic-plastic true stress-strain curves. Also checked using irradiated material properties.	Burst pressure defined to be internal pressure at which the stress intensity at any location in the tube first reaches the true ultimate strength. Then, a factor of safety of 2.0 is used to determine an allowable pressure.
Pressurization Stress on Absorber Tubes: Finite element analysis is used to determine the radial, hoop, and axial stress in the absorber tube at allowable internal pressure.	3.6.4	3.6.4	ESBWR: Nominal tube dimensions. (Note 1) M-5S: Worst-case tube dimensions.	Maximum allowable pressure determined in internal pressure analysis.	Unirradiated elastic-plastic true stress-strain curves.	Combined stresses less than material allowable stresses.
Combined Internal Pressure + Fuel Channel Bow Induced Bending: Determines maximum stresses in the absorber tube to tie rod weld.	3.4.2	3.4.2	Worst-case absorber tube dimensions. ESBWR: Model consists of tie rod and first tube. M-5S: Model consists of tie rod and entire wing of absorber tubes.	Lateral loads from channel bow studies and seismic event limits.	Unirradiated elastic-plastic true stress-strain curves. ESBWR: Also checked using irradiated material properties.	Maximum stress intensity less than material allowable stress.

Note 1: Analysis using worst-case dimensions is in progress