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Evaluation of fast neutron fluence for Kori Unit 2 pressure vessel

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1. Introduction

Unit 2 at kori reactor has been put into operation in 1983. During 24 cycle operation, five surveillance capsules at inner vessel and three ex-vessel dosimeter at cavity both are taken out for evaluation to neutron fluence. The evaluations following the surveillance program of kori 2 unit which are required detect and prevent degradation of safety-related structures and components of the vessel. The fast (E > 1.0 MeV) neutron fluencies are necessary to estimate the fracture toughness of the pressure vessel materials [1]. The determination of the pressure vessel neutron fluence is based on both calculations and measurements. The fluence prediction is made with a calculation, and the measurements are used to qualify the calculational methodology. Measurement-to-calculation comparisons are used to identify biases in the calculations and to provide reliable estimates of the fluence uncertainties

As shown in Fig. 1, the kori unit 2 reactor vessel surveillance programs includes the analysis of flux dosimeters contained in capsules located on the inner vessel wall at the Beltline region (0◦, 15◦, 30◦ and 40◦ Azimuth) and Ex vessel dosimeter capsules located on the cavity at connected bid chain [2].

In this paper, the methodologies used to perform neutron transport calculations and dosimetry evaluations are described, the results of the plant specific transport calculations are given for the beltline region of Kori Unit 2 pressure vessel and the comparisons of calculations and measurements are discussed.

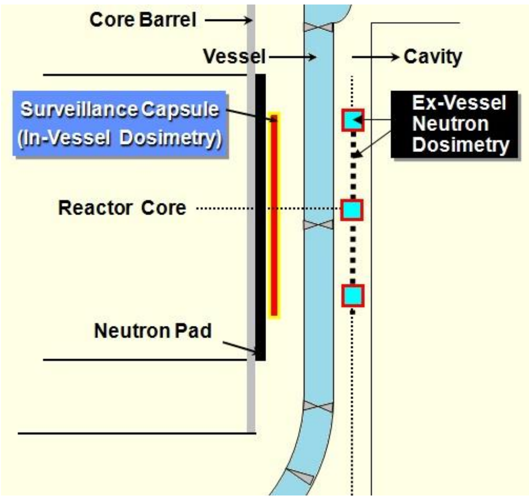

Figure 1. Axial view of inner vessel capsule and Ex vessel dosimetry location.

2. Calcuation methodology

In performing the fast neutron fluence evaluations, plant specific forward transport calculations were carried out using the 3D flux synthesis method. The neutron source for each steady state is represented by the assembly pin-wise power distribution, preliminarily calculated by SORCERY code. This code calculates a fixed distributed source in DORT geometries by area weighting from a regular pin-by-pin power distribution array. DORT was used as computational tool since computations for 3D reactor models require much more computational process time. Also, since DORT is based on the discrete ordinate method, problems involving neutron deep penetration and high anisotropy, as those related to pressure vessel fluence calculation, can be solved with good accuracy at reasonably computational effort.

The 3D solutions for the neutron flux and activities are derived by the synthesis method (Brodkin, 1996), based on the 2D and 1D DORT solution of the neutron transport equation: radial-azimuthal $\Phi_g(r, \theta)$, radial-axial $\Phi_g(r, z)$ and radial $\Phi_g(r)$, using the expression.

$$\Phi_g(r, \theta, z) = \Phi_g(r, \theta)* \Phi_g(r, z)/ \Phi_g(r) \qquad (1)$$

The BUGLE-96 cross-section library is used calculations [3]. This library provides a 67 group coupled neutron gamma ray cross-section data set produced specifically for PWR application. In these analyses, anisotropic scattering was treated with a P5 legendre expansion and the angular discretization was modeled with an S16 order of angular quadrature.

3. Measurements

The neutron fluence is obtained from the response of passive integral detectors placed in surveillance capsules and the ex-vessel cavity. Dosimetry measurements provide independent estimates of specific activities and isotopic production rates that are used for validating the neutron transport calculations.

Measurements of gamma emission rates from dosimeters that have been exposed to the neutron irradiation on a reactor vessel are used to estimate the absolute neutron fluence, since the dosimeter's activity is related to the total neutron exposure. Experimental values of the neutron flux can be determined from measurements of gamma emission rates from different types of dosimeters extracted from the reactor vessel [4].

The measurements activity of the dosimeter using by HPGe(high purity germanium) semiconductor detector. The nuclides of these spices are ^{63}Cu, ^{46}Ti, ^{54}Fe, ^{58}Ni, ^{238}U, ^{237}Np, ^{59}Co, ^{93}Nb.

4. Comparision of Conclusions and Measurements

The calculated and the best estimated neutron flux are shown in Table 1. A comparison is presented of calculated and best estimated fast fluxes and uncertainties determined by measurements from the dosimeter's gamma emission rates of the kori 2 Unit. The results are all well within the 20% required by regulation [4], when used for analysis of embrittlement of vessel materials by radiation.

TABLE 1– Comparison of Calculated and Best Estimate Flux at the Dosimetry capsule Center

Capsule ID	*Irradiation Time (EFPY)*	*Flux (E >1.0 MeV) (n/cm^2-s)*		*Uncertainty (1σ)*
		Calculated	*Best Estimate*	
V	0.77	1.412e11	1.258e11	8 %
R	3.26	1.222e11	1.066e11	8 %
P	7.28	1.049e11	9.870e10	8 %
T	11.3	1.034e11	1.039e11	6 %
N	14.09	9.962e10	1.024e11	6 %
EX 1	1.07	3.159e9	2.771e9	5 %
EX 2	1.02	3.143e9	2.835e9	6 %
EX 3	1.03	3.182e9	2.942e9	6 %

Also, a comparison for calculated and best estimate exposure rate expressed in terms of neutron (E > 1.0 MeV) flux and iron atom displacement rate (dpa/s) are summarized in Table 2. This value is kori 2 unit average of the total cycle [4].

TABLE 2– Fast Neutron Exposure Least-Squares Best Estimates-to-Calculated Ratios for In-Vessel, Midplane Ex-Vessel and Combine Data Base

Exposure Parameter	*In-Vessel*	*Midplane Ex-Vessel*	*Combined*	
	Average BE/C	*Average BE/C*	*Average BE/C*	*Unc. (1σ)*
Flux (E >1.0MeV)	0.95	0.88	0.91	5.5
dpa/s	0.97	0.89	0.93	5.9

5. Conclusions

The neutron fluence of the kori 2 unit vessel is carried out. Comparison of calculated and measured flux values have indicated that the calculated values for the fast neutron fluence are estimated within the 20%. The results show the typical tendency of fluence profiles on kori unit 2 pressure vessels. The difference between the calculation and measurement is due to the uncertainties from the reactor dimension, coolant temperature, power distribution, as well as from other parameters. The ratios (measurement/calculation) are results shows that the calculated values are in good agreement compared to the measurements for various neutron energy ranges. These results can be used in the assessment of the state of embrittlement of Kori Unit 2 pressure vessel.

REFERENCES

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