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ROBER,R.W. Rochester Gas & Electric Corp.
RECIP.NAME RECIPIENT AFFILIATION
PAULSON,W.A. Operating Reactors Branch 5.

SUBJECT: Discusses encl results of analysis or Reactor Vessel Surveillance Capsule T,supporting 821208 application for amend to License DPR-18.Fluence data & analysis presented in WCAP-10086 verified.

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ROGER W. KOBER
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August 8, 1984

Director of Nuclear Reactor Regulation
Attention: Mr. Walter A. Paulson, Acting Chief
Operating Reactors Branch No. 5
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Reactor Vessel Surveillance Capsule T
R. E. Ginna Nuclear Power Plant
Docket No. 50-244

Dear Mr. Paulson:

On December 8, 1982 an Application for Amendment to Operating License was submitted to the NRC incorporating the results of the analysis of reactor vessel surveillance capsule T. This analysis was performed by Westinghouse and published as WCAP-10086.

The results of the neutron transport calculations presented in WCAP-10086 were obtained using a statistically based generic 2-loop core power distribution and cross-sections employing a P_1 expansion of the scattering matrix. In spite of the good agreement between measurements and calculations at the surveillance capsule locations, both of these assumptions were questioned by the NRC staff in their review of WCAP-10086. In particular, the consideration of plant specific core power distributions and the use of a P_3 expansion of the neutron scattering cross-sections were requested.

In order to address these two issues, neutron transport calculations in R,θ geometry were carried out using the DOT[1] discrete ordinates code[1] and the SAILOR cross-section library[2]. The SAILOR library is a 47 group, ENDF-BIV based data set produced specifically for light water reactor applications. Anisotropic neutron scattering is treated with a P_3 expansion of the cross-sections.

Two sets of transport calculations were carried out to provide the appropriate data to address the issues at hand. The first, a single computation in the forward mode, utilized the P_3 cross-sections in conjunction with the generic 2-loop power distribution to provide a direct P_3/P_1 comparison. The second set of calculations consisted of a series of seven adjoint analyses relating power distributions within the core to the fast neutron flux at four locations on the pressure vessel as well as at the

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center of each surveillance capsule. These adjoint importance functions were then used along with actual core burnup information to generate plant specific fluence levels on a cycle by cycle basis for the R. E. Ginna reactor. A P_3 scattering cross-section expansion was used for all of the adjoint analyses.

The transport methodology, both forward and adjoint, using the SAILOR cross-section library has been benchmarked against the ORNL PCA facility[3] as well as against the Westinghouse power reactor surveillance capsule data base. The results of these benchmarking studies will be available in a report to be issued by Westinghouse by the end of 1984. However, as indicated in our letter of October 10, 1983, the benchmarking studies indicate that the use of SAILOR cross-sections and generic design basis power distributions produces flux levels that tend to be conservative by about 7-22%. This conservatism is to be expected since the generic power distributions include a 2σ statistical uncertainty based on plant-to-plant and cycle-to-cycle variations in peripheral power. It is unlikely that a single reactor would have a power distribution at the nominal $+2\sigma$ level for a large number of fuel cycles.

When plant specific power distributions are used with the adjoint importance functions, the benchmarking studies show that fluence predictions are within $\pm$15% of measured values at surveillance capsule locations. Further, these predictions also tend to be in good agreement with the P_1 calculations based on the generic power distribution. That is, the 2σ uncertainty added to the peripheral power tends to offset deficiencies in the P_1 analysis relative to the P_3 approach.

Results of Analysis

Results of the plant specific fluence evaluations for the R. E. Ginna reactor are summarized in Tables 1 through 7. Data are presented for the 0°, 14.5°, 30°, and 44.5° azimuthal locations at the pressure vessel inner radius in Tables 1 through 4, respectively. Corresponding data applicable to the center of surveillance capsules positioned at 13°, 23°, and 33° are given in Tables 5 through 7. In all cases, plant specific fast neutron flux and fluence levels for each operating cycle are listed along with predictions using a constant flux level based on P_3 and P_1 cross-sections and the generic design basis core power distributions.

In regard to the data contained in Tables 1 through 7, the plant specific core power distributions used for cycles 1A through 13 were derived from actual burnup data. The cycle 14 power distribution was taken from the nuclear design data given in WCAP-10505. As with the power distribution data, the full power irradiation times for cycles 1A through 13 were obtained from the cycle specific burnup data. The irradiation time for cycle 14 was computed from the design burnup of 8800 MWD/MTU specified in WCAP-10505. Cycle 14 began in Spring 1984.

Where appropriate, measured fluence values from surveillance capsules V, R, and T have been compared with calculated values. These analytical/experimental comparisons are shown in Tables 5 and 6. It should be noted that the measured values represent the average fluence derived from all neutron sensors contained in each surveillance capsule. Further, in keeping with the NRC request, the fluence levels are based on spectrum average cross-sections obtained from the SAILOR P_3 analysis. Therefore, measured fluence values listed in Tables 5 and 6 differ slightly (from 1% to 8%) from the corresponding values given in Table 6-12 of WCAP-10086. These variations in the experimental values are well within the uncertainty in the measurements themselves.

The following conclusions can be drawn from an examination of Tables 1 through 7.

1. Over the long term the plant specific SAILOR P_3 analysis is in excellent agreement with the GAMBIT P_1 analysis. At the projected end of cycle 14 the P_3/P_1 fluence ratios are as follows:

	SAILOR P_3/GAMBIT P_1
0° vessel	0.98
14.5° vessel	1.01
30° vessel	1.04
44.5° vessel	1.14
13° capsule	0.92
23° capsule	0.95
33° capsule	0.92

2. For surveillance capsules, V, R, and T the fluence predictions based on plant specific SAILOR P_3 analysis are in excellent agreement with dosimetry data. Analytical/experimental comparisons are as follows:

	SAILOR P_3/MEASUREMENT
Capsule V	0.99
Capsule R	0.95
Capsule T	0.92

3. Analysis using SAILOR P_3 cross-sections and the generic design basis core power distribution produces conservative results relative to the other two analytical approaches as well as to the surveillance capsule measurements.

Based on these conclusions, the fluence data and analysis presented by WCAP-10086 is verified and supports our application of December 8, 1982.

Very truly yours,

Roger W. Kober

Roger W. Kober

References:

1. Soltesz, R. G., R. K. Disney, J. Jedruch, and S. L. Zeigler, "Nuclear Rocket Shielding Methods, Modification, Updating and Input Data Preparation - Volume 5 - Two-Dimensional Discrete Ordinates Transport Technique", WANL-PR-(LL)-034, Vol. 5, August 1970.

2. SAILOR RSIC DATA LIBRARY COLLECTION DLC-76, "Coupled, Self-shielded, 47 Neutron, 20 Gamma-ray, P3, Cross-section Library for Light Water Reactors".

3. McElroy, W. N., "LWR Pressure Vessel Surveillance Dosimetry Improvement Program: PCA Experiments and Blind Test", NUREG/CR-1861, June 1981.

4. Letter J. E. Maier to D. M. Crutchfield, October 10, 1983.

Table 1

FAST NEUTRON (E > 1.0 MeV) EXPOSURE AT THE PRESSURE VESSEL INNER RADIUS - 0° AZIMUTHAL ANGLE

Cycle No.	Irradiation Time (EFPS)	Cycle Avg. Flux (n/cm^2-sec)	CUMULATIVE FLUENCE (n/cm^2)		
			Plant Specific P_3	Generic[1] P_1	Generic[2] P_3
1A	2.09×10^7	3.88×10^{10}	8.10×10^{17}	8.26×10^{17}	1.01×10^{18}
1B	2.38×10^7	4.16×10^{10}	1.80×10^{18}	1.77×10^{18}	2.15×10^{18}
2	0.71×10^7	4.22×10^{10}	2.10×10^{18}	2.05×10^{18}	2.50×10^{18}
3	2.88×10^7	3.62×10^{10}	3.14×10^{18}	3.18×10^{18}	3.88×10^{18}
4	2.17×10^7	3.60×10^{10}	3.93×10^{18}	4.04×10^{18}	4.93×10^{18}
5	1.84×10^7	4.63×10^{10}	4.78×10^{18}	4.77×10^{18}	5.82×10^{18}
6	2.42×10^7	3.93×10^{10}	5.73×10^{18}	5.72×10^{18}	6.98×10^{18}
7	2.35×10^7	3.74×10^{10}	6.61×10^{18}	6.65×10^{18}	8.12×10^{18}
8	2.20×10^7	4.40×10^{10}	7.58×10^{18}	7.52×10^{18}	9.18×10^{18}
9	2.62×10^7	4.13×10^{10}	8.66×10^{18}	8.55×10^{18}	1.04×10^{19}
10	2.51×10^7	3.97×10^{10}	9.65×10^{18}	9.55×10^{18}	1.16×10^{19}
11	1.83×10^7	3.86×10^{10}	1.04×10^{19}	1.03×10^{19}	1.25×10^{19}
12	2.30×10^7	4.53×10^{10}	1.14×10^{19}	1.12×10^{19}	1.37×10^{19}
13	2.32×10^7	3.11×10^{10}	1.21×10^{19}	1.21×10^{19}	1.48×10^{19}
14	2.27×10^7	3.05×10^{10}	1.28×10^{19}	1.30×10^{19}	1.59×10^{19}

Notes: 1 - $\phi_{avg} = 3.95 \times 10^{10}$ n/cm^2-sec.
2 - $\phi_{avg} = 4.82 \times 10^{10}$ n/cm^2-sec.

Table 2

FAST NEUTRON (E > 1.0 MeV) EXPOSURE AT THE PRESSURE VESSEL INNER RADIUS - 14.5° AZIMUTHAL ANGLE

Cycle No.	Irradiation Time (EFPS)	Cycle Avg. Flux (n/cm^2-sec)	CUMULATIVE FLUENCE (n/cm^2)		
			Plant Specific P_3	Generic[1] P_1	Generic[2] P_3
1A	2.09×10^7	2.34×10^{10}	4.89×10^{17}	4.97×10^{17}	6.11×10^{17}
1B	2.38×10^7	2.48×10^{10}	1.08×10^{18}	1.06×10^{18}	1.31×10^{18}
2	0.71×10^7	2.57×10^{10}	1.26×10^{18}	1.23×10^{18}	1.52×10^{18}
3	2.88×10^7	2.22×10^{10}	1.90×10^{18}	1.92×10^{18}	2.37×10^{18}
4	2.17×10^7	2.38×10^{10}	2.42×10^{18}	2.44×10^{18}	3.01×10^{18}
5	1.84×10^7	2.81×10^{10}	2.94×10^{18}	2.87×10^{18}	3.55×10^{18}
6	2.42×10^7	2.47×10^{10}	3.53×10^{18}	3.45×10^{18}	4.27×10^{18}
7	2.35×10^7	2.48×10^{10}	4.12×10^{18}	4.01×10^{18}	4.96×10^{18}
8	2.20×10^7	2.67×10^{10}	4.70×10^{18}	4.53×10^{18}	5.61×10^{18}
9	2.62×10^7	2.59×10^{10}	5.38×10^{18}	5.16×10^{18}	6.38×10^{18}
10	2.51×10^7	2.46×10^{10}	6.00×10^{18}	5.75×10^{18}	7.12×10^{18}
11	1.83×10^7	2.39×10^{10}	6.44×10^{18}	6.19×10^{18}	7.66×10^{18}
12	2.30×10^7	2.61×10^{10}	7.04×10^{18}	6.74×10^{18}	8.34×10^{18}
13	2.32×10^7	1.93×10^{10}	7.49×10^{18}	7.29×10^{18}	9.03×10^{18}
14	2.27×10^7	1.97×10^{10}	7.94×10^{18}	7.83×10^{18}	9.70×10^{18}

Notes: 1 - $\phi_{avg} = 2.38 \times 10^{10}$ n/cm^2-sec.
2 - $\phi_{avg} = 2.95 \times 10^{10}$ n/cm^2-sec.

Table 3

FAST NEUTRON (E > 1.0 MeV) EXPOSURE AT THE PRESSURE VESSEL INNER RADIUS - 30° AZIMUTHAL ANGLE

Cycle No.	Irradiation Time (EFPS)	Cycle Avg. Flux (n/cm^2-sec)	CUMULATIVE FLUENCE (n/cm^2) Plant Specific P_3	Generic[1] P_1	Generic[2] P_3
1A	2.09×10^7	1.50×10^{10}	3.14×10^{17}	3.24×10^{17}	4.12×10^{17}
1B	2.38×10^7	1.53×10^{10}	6.78×10^{17}	6.93×10^{17}	8.81×10^{17}
2	0.71×10^7	1.75×10^{10}	8.02×10^{17}	8.03×10^{17}	1.02×10^{18}
3	2.88×10^7	1.46×10^{10}	1.22×10^{18}	1.25×10^{18}	1.59×10^{18}
4	2.17×10^7	1.80×10^{10}	1.61×10^{18}	1.59×10^{18}	2.02×10^{18}
5	1.84×10^7	1.71×10^{10}	1.93×10^{18}	1.87×10^{18}	2.38×10^{18}
6	2.42×10^7	1.62×10^{10}	2.32×10^{18}	2.25×10^{18}	2.85×10^{18}
7	2.35×10^7	1.71×10^{10}	2.72×10^{18}	2.61×10^{18}	3.32×10^{18}
8	2.20×10^7	1.76×10^{10}	3.11×10^{18}	2.95×10^{18}	3.75×10^{18}
9	2.62×10^7	1.84×10^{10}	3.59×10^{18}	3.36×10^{18}	4.27×10^{18}
10	2.51×10^7	1.78×10^{10}	4.04×10^{18}	3.75×10^{18}	4.76×10^{18}
11	1.83×10^7	1.48×10^{10}	4.31×10^{18}	4.03×10^{18}	5.12×10^{18}
12	2.30×10^7	1.43×10^{10}	4.63×10^{18}	4.39×10^{18}	5.58×10^{18}
13	2.32×10^7	1.27×10^{10}	4.92×10^{18}	4.74×10^{18}	6.03×10^{18}
14	2.27×10^7	1.54×10^{10}	5.27×10^{18}	5.09×10^{18}	6.48×10^{18}

Notes: 1 - $\phi_{avg} = 1.55 \times 10^{10}$ n/cm^2-sec.
2 - $\phi_{avg} = 1.97 \times 10^{10}$ n/cm^2-sec.

Table 4

FAST NEUTRON (E > 1.0 MeV) EXPOSURE AT THE PRESSURE VESSEL INNER RADIUS - 44.5° AZIMUTHAL ANGLE

Cycle No.	Irradiation Time (EFPS)	Cycle Avg. Flux (n/cm^2-sec)	CUMULATIVE FLUENCE (n/cm^2)		
			Plant Specific P_3	Generic[1] P_1	Generic[2] P_3
1A	2.09×10^7	1.29×10^{10}	2.70×10^{17}	2.65×10^{17}	3.64×10^{17}
1B	2.38×10^7	1.31×10^{10}	5.81×10^{17}	5.68×10^{17}	7.78×10^{17}
2	0.71×10^7	1.60×10^{10}	6.95×10^{17}	6.58×10^{17}	9.01×10^{17}
3	2.88×10^7	1.30×10^{10}	1.07×10^{18}	1.02×10^{18}	1.40×10^{18}
4	2.17×10^7	1.62×10^{10}	1.42×10^{18}	1.30×10^{18}	1.78×10^{18}
5	1.84×10^7	1.36×10^{10}	1.67×10^{18}	1.53×10^{18}	2.10×10^{18}
6	2.42×10^7	1.30×10^{10}	1.99×10^{18}	1.84×10^{18}	2.52×10^{18}
7	2.35×10^7	1.38×10^{10}	2.31×10^{18}	2.14×10^{18}	2.93×10^{18}
8	2.20×10^7	1.58×10^{10}	2.66×10^{18}	2.42×10^{18}	3.31×10^{18}
9	2.62×10^7	1.68×10^{10}	3.10×10^{18}	2.75×10^{18}	3.77×10^{18}
10	2.51×10^7	1.63×10^{10}	3.51×10^{18}	3.07×10^{18}	4.21×10^{18}
11	1.83×10^7	1.45×10^{10}	3.77×10^{18}	3.30×10^{18}	4.52×10^{18}
12	2.30×10^7	1.39×10^{10}	4.09×10^{18}	3.59×10^{18}	4.92×10^{18}
13	2.32×10^7	1.05×10^{10}	4.34×10^{18}	3.84×10^{18}	5.33×10^{18}
14	2.27×10^7	1.54×10^{10}	4.69×10^{18}	4.13×10^{18}	5.72×10^{18}

Notes: 1 - $\phi_{avg} = 1.27 \times 10^{10}$ n/cm^2-sec.
2 - $\phi_{avg} = 1.74 \times 10^{10}$ n/cm^2-sec.

Table 5

FAST NEUTRON (E > 1.0 MeV) EXPOSURE AT THE 13° SURVEILLANCE CAPSULE CENTER

Cycle No.	Irradiation Time (EFPS)	Cycle Avg. Flux (n/cm^2-sec.)	CUMULATIVE FLUENCE (n/cm^2) Plant Specific P_3	Capsule Measurement	Generic[1] P_1	Generic[2] P_3
1A	2.09×10^7	1.19×10^{11}	2.49×10^{18}		2.78×10^{18}	3.07×10^{18}
1B	2.38×10^7	1.27×10^{11}	5.51×10^{18}		5.95×10^{18}	6.57×10^{18}
2	0.71×10^7	1.30×10^{11}	6.44×10^{18}	6.53×10^{18}	6.89×10^{18}	7.61×10^{18}
3	2.88×10^7	1.13×10^{11}	9.69×10^{18}	1.02×10^{19}	1.07×10^{19}	1.18×10^{19}
4	2.17×10^7	1.17×10^{11}	1.22×10^{19}		1.36×10^{19}	1.50×10^{19}
5	1.84×10^7	1.43×10^{11}	1.49×10^{19}		1.61×10^{19}	1.77×10^{19}
6	2.42×10^7	1.24×10^{11}	1.79×10^{19}		1.93×10^{19}	2.13×10^{19}
7	2.35×10^7	1.23×10^{11}	2.08×10^{19}		2.24×10^{19}	2.48×10^{19}
8	2.20×10^7	1.36×10^{11}	2.37×10^{19}		2.53×10^{19}	2.80×10^{19}
9	2.62×10^7	1.29×10^{11}	2.71×10^{19}		2.88×10^{19}	3.18×10^{19}
10	2.51×10^7	1.23×10^{11}	3.02×10^{19}		3.21×10^{19}	3.55×10^{19}
11	1.83×10^7	1.22×10^{11}	3.24×10^{19}		3.46×10^{19}	3.82×10^{19}
12	2.30×10^7	1.36×10^{11}	3.56×10^{19}		3.76×10^{19}	4.16×10^{19}
13	2.32×10^7	9.43×10^{10}	3.78×10^{19}		4.07×10^{19}	4.50×10^{19}
14	2.27×10^7	9.49×10^{10}	4.00×10^{19}		4.37×10^{19}	4.83×10^{19}

Notes: 1 - Ø = 1.33×10^{10} n/cm^2-sec.
2 - Ø = 1.47×10^{11} n/cm^2-sec.

Table 6

FAST NEUTRON (E > 1.0 MeV) EXPOSURE AT THE 23° SURVEILLANCE CAPSULE CENTER

Cycle No.	Irradiation Time (EFPS)	Cycle Avg. Flux (n/cm^2-sec.)	CUMULATIVE FLUENCE (n/cm^2) Plant Specific P_3	Capsule Measurement	Generic[1] P_1	Generic[2] P_3
1A	2.09×10^7	6.86×10^{10}	1.43×10^{18}		1.60×10^{18}	1.86×10^{18}
1B	2.38×10^7	7.14×10^{10}	3.13×10^{18}		3.42×10^{18}	3.98×10^{18}
2	0.71×10^7	7.80×10^{10}	3.69×10^{18}		3.97×10^{18}	4.61×10^{18}
3	2.88×10^7	6.61×10^{10}	5.59×10^{18}		6.18×10^{18}	7.18×10^{18}
4	2.17×10^7	7.82×10^{10}	7.29×10^{18}		7.84×10^{18}	9.11×10^{18}
5	1.84×10^7	8.14×10^{10}	8.79×10^{18}		9.25×10^{18}	1.08×10^{19}
6	2.42×10^7	7.50×10^{10}	1.06×10^{19}		1.11×10^{19}	1.29×10^{19}
7	2.35×10^7	7.82×10^{10}	1.24×10^{19}		1.29×10^{19}	1.50×10^{19}
8	2.20×10^7	7.95×10^{10}	1.42×10^{19}		1.46×10^{19}	1.70×10^{19}
9	2.62×10^7	8.07×10^{10}	1.63×10^{19}	1.78×10^{19}	1.66×10^{19}	1.93×10^{19}
10	2.51×10^7	7.74×10^{10}	1.82×10^{19}		1.85×10^{19}	2.15×10^{19}
11	1.83×10^7	7.18×10^{10}	1.96×10^{19}		1.99×10^{19}	2.32×10^{19}
12	2.30×10^7	6.85×10^{10}	2.11×10^{19}		2.17×10^{19}	2.52×10^{19}
13	2.32×10^7	5.95×10^{10}	2.25×10^{19}		2.35×10^{19}	2.73×10^{19}
14	2.27×10^7	6.55×10^{10}	2.40×10^{19}		2.52×10^{19}	2.93×10^{19}

Notes: $1 - \phi_{avg} = 7.66 \times 10^{10}$ n/cm^2-sec.
$2 - \phi_{avg} = 8.91 \times 10^{10}$ n/cm^2-sec.

Table 7

FAST NEUTRON (E > 1.0 MeV) EXPOSURE AT THE 33° SURVEILLANCE CAPSULE CENTER

Cycle No.	Irradiation Time (EFPS)	Cycle Avg. Flux (n/cm^2-sec)	CUMULATIVE FLUENCE (n/cm^2) Plant Specific P_3	Generic[1] P_1	Generic[2] P_3
1A	2.09×10^7	6.06×10^{10}	1.27×10^{18}	1.48×10^{18}	1.68×10^{18}
1B	2.38×10^7	6.14×10^{10}	2.73×10^{18}	3.16×10^{18}	3.60×10^{18}
2	0.71×10^7	7.24×10^{10}	3.24×10^{18}	3.66×10^{18}	4.18×10^{18}
3	2.88×10^7	5.95×10^{10}	4.96×10^{18}	5.69×10^{18}	6.50×10^{18}
4	2.17×10^7	7.40×10^{10}	6.56×10^{18}	7.22×10^{18}	8.25×10^{18}
5	1.84×10^7	6.75×10^{10}	7.80×10^{18}	8.52×10^{18}	9.73×10^{18}
6	2.42×10^7	6.45×10^{10}	9.37×10^{18}	1.02×10^{19}	1.17×10^{19}
7	2.35×10^7	6.86×10^{10}	1.10×10^{19}	1.19×10^{19}	1.36×10^{19}
8	2.20×10^7	7.22×10^{10}	1.26×10^{19}	1.34×10^{19}	1.53×10^{19}
9	2.62×10^7	7.61×10^{10}	1.46×10^{19}	1.53×10^{19}	1.75×10^{19}
10	2.51×10^7	7.39×10^{10}	1.64×10^{19}	1.71×10^{19}	1.95×10^{19}
11	1.83×10^7	6.03×10^{10}	1.75×10^{19}	1.84×10^{19}	2.10×10^{19}
12	2.30×10^7	5.78×10^{10}	1.88×10^{19}	2.00×10^{19}	2.28×10^{19}
13	2.32×10^7	5.00×10^{10}	2.00×10^{19}	2.16×10^{19}	2.47×10^{19}
14	2.27×10^7	6.38×10^{10}	2.14×10^{19}	2.32×10^{19}	2.65×10^{19}

Notes: 1 - $\phi_{avg} = 7.08 \times 10^{10}$ n/cm^2-sec.
2 - $\phi_{avg} = 8.06 \times 10^{10}$ n/cm^2-sec.