UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

EVALUATION OF THE FLUX REDUCTION USING LOW-LEAKAGE FUEL MANAGEMENT SCHEMES IN ORDER TO COMPLY WITH THE NRC PRESSURIZED THERMAL SHOCK REQUIREMENTS

OCONEE NUCLEAR STATION, UNIT 2

DUKE POWER COMPANY

DOCKET NO. 50-270

INTRODUCTION

As part of the effort to reduce the neutron induced radiation embrittlement of the Oconee-2 pressure vessel, the Duke Power Co. is implementing a low leakage fuel management scheme. Oconee-2 is now in its 8th cycle and has a low leakage reactor core. Based on information supplied by Duke Power Co. the staff performed audit calculations to estimate the fluence accumulation at the peripheral vessel welds and the expected time to reach the NRC PTS screening criteria. In this calculation the geometrical configuration of the Rancho Seco plant has been used and is shown in Figure 1. Oconee-2 and Rancho Seco have almost identical geometries, with the radial dimensions and the material layout being the same. A calculation of the neutron transport from the core out to the pressure vessel was carried out at BNL using the DOT-3.5 two dimensional discrete ordinates transport code (Ref.1). Using core symmetry, a 1/8 core geometry was analyzed in the azimuthal direction and with a two step (bootstrap) calculational process in the radial direction. The calculations were performed in a fixed source mode with an $S_8 - P_3$ approximation using an ENDF/B-IV derived cross section library (Ref.2). The DOT spatial representation included 120 radial mesh intervals and 44 azimuthal sectors which are shown in Tables 1 and 2 respectively. The angular mesh was chosen so as to accentuate the region of peak flux. The accumulated source distribution for cycles 1 to 7 is shown in Figure 2 (Ref. 3). The assembly average source for reference low leakage (RLL), low leakage (LL) and extreme low leakage (ELL) fuel management schemes are shown in Figures 3 to 5.*

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* The RLL, LL and ELL loadings were specified in the Rancho Seco submittal and applied to Oconee-2.

More than 98% of the vessel flux originates in the 10 outer assemblies shown in Figure 2. These assembly-wise distributions were mapped onto the r-Θ geometry for input to DOT-3.5 using the MESH program (Ref. 4).

Evaluation

Calculations were performed to estimate the end of life (EOL) peak weld fluence for 32 effective full power years (EFPY) based on the average of cycles 1 to 7, a RLL, a LL and an ELL loading. The fluence estimation was performed by using the expressions of Figure 6. The results are shown in Table 3. Given that the required fluence for Oconee-2 to operate for 32 EFPYs is 9.9 x 10^{18} n/cm^2 (Ref. 5), the results presented in Table 3 show that Oconee-2 will be able to operate for nearly 32 EFPYs. The absolute value of the azimuthal fluence distribution is shown in Figure 7. Oconee-2 has been on low leakage loadings since 1980 (Ref. 6). However, because there are only about 20 EFPYs to the end of the present operating license in 2007 it is obvious that Oconee-2 can operate well beyond this point without exceeding the screening criteria.

Conclusion

The staff has reviewed the information submitted by the Duke Power Co. regarding the neutron source for cycles 1 through -7 in the Oconee-2 power plant. An audit calculation performed at BNL indicates that, under the present low leakage loading scheme, Oconee-2 can operate beyond the year 2007, i.e., when its current license expires. Indeed it seems that Oconee-2 can operate for nearly 32 effective power years before reaching the PTS screening criteria.

Dated: June 4, 1985

Principal Contributor: L. Lois.

REFERENCES

1. CCC-276, "DOT-3.5, Two Dimensional Discrete Ordinates Transport Code", ORNL (RSIC) 1975, including modifications and corrections as described in the RSIC newsletter dated August 1983.

2. W. E. Ford, II, et. al., "Modification Number One to the 100 N-218 γ Cross Section Library" ORNL-TM-5249 March 1976. (Available as DLC-370 EPR RSIC, ORNL).

3. "Oconee Nuclear Power Station Docket Nos. 50-269, 270, 287," Letter to H. R. Denton (NRC) from H. B. Tucker (Duke Power Co.), February 3, 1983.

4. "MESH - A Code for Determining the DOT Fixed Neutron Source," BNL Memo to J. F. Carew from M. Zentner, August 1981.

5. W. Dircks to Commissioners, SECY-82-465, November 23, 1982.

6. W. Dircks to Commissioners, SECY-83-443, October 28, 1983.

TABLE 1

Radial Mesh for DOT Calculations

Material	Outer Radius (cm)	Number of Radial Mesh Intervals
Core	141.77	48
Core/Shroud/Water	174.16	3
Water	179.07	8
Barrel	184.15	4
Water	186.69	8
Thermal-Shield	191.77	31
Water	216.69	1
Vessel Clad	217.17	13
Vessel	238.60	3
Air	246.22	1

Table 2

Angular Mesh for DOT Calculations

Angular Sector	(Degrees	Angular Sector	(Degrees)
1	.9560	23	22.0450
2	1.9090	24	22.5140
3	2.8620	25	22.7460
4	4.0000	26	23.4510
5	4.7630	27	23.9200
6	5.7110	28	24.3690
7	6.6530	29	25.4770
8	7.5950	30	26.5650
9	8.5200	31	27.4330
10	9.4620	32	28.3010
11	10.3660	33	29.1420
12	11.3100	34	29.9520
13	12.2220	35	30.7950
14	13.1340	36	31.6070
15	14.0330	37	33.1510
16	14.9310	38	34.6950
17	15.6150	39	36.9920
18	16.6990	40	39.2590
19	17.5670	41	40.7826
20	18.4350	42	42.2740
21	20.2000	43	43.6370
22	21.5760	44	45.0000

TABLE 3

Present and Projected EOL Peak Wall (> 1-MeV) Vessel Fluences (n/cm^2 x 10^{18})

	OCONEE-2	
	fluence	decrease(%)
Present	10.7	-
Low-leakage	10.5	2.1
Reference Low-leakage	10.2	5.3
Extreme Low-leakage	7.9	26.1

Figure 1 - Rancho Seco Geometry

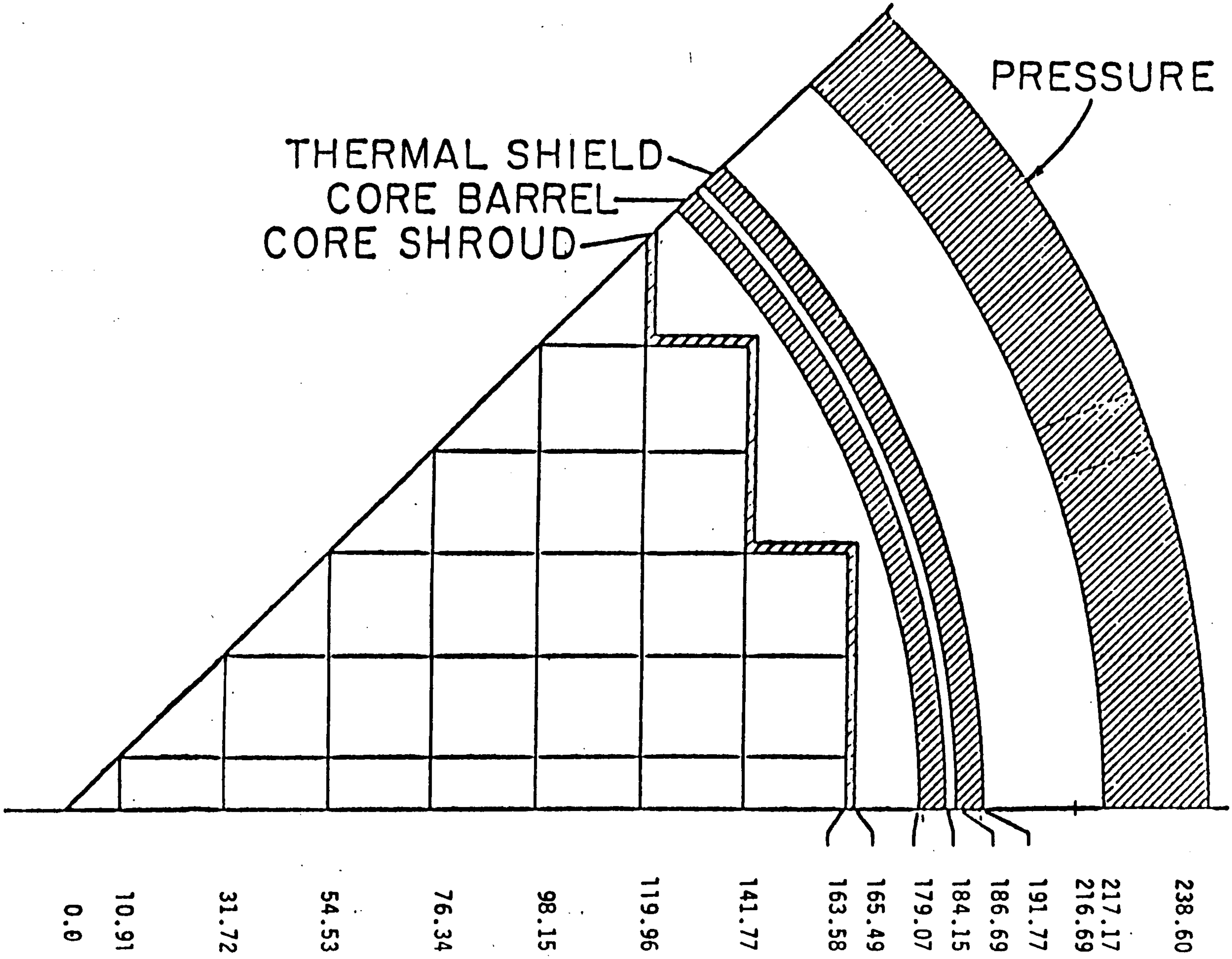


Figure 2

Oconee-2 Assembly Average Source for Cycles 1 to 7

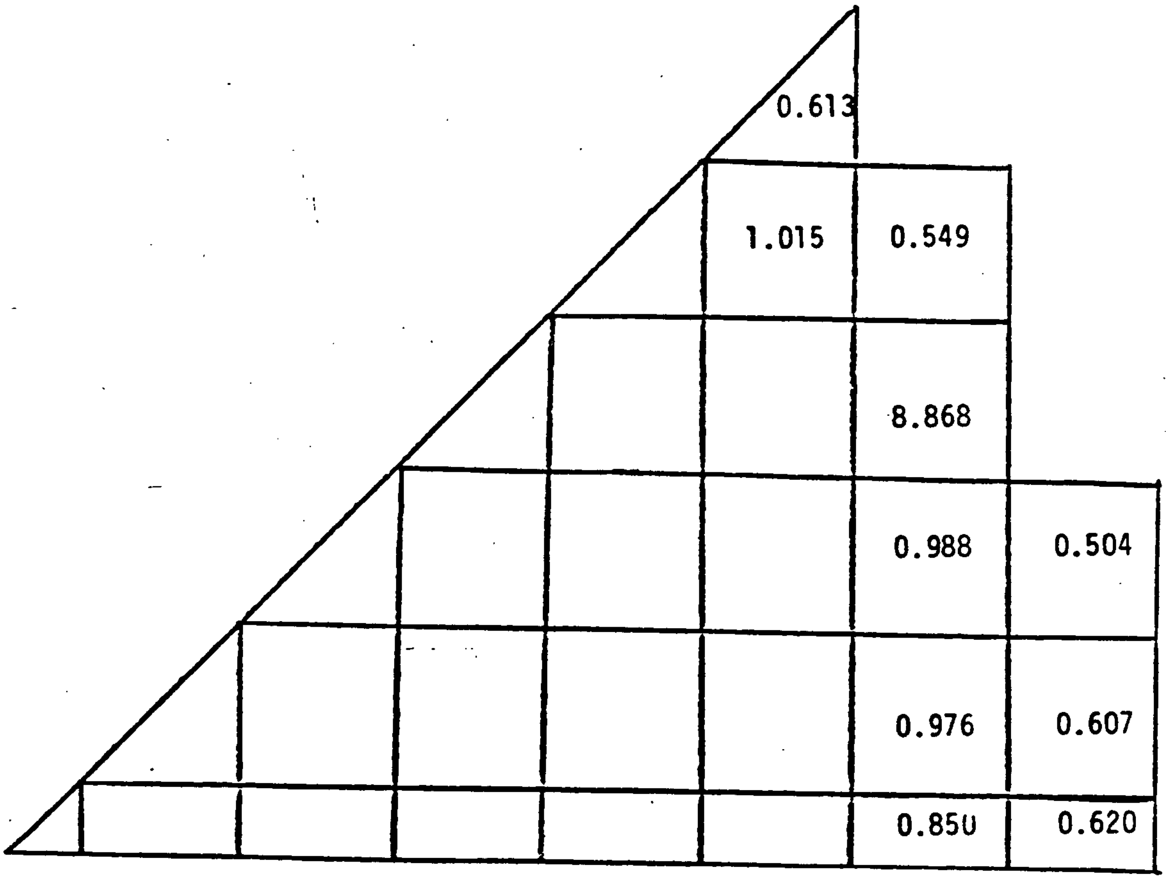


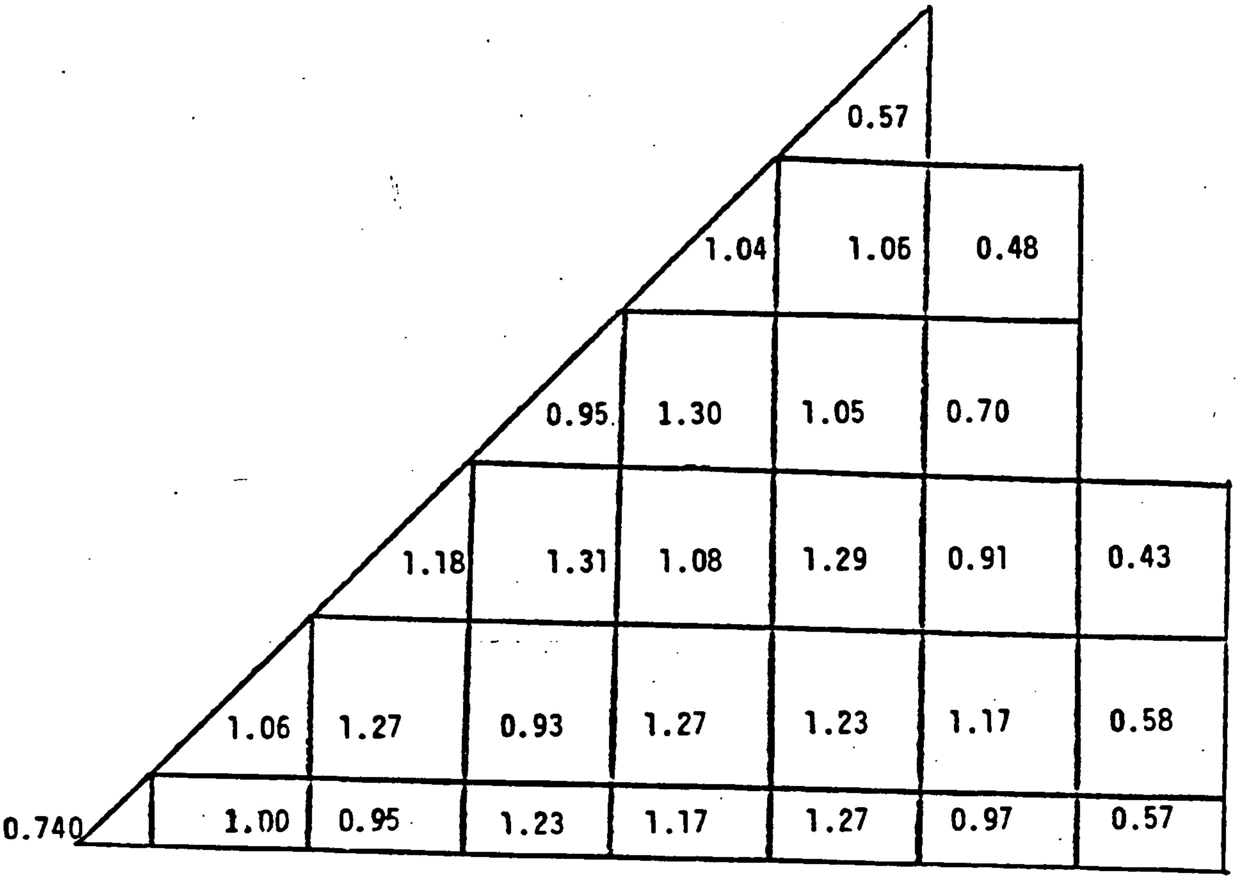
Figure 3

Assembly Average Source for Reference Low-Leakage Pattern

					0.499		
				0.987	0.930	0.412	
			1.134	1.262	0.998	0.634	
		1.152	1.353	1.029	1.244	0.907	0.411
	1.027	1.346	1.152	1.354	1.130	1.117	0.556
0.839	1.038	1.085	1.386	1.160	1.353	1.009	0.548

Figure 4

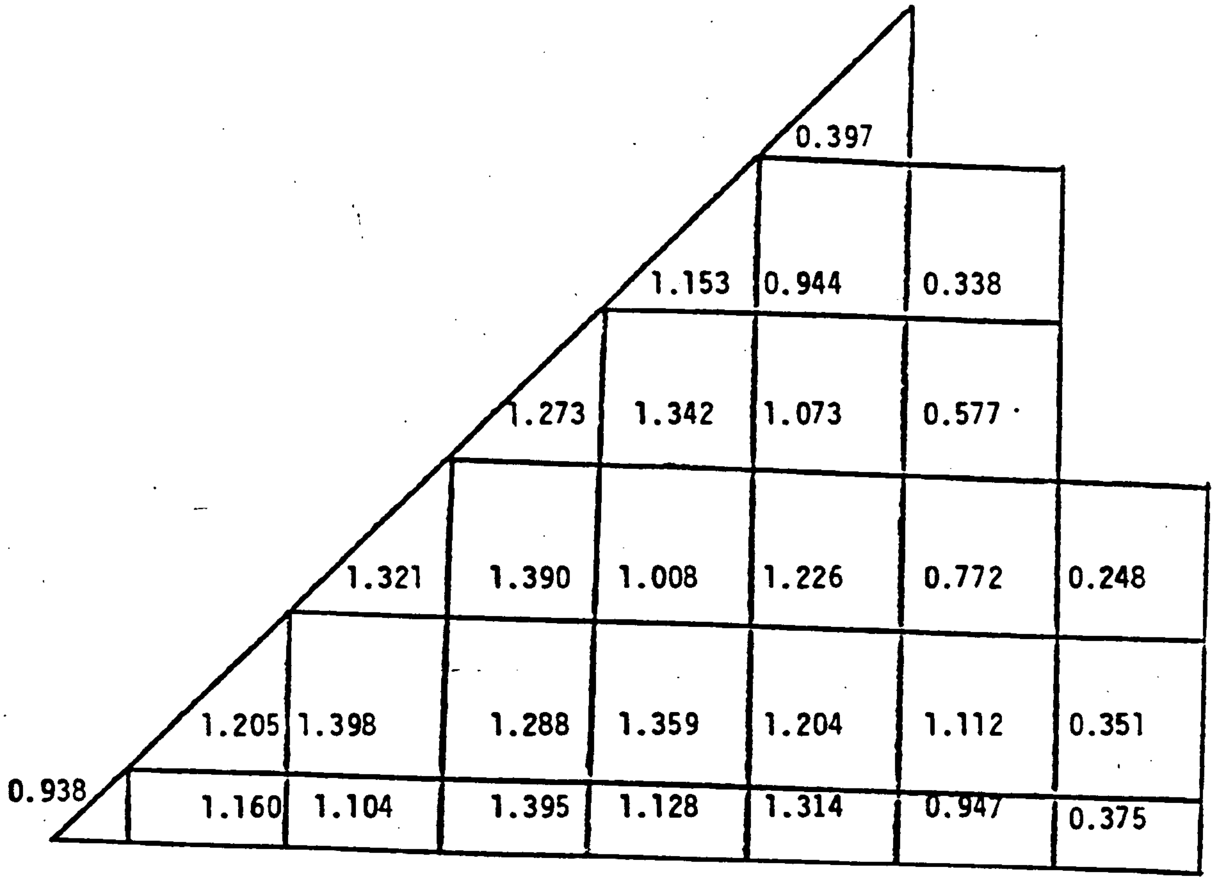
Assembly Average Source for Low-Leakage (In-Out-In) Pattern



					0.57		
				1.04	1.06	0.48	
			0.95	1.30	1.05	0.70	
		1.18	1.31	1.08	1.29	0.91	0.43
	1.06	1.27	0.93	1.27	1.23	1.17	0.58
0.740	1.00	0.95	1.23	1.17	1.27	0.97	0.57

Figure 5

Assembly Average Source for Extreme Low-Leakage Pattern



					0.397		
				1.153	0.944	0.338	
			1.273	1.342	1.073	0.577	
		1.321	1.390	1.008	1.226	0.772	0.248
	1.205	1.398	1.288	1.359	1.204	1.112	0.351
0.938	1.160	1.104	1.395	1.128	1.314	0.947	0.375

Figure 6

Fluence Estimation Formulae

$$F_{P}^{EOL} = [(\phi_P)\ (EFPY_P) + \phi_P\ (32-EFPY_P)\ (C_P^E)]\ (C^{Ax})\ (C^{Pin})$$

$$F_{LL}^{EOL} = [(\phi_P)\ (EFPY_P) + \phi_{LL}\ (32-EFPY_P)\ (C_{LL}^E)]\ (C^P)\ (C^{Ax})\ (C^{Pin})$$

$$F_{RL}^{EOL} = [(\phi_P)\ (EFPY_P) + \phi_{RL}\ (32-EFPY_P)\ (C_{RL}^E)]\ (C^P)\ (C^{Ax})(C^{Pin})$$

$$F_{ELL}^{EOL} = [(\phi_P)(EFPY_P) + \phi_{ELL}(32-EFPY_P)\ (C_{LL}^E)]\ (C^P)\ (C^{Ax})(C^{Pin})$$

F_X^{EOL} = EOL Vessel wall fluence

X = P - Present (average cycle) power distribution
LL - Low-leakage power distribution
RL - Reference low-leakage power distribution
ELL- Extreme low-leakage power distribution

ϕ_P = Peak (>1 MeV) wall flux for present power distribution

$\phi_{LL,RL,ELL}$ = Peak (>1 MeV) wall flux for the low-leakage (LL), reference low-leakage (RL) and extreme low-leakage (ELL) power distributions.

$EFPY_P$ = Present accumulated effective full power years

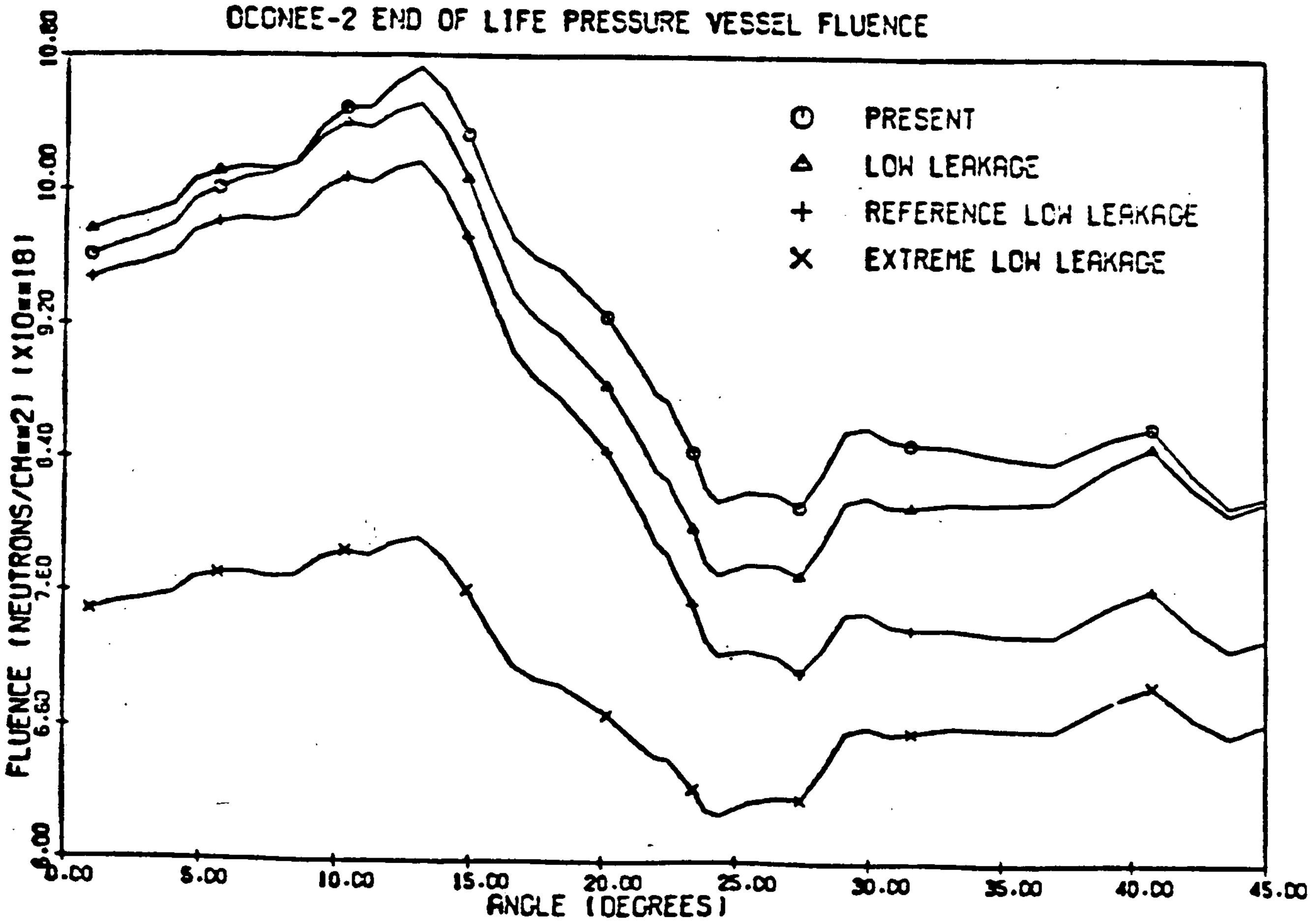
$C^E_{P,\ LL,RL,ELL}$ = power distribution dependent exposure correction factor

C^P = A scaling factor to account for differences in the power ratings of the individual plants

C^{Ax} = Axial peaking factor for peak wall location

C^{Pin} = Pin factor to account for the effects of peripheral source gradients

Figure 7


OCONEE-2 END OF LIFE PRESSURE VESSEL FLUENCE
○ PRESENT
△ LOW LEAKAGE
+ REFERENCE LOW LEAKAGE
× EXTREME LOW LEAKAGE
FLUENCE (NEUTRONS/CM**2) (X10**18)
6.00
6.80
7.60
8.40
9.20
10.00
10.80
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
ANGLE (DEGREES)